Integrating Circular Economy Principles into Urban Waste Management: A Case Study of Bengaluru's Solid Waste Initiatives

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KEYWORDS

Circular Economy, Solid Waste Management, Urban Waste, Sustainability, Socio-Economic Impacts, Environmental Resilience, Sustainable Urban Development

ABSTRACT

This study examines the application of circular economy (CE) principles in solid waste management (SWM) within Bengaluru, India, assessing their socio-economic and environmental impacts while aligning with the city's sustainable development goals. Utilizing qualitative research methods such as interviews and site visits, the research highlights impactful models, including the Zero Waste Initiative at Madiwala Market, sustainable practices during Ganesha festival celebrations, community-driven composting projects, and the Swachagraha Kalikakendra initiative.

These initiatives showcase the potential of CE strategies to transform waste management into a system that bolsters environmental sustainability, promotes social equity, and enhances economic productivity. The findings underscore how embracing CE frameworks can repurpose waste into valuable resources, tackle urban challenges, and contribute to sustainable urban development. The study concludes by advocating for the integration of CE approaches into urban SWM systems as a pathway to building resilient and sustainable cities, providing a replicable model for urban centers globally.

1. Introduction

The solid waste management (SWM) has long been a challenge for many communities in developing nations. Significant waste-related environmental and socioeconomic issues were brought on by urbanization, population increase, and an excessive demand for resources in cities. Many countries around the world have completely embraced CE principles and abandoned the use of outdated waste management procedures and regulations (Mathews & Tan, 2011). For low- and middle-income nations adopting CE policies and practices, there is a dearth of information and understanding regarding the implementation procedures as well as a number of other challenges (Geme et al., 2023).

Typically, local governments oversee the waste management process, and it is their responsibility to ensure that the public has access to an effective and efficient system. According to (Yukalang et al., 2017), they frequently struggle with issues that go beyond the purview of municipal government, such as a lack of organization and funding, subject complexity, and multidimensionality. The linear economy has been crucial to economic growth throughout the last few decades (Andrews, 2015). According to Vaish et al., 2016, the present linear production model does not follow a holistic approach to waste and resource management that addresses every stage of the production process, from product design to raw material extraction, production, consumption, and final disposal (Vaish et al., 2016). This issue has

gotten worse as a direct result of consumerism and the linear economic model because of inadequate waste management and landfill pressure(Mavropoulos et al., 2015).

The circular economy is a concept that has evolved with a sustainable resource management perspective adopted in this study to support the scientific decision-making process for urban planners and policymakers. The CE attempts to close the economic and ecological cycles of resource flows by reducing waste generation, and the circularity of the raw materials used (Haas et al., 2015). Therefore, effective policies and practices have become necessary to integrate the CE principle into the formulation and implementation to ensure positive outcomes.

To a certain degree, an efficient SWM is helping the city achieve its sustainable development objectives. It also helps to protect the planet's ecosystems, improve health and quality of life in cities, maintain the sustainability of local communities, lessen the negative environmental effects of cities individually, and create jobs that promote social and economic growth. Additionally, it supports the creation of transparent institutional structures that guarantee cooperation with various parties and businesses (Elsheekh et al., 2021).

The solid waste is classified into two types: dry and wet waste. The dry waste is collected bi-weekly by NGOs Hasirudala, and DWCC in the city. Further, they segregate the waste in different streams and send it to the recycling centre. Bengaluru city generated the highest quantity of organic waste at 61% every day (BBMP SWM Manual 2017). Hence, BBMP, NGOs, SHGs, Households, and individuals are focused more on recycling organic waste by using aerobic and anaerobic composting, vermicomposting, windrow composting, leaf composting, and lane composting methods (Naveen & Sivapullaiah, 2020). In order to turn biodegradable trash into compost and electricity, BBMP has set up facilities for wet waste processing and biomethanation. garbage management is crucial for developing solutions for reuse that add economic value in addition to reducing the amount of garbage that ends up in landfills. Moving from a linear economy to a circular economy presents challenges for waste management in this setting.

The purpose of this study is to evaluate Bengaluru's solid waste management practices through the lens of the circular economy (CE). This research examines the current solid waste management initiatives and circular economy models implemented in Bengaluru. The primary objective is to review the socio-economic implications and environmental benefits of these initiatives. The final section presents the findings and key insights derived from the study.

2. Literature Review

A study by Vij, 2012 states that with the rise of urbanization, changing lifestyles, and consumerism, solid waste management has become more difficult. Financial restrictions, institutional deficiencies, poor technology selection, and public apathy toward Municipal Solid Waste (MSW) have exacerbated the problem (Vij, 2012). Life cycle assessment, categorization, recycling, and reduction in all types of wastes and proper landfilling, Cities with equal income levels have vastly different magnitudes of MSW management issues. A well-managed city with a medium or low income could be very different from one with bad urban MSW management. Waste stream analysis, material balance, and lifespan assessment may be useful to manage landfills sustainably (Jha et al., 2011). A percentage of total consumer spending on goods and services results in MSW generation (Daskalopoulos et al., 1998). Bohm et al., 2010 study highlighted that recycling systems have lower marginal and average costs than trash collection and disposal systems. For all observed garbage collection and disposal quantities, economies of scale were estimated. There were economies of scale at large levels of recycling (Bohm et al., 2010). The study also focused on certain key issues of waste management such as the existing state of waste collection, transportation, and disposal (Minghua et al., 2009). In a study by Sembiring & Nitivattananon, 2010 decision-makers have

