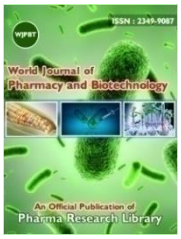

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Policy and challenges in municipal Solid waste management in India

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A B S T R A C T

Urbanization and industrialization have led to increased migration, causing city expansion and placing immense pressure on basic amenities and infrastructure. One of the critical challenges in Indian cities is Solid Waste Management (SWM), which is hindered by factors such as inadequate waste segregation, poor management capacity, lack of waste composition data, and weak regulatory enforcement. This study examines municipal solid waste management policies and execution in India, with a focus on Nellore. A household survey of 198 respondents across five colonies was conducted to assess awareness and satisfaction regarding waste management services. Findings indicate that while awareness is moderate, knowledge about waste disposal methods and recycling is limited. Key challenges include lack of segregation at source, public unawareness, and inadequate facilities. Decentralized waste management approaches, transitioning to a circular economy, and implementing Extended Producer Responsibility (EPR) are essential. The study suggests improved segregation, awareness programs, stricter regulations, and sustainable waste processing techniques such as composting, waste-to-energy, and plastic waste reuse for long-term waste management solutions in Rohtak.

Keywords: Urbanization, Industrialization, Solid Waste Management, Waste Segregation, Circular Economy, Public Awareness, Policy Implementation, Decentralized Waste Management.

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C O N T E N T S

1. Introduction

The rapid increase in consumption, globalization, and technological advancements has led to an unprecedented surge in waste generation. This escalating waste crisis has severe environmental consequences, contributing to climate change, water and air pollution, and soil contamination, among other ecological issues. The negative impacts of improper waste disposal are becoming increasingly evident, not only harming ecosystems but also posing significant economic challenges. Furthermore, the depletion of natural resources due to excessive waste production and inefficient management has become a pressing global concern. To address these challenges, there is an urgent need for innovative research and the development of sustainable waste management strategies. Implementing effective waste management models can help balance economic growth with environmental sustainability. One of the most critical areas of focus is the environmentally sound management of municipal waste, which remains a major concern for nations worldwide. Sustainable waste management practices must integrate waste reduction, recycling, circular

economy principles, and efficient policy enforcement to mitigate environmental damage and promote long-term ecological and economic stability.

Current status of municipal solid waste management