a challenge when attempting to include informal recycling in the SWM toward a more inclusive society. Improved waste collection efficiency may result in the unemployment of scavengers and rubbish pickers who work in low-wage jobs, yet issues surrounding inclusive society urge municipalities to combat social exclusion. (Sembiring & Nitivattananon, 2010). Akil & Ho, 2014 study 2014 argues that households have a decent understanding of solid waste recycling. They had limited awareness of disposal methods. If the facility was located near their curbside, the majority of residents agreed to participate in garbage separation activities. It recommended the government provide more detailed information by raising household awareness of recycling programs (Akil & Ho, 2014). Formal and informal scavengers to participate in the recycling chain on a social and economic level are essential to maintaining a sustainable waste management system (Poletto et al., 2016). The socioeconomic features of household recyclers and non-recyclers as well as their levels of recycling awareness had major effects on waste management (Lumpur et al., 2014). The demographic characteristics and environmental attitudes had a significant impact on recycling and waste management habits (Lee & Sun, 2011). Raising awareness at all levels is essential to reduce waste and inform people about the health and environmental risks. Various professionals across different fields participated in implementing, evaluating, and monitoring the progress of waste reduction projects. Recycling initiatives were closely tracked in all locations (Gajalakshmi, 2020). Municipal solid waste management can be categorized into six functional aspects: generation, storage, collection, transportation, segregation and processing, and disposal. Each step plays a crucial role in the waste management process (Mishra1 et al., 2018). According to Mishra1 (2018), all solid waste was disposed of in landfills, which requires a large amount of space. This management condition often leads to the most expensive waste transportation, as the least available land is usually situated where the majority of waste is generated (Mishra1 et al., 2018).

In summary, the waste management process should be controlled by households, formal and informal scavengers', the public, and recyclers. The majority of households and participants have a good awareness of waste segregation and recycling but they lack of ideas about disposal.

3. Research Method

This study's research methodology was designed to carefully assess, from the standpoint of the circular economy (CE), how solid waste management (SWM) methods are being implemented in Bengaluru, India. To fully comprehend the socioeconomic and environmental effects of these activities and to evaluate the efficacy of ongoing waste management programs, a qualitative method was chosen. The approach used primary and secondary data collection techniques and covered a few important phases.

The choice of a qualitative research design was made because of its capacity to investigate complex phenomena and obtain thorough, contextual information. Examining the procedures, difficulties, and results related to Bengaluru's switch from conventional waste management to CE-based methods was the main goal of the study. A comprehensive examination of SWM efforts was made possible by this approach, which highlighted the interplay of social, environmental, and economic variables.

Data collection was conducted through a combination of literature reviews, in-depth interviews, non-participant observations, and field visits. These methods were selected to capture a broad spectrum of information on practical implementation details.

a) *Literature Review:* The study began with an extensive review of existing literature on SWM and CE. The literature review provided a foundation for understanding the current state of SWM in Bengaluru.

b) *In-depth interviews:* Key participants in SWM in Bengaluru participated in a number of semi-structured interviews. Members of Residents' Welfare Associations (RWAs),

representatives from NGOs such as Hasirudala, members of the Solid Waste Management Round Table (SWMRT), and BBMP officials were among the attendees. A varied sample of 32 individuals was found and recruited using a purposive and snowball selection strategy. The 45- to 1-hour-long interviews offered insightful information about the difficulties, tactics, and achievements of SWM projects from a range of viewpoints.

c) *Non-Participant Observations:* To supplement the interviews, non-participant observations were conducted at key SWM sites, including Madiwala Market, Kora3B Compost, and SwachaGraha Kalika Kendra (SGKK). These observations allowed the researchers to witness the waste management processes directly, assess the effectiveness of CE practices, and identify any operational challenges.

d) *Field Visits:* The visits included interactions with waste workers, RWAs', residents, and volunteers involved in SWM activities. These visits provided first-hand information on the practical aspects of waste collection, segregation, and processing, as well as the socio-economic implications of these activities.

The research was conducted in three distinct stages of sampling procedures:

Stage 1: Pilot Study: The initial stage involved a pilot study to gather preliminary data and refine the research framework. Documents and information related to municipal SWM in Bengaluru, including BBMP reports, budgets, and roadmaps, were analyzed. This stage helped in identifying key areas of focus for the subsequent stages of the research.

Stage 2: Data Collection and Interviews: 32 people were interviewed informally at this phase between July and November of 2023. The data acquired during the pilot research was updated and validated using the information obtained. The purpose of the interviews was to gather detailed information about the socioeconomic and environmental effects of municipal solid waste (MSW) segregation, collection, transportation, and processing processes from a CE standpoint.

Stage 3: Site Visits and Case Study Development: The final stage involved detailed site visits to specific SWM initiatives in Bengaluru. These visits were aimed at developing case studies that illustrate the application of CE principles in real-world scenarios. The case studies focused on initiatives such as the Zero Waste Madiwala Market, the transition to eco-friendly Ganesha festival practices, community-led leaf composting projects, and SwachGraha Kalika Kendra initiative.

Thematic analysis was used to methodically examine the information gathered from field visits, observations, and interviews. The researchers were able to find recurrent themes, patterns, and insights regarding the efficacy of CE models in SWM attributable to this methodology.

4. Results

4.1: Case Studies on Solid Waste Management under Circular Economy Models in Bengaluru City

This study observed that a substantial amount of waste is generated from market activities, leaf litter, and festivals in Bengaluru city. Various stakeholders, including Resident Welfare Associations (RWAs), civic agencies, NGOs, and volunteers, actively participate in managing this waste from a circular economy perspective. The study examines several innovative cases, such as the zero-waste Madiwala market model, zero-waste Ganesha idol initiative, leaf composting methods, Kora 3B compost, and Swacchagraha Kalika Kendra. These case studies demonstrate how today's waste can be transformed into tomorrow's resources, thereby minimizing environmental impact. To protect the environment, it is crucial to use and process all raw materials sustainably and efficiently. This study employs circular economy models to address the prevalent wastefulness of both businesses and individuals.

4.1.1. Case Study: Zero Waste Initiative at Madiwala Market

Madiwala Market, located in Bengaluru City, Karnataka, India, has been a bustling hub of trade and commerce for nearly four decades. Established almost 40 years ago, the market has served as a vital economic lifeline for hundreds of farmers and vendors from the surrounding areas, providing a platform for the sale of fresh produce, flowers, and other goods.

However, despite its economic significance, Madiwala Market has long grappled with the challenge of waste management. The bustling market, characterized by its crowded alleys and vibrant atmosphere, generated a significant amount of waste daily, including organic and inorganic materials, packaging, and other discarded items.

Until recently, waste disposal practices at Madiwala Market were rudimentary, with farmers and vendors often leaving unsold produce and waste at the point of sale or dumping it in communal areas. Pourakarmikas, responsible for waste collection and disposal, faced the daunting task of manually cleaning up the market area, often dealing with overflowing bins and unsanitary conditions.

Recognizing the urgent need for sustainable waste management solutions, stakeholders at Madiwala Market embarked on a transformative journey towards zero waste. The Zero Waste initiative aimed to revolutionize waste management practices in the market, promoting segregation, recycling, and resource recovery to minimize landfill-bound waste and environmental pollution.

Over the years, the Zero Waste initiative at Madiwala Market has evolved into a model of circular economy principles in action. Through collaborative efforts and innovative strategies, the market has achieved remarkable success in waste segregation, stakeholder engagement, and environmental sustainability, serving as a beacon of inspiration for other markets and urban areas seeking to adopt similar initiatives.

Table 1: Waste Segregation and Management Statistics at Madiwala Market

Waste Category	Amount Produced per Day	Management Method
Dry Waste	200-500 kg	Recycling Centre
Wet Waste (Lean Period)	7,000-12,000 kg	NGOs (fresh leftover vegetables and greens), composting centre (remaining)
Wet Waste (Peak Period)	18,000-22,000 kg	Animal feed (cows, pigs, sheep)
Animal Feed	1,000-1,300 kg	Owners of cows, pigs
Leftover Quality Greens	100 kg	NGOs (old age homes, slums, orphanages)
Consumable Vegetables	800 kg	NGOs (old age homes, slums, orphanages)

Source: Field visit at Madiwala Market (October -November 2023)

Figure 1: Zero Waste at Madiwala Market, Source: Field Visit

Figure 1 shows that Farmers deliver their products to the market, where merchants buy them. Farmers only attend the market for a short time to sell their products before leaving any unsold items there. These extra/unsold fresh vegetables can be given to charities and orphans. The owner of the cow and pig, who brings them home from the market each day, receives the remaining green trash. The residual moist garbage is also delivered to a composting facility. Recycling is possible for 1% of the total amount of dry waste. Zero waste exists in the market at the end of the day.

While distribution is free and primarily intended to aid the poor, activists do not consider engaging in commercial endeavours. They established a network of between 50 and 60 NGOs in Bengaluru that work with old people's homes, slums, and orphanages. After the morning auction, the market closes, and our civic workers gather the unsold produce from the stores and share it with the group. The product is given to the NGOs for either self-consumption or distribution to the less fortunate, depending on the booking (Niranjan Kaggere, Aug 5, 2022, ToI).

Table no. 2: Thematic analysis of the Zero Waste initiative at Madiwala Market in Bengaluru City

Key Aspect	Thematic Analysis
The Success of Waste Segregation	Achieved 95% waste segregation at the source, significantly reducing landfill-bound waste. This has led to environmental benefits such as reduced pollution and greenhouse gas emissions.
Improved Working Conditions for Pourakarmikas	Pourakarmikas now works with fresh waste, eliminating health risks associated with handling stale and harmful waste. This highlights the importance of prioritizing worker safety in waste management initiatives.
Collaborative Stakeholder Engagement	Success is attributed to the collaborative efforts of multiple stakeholders, including market vendors, pourakarmikas, NGOs, civic activists, BBMP, and government agencies. Engagement of diverse stakeholders is crucial for success.
Socio-Economic Implications	Lower emissions of greenhouse gases decreased transportation expenses of the BBMP and increased work productivity among pourakarmikas. Banning single-use items has encouraged the use of eco-friendly alternatives.

Key Aspect	Thematic Analysis
Role of Standard Operating Procedures	The establishment of clear guidelines and protocols for waste management is crucial for success. Includes distribution of crates to vendors for waste segregation and setup of 2 waste aggregation centres.
Scalability and Replicability	Zero Waste model serves as a role model for other markets and urban areas. Success demonstrates scalability and replicability potential, providing valuable insights for similar initiatives elsewhere.

4.1.2. Case Study: Transition to Eco-Friendly Practices in Ganesha Festival Celebrations

This study revolves around the traditional practice of celebrating the Ganesha Chaturthi festival in India, particularly focusing on the idol-making process and its environmental implications. Historically, Ganesha idols were predominantly made using plaster of Paris (PoP), a non-biodegradable material that poses significant environmental challenges upon immersion in water bodies. This practice became widespread in the 1970s due to its convenience and affordability.

However, concerns over environmental degradation, pollution of water bodies, and adverse effects on marine life prompted a reevaluation of this traditional method. Folklore suggests that Ganesha idols should ideally be made from clay or shaadu maati, a biodegradable material that aligns with sustainable practices. Despite this, the prevalence of PoP idols persisted due to logistical reasons, such as the fragility of clay idols during transportation.

Over time, environmental activists, government bodies, and local communities recognized the need to transition towards eco-friendly practices in Ganesha festival celebrations. This led to the implementation of regulatory measures, awareness campaigns, and community initiatives aimed at promoting the use of clay idols and discouraging the use of PoP and harmful materials.

The evolution of idol-making customs, changes in public opinion and knowledge, and the function of government action in resolving environmental issues related to the Ganesha

Chaturthi celebration are all highlighted in this paper. It lays the groundwork for comprehending the driving forces behind the shift to environmentally friendly behaviours and how these activities affect environmental sustainability in urban settings like Bengaluru.

Figure 2: Zero waste Ganesha idol, Source: Field Visit

Figure 2 describes that After the Ganesh idols were immersed, clay sludge was collected from the sites and given to Ganesh idol sculptors and various educational institutions for reuse in an environmentally friendly manner (Hindustan Times, August 30, 2023). Setting the price below one of the market prices for recently obtained clay should promote its use. Additionally, recycled clay must be made available to other fields in cases of excess. Regarding idol manufacturing, the objective will continue to be to try and recycle all organic waste while

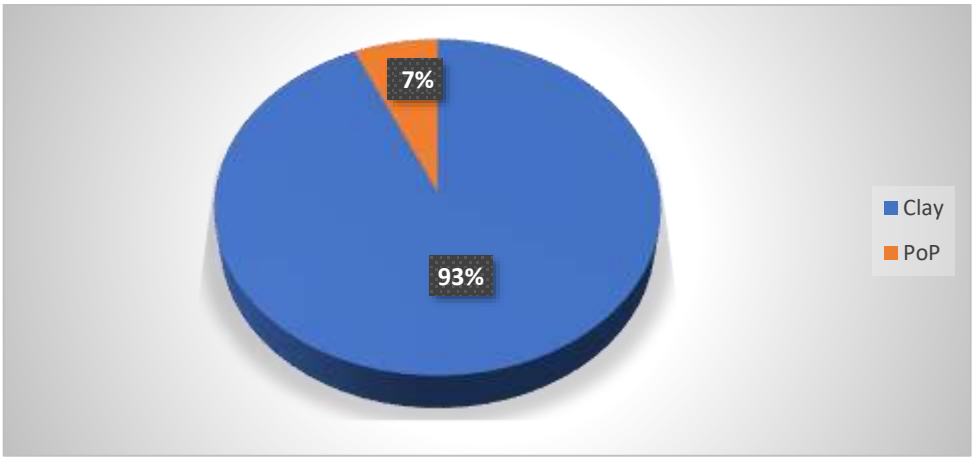
also trying to eliminate waste and develop a market with environmentally friendly alternatives to clay murtis, seasoned artists should be asked to investigate other materials for murtis, such as cow dung. In addition to creating more jobs, this will advance the circular economy (Ecoexist-foundation 2023).

Table No. 3: Reasons for Transformation

Reasons for shifting from Clay to POP	Reasons for shifting from POP to Clay
Many idols were damaged during long-distance transportation. As a result, Ganesh idols were created using plaster of Paris.	Motives behind the switch from POP to Clay
These idols appear more attractive and polished.	Reduce pollution by creating eco-friendly idols However, marine biologists caution against using very hazardous paints that include harmful chemicals like mercury, lead, and sulphur. They also warn against using clay or PoP. In addition to harming the fish, these chemicals contaminate the water, endangering anyone who consumes the fish.
They are more durable than the clay ones and easier to carry while also being lighter on the wallet.	
Because of their complex design and decorations, worshippers also favour them.	
Clay model demand is quite low; most people aren't even aware of the differences.	
Local "shaadu" clay models are only available in smaller sizes and do not fit the "norms" of worship in some households/communities.	Government rules and legislation (Ministry of Environment, Forests, and Climate Change, 2020)

Source: Field Visit

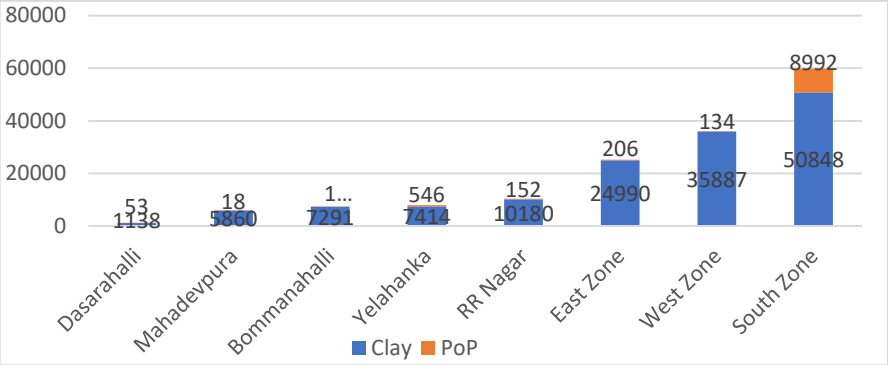
Figure 3: Ganesha Idol Immersed in Bengaluru in 2023



Source: Compilation by author

Figure 3 shows that the worshippers used 93% of the clay Ganesh idol and 7% of the PoP. The number of PoP idols has significantly decreased because of the new regulations and increased awareness.

Figure 4: Number of Ganesha Idols Immersed in Bengaluru City



Source: Compilation by author

The greatest number of idol immersions occurred in Bengaluru South. The Yediyuru Lake served as the immersion site for 93% of the clay Ganesha statues. 99.5% of the clay Ganesha statues in the western zone were submerged in Sankey Tank Kalyani. Despite the prohibition, 10,248 PoP Ganesha statues were discovered in the mobile immersion tanks. PoP idols were not permitted to be immersed in lakes (New Indian express-2023). The local body has constructed 150 mobile tanks in addition to artificial tanks at 35 lakes for the immersion of idols from various wards throughout the city (Deccan Herald, September 2022).

This case study highlights the transition to eco-friendly practices, the role of government regulations and community participation, the impact on waste management, the shift in consumer preferences, and policy implications for future sustainability initiatives.

The results of the study demonstrate how well government organisations, communities, and stakeholders work together to promote environmental stewardship and sustainable transformation in urban settings like Bengaluru. The adoption of environmentally friendly techniques during the Ganesha festival celebrations is a good illustration of how group efforts may address environmental problems and advance sustainable development with significant results.

The transition to eco-friendly practices in Ganesha festival celebrations in Bengaluru exemplifies a concerted effort towards sustainable living and environmental conservation. The city is adopting clay idols and reducing the use of PoP and hazardous materials in order to transition to a circular economy model, which will benefit the environment and its residents. Bengaluru is positioned to provide an example for other cities moving towards circular economy practices with its continuous efforts at eco-friendly celebrations and sustainable trash management. By prioritizing environmental conservation in festival celebrations, the city sets a precedent for responsible and mindful living. This systemic case study highlights the journey towards eco-friendly Ganesha festival celebrations in Bengaluru, emphasizing the importance of community participation, regulatory measures, and environmental consciousness in shaping a sustainable future.

Table no 4: The Thematic Analysis of the Eco-Friendly Practices in Ganesha Festival Celebrations

Aspect	Description
Transition to Eco-Friendly Practices	Growing awareness and concern for environmental sustainability is seen in the notable shift away from PoP idols and towards more environmentally friendly substitutes like clay.
Government Regulations and Enforcement	Environmental pollution has decreased as a result of the Ministry of Environment, Forests and Climate Change, BBMP, and other government agencies enforcing stringent rules.

Aspect	Description
Awareness and Involvement of the Community	Active involvement of local communities, NGOs, and environmental activists in promoting eco-friendly practices and raising awareness about the harmful effects of PoP usage.
Effects of the Solid Waste Management	Initiatives to collect clay sludge for reuse, recycling, and setup of mobile immersion tanks helped prevent pollution of water bodies and minimize environmental damage.
Shift in Consumer Preferences	Growing preference for clay idols over PoP idols indicates a shift in consumer behaviour toward sustainable practices driven by concerns for environmental conservation.
Policy Implications and Future Outlook	The success of eco-friendly initiatives has significant policy implications for promoting sustainable practices in cultural and religious events, fostering a circular economy model.

Source: Filed visit

4.1.3. Case study: Community-Led Leaf Composting Initiatives in Bengaluru

Bengaluru's Kora3B Compost and leaf composting programs were born out of urgent environmental issues with pollution and garbage management. Bengaluru, which is well-known for its fast urbanisation and growing population, has struggled with increasing garbage production and insufficient infrastructure for disposing of waste, which has resulted in threats to public health and environmental deterioration.

One of the significant contributors to waste accumulation in Bengaluru is the seasonal shedding of leaves and garden waste, particularly during autumn. Historically, these organic materials were either dumped in landfills or burnt on street corners, exacerbating pollution levels, and contributing to the city's waste crisis.

Residents, community organisations, and government agencies in Bengaluru launched composting projects in response to the problems caused by garden and leaf waste after seeing the pressing need to develop environmentally friendly waste management solutions. By using organic wastes to create nutrient-rich compost for horticultural and agricultural uses, these programs sought to lessen the negative environmental effects of trash accumulation.

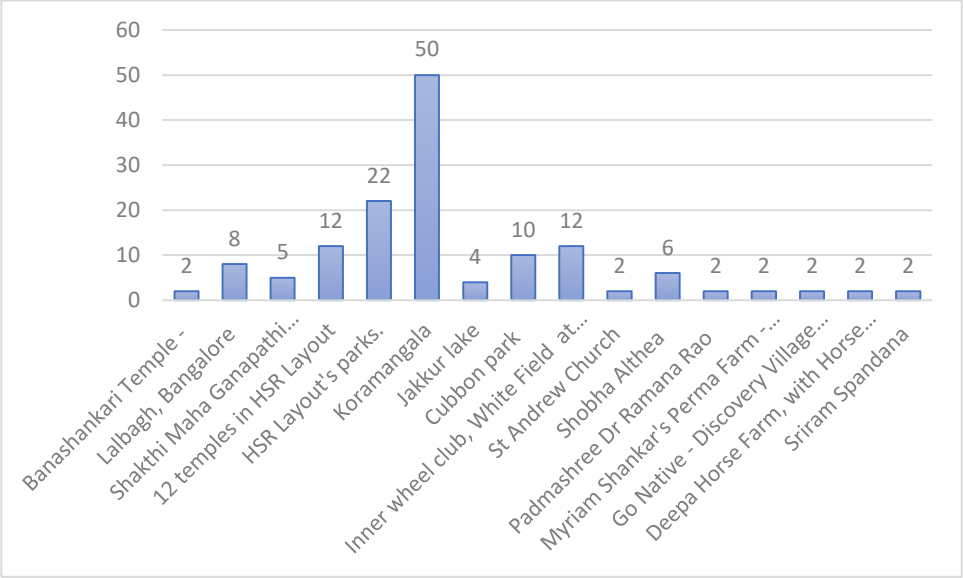
The leaf composting initiative sought to leverage natural processes of decomposition, primarily through aerobic decomposition facilitated by thermophilic bacteria. In order to remove organic waste from landfills and lessen pollution, stakeholders sought to create the ideal conditions for decomposition, such as temperature, moisture, and aeration.

Similarly, the Kora3B Compost project, spearheaded by the Koramangala 3rd Block Residents' Welfare Association (RWA), emerged as a grassroots effort to address local waste management challenges. Motivated by concerns over air pollution caused by burning dry leaves and the need for sustainable alternatives, the RWA invested in setting up a composting unit to process leaf litter into compost.

Over the years, these initiatives have garnered momentum and demonstrated tangible outcomes in waste reduction, environmental conservation, and community engagement. The accomplishments of the leaf composting and Kora3B Compost programs highlight the value of neighborhood-based solutions and teamwork in tackling Bengaluru's urban waste management issues and promoting sustainability.

Against the backdrop of rapid urbanization and environmental degradation, these initiatives represent proactive measures aimed at promoting a circular economy, reducing dependence on landfills, and enhancing environmental resilience in Bengaluru. By transforming waste into a valuable resource, these initiatives exemplify the potential for grassroots action to drive positive change and build more sustainable and resilient communities.

Figure 5: Number of Leaf Composters



Source: Compilation by author

Figure 5 shows the number of leave composting bins in a few areas of Bengaluru city, based on the availability of data. The RWA, civic body, NGOs, and BBMP have taken the initiative to spread awareness among the people to turn leaf litter into manure. Therefore, they have installed many leaves composting bins at temples/churches, apartments, streets, parks, and individual homes across Bengaluru. These active groups are transforming leaf and garden waste into green wealth in the city. Here we can observe that the maximum number of leaf composting bins in the Koramangala and HSR layouts as the best practice wards.

Figure 6: Kora3B Compost processed and sold details

Source: Compilation by author

Figure 6 shows that the RWA composted about 500 tonnes of leaves and sold 160 tonnes of compost in 2016. They processed more than 1500 tonnes of leaves in 2018 and sold more than 800 tonnes of compost to large farmers and city gardeners. Over 300 tonnes of leaves are treated annually by Kora3B Compost; otherwise, the garbage that is handled each year would be burned or transported by over 1500 auto trips and buried in a landfill. Every month, 15 tonnes of compost are created.

Even the name Kora3B compost is used to market the organic manure produced by this unit. It has been examined and approved as premium organic leaf compost by the University of Agricultural Sciences, Bengaluru. They offer three different types of Kora3B compost: fine compost (which is double-sieved with a finer wire mesh to produce a fine compost powder and sells for Rs. 10/kg), mulch compost/rough compost (which contains compost powder, and larger-sized organic matter like partially decomposed leaves and sells

for Rs. 5/kg), and enriched compost (which is compost that has been enriched with cow dung and microbes and costs Rs. 15/kg).

4.1.3.a. ***Initiative***

The leaf composting initiative in Bengaluru has shown promising results in diverting organic waste from landfills and reducing environmental pollution caused by burning dry leaves. Through the utilization of aerobic decomposition facilitated by thermophilic bacteria, stakeholders have successfully transformed leaf litter into nutrient-rich compost, contributing to soil fertility and agricultural productivity. The establishment of composting bins across various locations in the city has facilitated community engagement and participation in waste management, fostering a sense of environmental responsibility among residents. Challenges remain in ensuring consistent monitoring of composting bins, maintaining optimal conditions for decomposition, and addressing contamination issues. However, ongoing efforts by local authorities and community organizations are addressing these challenges and enhancing the effectiveness of the initiative.

The Kora3B Compost project has emerged as a successful model of community-driven waste management, driven by the initiative of the Koramangala 3rd Block Residents' Welfare Association (RWA). The RWA has been able to convert large amounts of dried leaves into high-quality compost by purchasing a composting unit and utilising nearby resources, supporting sustainable horticultural and agricultural practices in the region. Sales of compost have compensated operating costs and ensured the initiative's sustainability, proving the project's financial soundness. Moreover, the project has garnered recognition for its environmental benefits and contribution to waste reduction efforts in Bengaluru. Challenges such as operational costs, contamination issues, and market demand for compost products have been addressed through innovative strategies, community engagement, and partnerships with local stakeholders.

4.1.3.b. ***Implications:***

- The outcomes of the Kora3B Compost project and the leaf composting program have wider ramifications for environmentally friendly waste management techniques in urban settings.
- Community-driven initiatives are really important in addressing waste management challenges, fostering environmental stewardship, and promoting circular economy principles.
- By harnessing organic waste streams to produce valuable compost, cities like Bengaluru can reduce their dependence on landfills, mitigate environmental pollution, and enhance resource efficiency.
- In order to scale up composting projects and replicate successful models in other urban areas, policy backing, public awareness campaigns, and stakeholder participation are crucial.

The case study findings underscore the importance of community-driven approaches, innovative technologies, and supportive policy frameworks in encouraging environmentally friendly garbage management practices and building resilient communities in urban areas like Bengaluru. The success of these initiatives serves as a testament to the potential of grassroots action in addressing pressing environmental challenges and advancing the goals of sustainable development.

The case study highlights the significant strides made in encouraging environmentally friendly garbage management practices through leaf composting initiatives in urban Bengaluru. These programs have shown to be successful ways to deal with the problems of garbage accumulation and environmental contamination because they are the result of creative thinking and community cooperation. By using composting processes, organic waste—mostly garden

and leaf waste—is kept out of landfills and turned into nutrient-rich compost that may be used in horticulture and agriculture. This not only reduces the burden on landfill sites but also contributes to soil health improvement and carbon sequestration.

The success of these initiatives, exemplified by the Kora3B Compost project, underscores the importance of community engagement, stakeholder collaboration, and adaptive management practices in encouraging environmentally friendly garbage management. By involving residents, local organizations, and government bodies, these initiatives have fostered a sense of ownership and responsibility among stakeholders, leading to more sustainable behaviours and practices. However, challenges such as limited funding, logistical constraints, and regulatory hurdles remain prevalent. Addressing these challenges requires continued support from policymakers, investment in infrastructure, and capacity building among stakeholders. Moving forward, it is imperative to scale up these initiatives, replicate successful models in other urban areas, and advocate for supportive policy frameworks to mainstream composting as a viable waste management strategy. By harnessing the potential of composting and promoting community-led approaches, Bengaluru can pave the way towards a more sustainable and resilient future.

4.1.4. Case Study on SwachaGraha Kalika Kendra (SGKK) – HSR Layout

SwachaGraha Kalika Kendra (SGKK) is a pioneering initiative in Bengaluru, India, established in December 2018 to encouraging environmentally friendly garbage management through large-scale education and awareness. Located in the HSR Layout, SGKK functions as a learning center dedicated to kitchen and garden waste composting, with a broader mission to foster resource recovery through recycling, reuse, and home as well as community composting. The center is the result of a collaborative effort involving the Solid Waste Management Round Table (SWMRT), the HSR Citizen Forum (HCF), and various local stakeholders. SGKK serves as a public park designed by Foley Designs, showcasing a range of composting solutions, a community garden, and upcycled art installations, all aimed at promoting a circular economy within the community.

4.1.4.a. ***Initiatives and Operations:*** SGKK has been instrumental in guiding the community toward effective waste segregation at the source and minimizing waste through various innovative initiatives. The center provides tailored training to compost karigars (workers), enabling them to manage in-situ composting effectively. These karigars are trained in waste management techniques by the Samwadha Badhuku organization, ensuring that they possess the skills necessary to maintain and operate composting systems across the community.

The center not only teaches the technical aspects of composting but also emphasizes the broader benefits of chemical-free agriculture, offering hands-on workshops and educational programs. These workshops have attracted thousands of participants, including residents, government officials, and volunteers, who are now advocates for environmentally friendly garbage management practices in their communities. SGKK's philosophy, articulated by its founder Shanthi, revolves around the concept that "my waste is my responsibility," challenging the traditional mindset that waste management is solely a municipal duty.

4.1.4.b. ***Composting Techniques at SGKK***

1. *Aerobic Composting*: SGKK manages wet waste collected from 740 houses in the HSR Layout's 4th sector, processing approximately 600 kg of waste daily. Two pourakarmikas (sanitation workers) are responsible for segregating and managing this waste. The waste is shredded and then processed through aerobic composting, a technique that involves balancing green waste (kitchen waste) and brown waste (leaves and semi-compost) in a 1:1 ratio. This method ensures odourless composting, prevents fly and maggot infestations, and minimizes environmental impact. The composting process takes about 60 days, resulting in high-quality semi-compost.

2. *Vermicomposting*: SGKK operates nine vermicompost tanks, each with a capacity of 1800 kg. The process begins with creating a bed of crushed leaves, followed by the gradual addition of shredded waste and cow dung. Earthworms are introduced at an optimal temperature of 40 degrees Celsius, facilitating rapid decomposition. The worms convert the waste into nutrient-rich compost within 10-15 days. Despite high public demand for this vermicompost, SGKK sells it at a subsidized rate of Rs. 15 per kg, ensuring that it remains accessible to the community.
3. *Platform Composting*: Platform composting at SGKK involves processing 5 tonnes of wet waste per site per month. The composting process, which is facilitated using wooden or bamboo platforms, yields about 2.5 tonnes of compost due to the high moisture content in the waste. This method is particularly effective for large-scale composting and serves as a model for similar initiatives in other urban areas.

4.1.4.c. *Implications*

1. *Environmental Impact*: By drastically cutting down on the amount of garbage dumped in landfills, SGKK's composting programs have decreased methane emissions, groundwater contamination, and the urban heat island effect. SGKK helps to increase soil health, sequester carbon, and advance sustainable farming methods by turning organic waste into manure.
2. *Socio-Economic Benefits:* The center has created employment opportunities for residents as compost karigars and has also provided cost savings to the community by reducing the need for chemical fertilizers. The availability of low-cost compost encourages widespread adoption of organic farming practices, further contributing to the local economy.
3. *Community Engagement and Education*: The awareness initiatives of SGKK have changed the way the community views trash management. The centre has encouraged a sustainable culture by encouraging residents to take ownership of their waste by promoting the "Yes in My Backyard" (YIMBY) approach. The center's accomplishments show how crucial grassroots efforts are to bringing about significant environmental change.
4. *Scalability and Replicability*: In other cities with comparable trash management issues, the SGKK methodology is very reproducible and scalable. A circular economy is promoted on a larger scale by combining community involvement, creative composting methods, and robust policy backing to create a model that other communities can adopt.

SwachaGraha Kalika Kendra stands as a beacon of sustainable waste management, demonstrating the power of community-driven initiatives in fostering environmental stewardship and resource efficiency. SGKK is laying the foundation for a cleaner, greener, and more sustainable future in Bengaluru and beyond by incorporating composting into everyday life and encouraging a culture of accountability. The accomplishments of SGKK demonstrate how circular economy models have the power to improve socioeconomic results, lessen their negative effects on the environment, and change waste management procedures.

4.2. Discussions

The solid waste management (SWM) initiatives in Bengaluru highlight the city's efforts to integrate circular economy (CE) principles into everyday practices. By focusing on reducing waste, recycling materials, and fostering community involvement, these initiatives provide valuable insights into how urban environments can address waste challenges sustainably. This discussion synthesizes key findings from case studies on the Madiwala Market, the Ganesha idol-making transition, leaf composting initiatives, and the SwachaGraha Kalika Kendra (SGKK).

The Zero Waste Initiative at Madiwala Market illustrates a successful shift away from conventional trash disposal to a model that prioritizes resource recovery and sustainability. The market's strategy of segregating waste at the source and creating systems for recycling and composting has significantly reduced landfill dependency. The involvement of various stakeholders, including vendors, local authorities, NGOs, and waste workers, has been crucial in fostering a collaborative environment where sustainable practices can thrive. This initiative demonstrates how markets can function as effective hubs for circular economy practices, reducing environmental impact while supporting economic and social goals.

The shift towards eco-friendly practices in Ganesha idol-making represents a critical cultural adaptation to environmental needs. By moving away from plaster of Paris (PoP) idols to those made from biodegradable clay, Bengaluru has mitigated the pollution of water bodies and reduced harm to aquatic life. The proactive stance of regulatory bodies and increased public awareness have been instrumental in driving this change. This case emphasizes the power of policy interventions and community education in transforming traditional practices into more sustainable ones, demonstrating the potential for cultural events to align with environmental objectives.

The leaf composting initiatives, including the Kora3B Compost project, exemplify the power of community-driven approaches to trash management. These projects address the specific challenge of organic trash, such as leaf litter, by converting it into nutrient-rich compost. This not only diverts waste from landfills but also supports agricultural productivity and reduces pollution. The success of these initiatives lies in their ability to mobilize local residents, promote environmental responsibility, and create economic value from waste. By turning a waste product into a resource, these projects illustrate a practical application of circular economy principles at the grassroots level.

The Swacha Graha Kalika Kendra (SGKK) serves as a comprehensive model for community engagement and education in waste management. Located in HSR Layout, this initiative combines hands-on training with practical demonstrations of various composting techniques, fostering a deep understanding of sustainable practices among residents. By encouraging the notion that "my waste is my responsibility," SGKK has enabled people to take charge of their trash management procedures, which has resulted in a notable decrease in the amount of trash dumped in landfills. This case study emphasises how crucial community engagement and education are to promoting long-term behavioural change and creating a circular economy locally.

5. Conclusion

The study finds that incorporating circular economy principles into solid waste management practices is crucial for achieving sustainable urban development in Bengaluru. The case studies illustrate that circular economy models not only reduce environmental impacts but also provide substantial socio-economic advantages. Transitioning to sustainable trash management practices necessitates active community participation, strong policy backing, and ongoing investments in infrastructure and capacity building. As Bengaluru continues to innovate in this space, it sets a precedent for other cities to follow, illustrating that sustainable urban living is both achievable and beneficial for future generations.

Ethical Approval and Consent to Participate

This study was approved by the ethical clearance committee at Institute for Social and Economic Change, Nagarabhavi, Bengaluru. All participants provided written informed consent before participation.

Conflict of Interest

The authors declare that they have no competing interests.

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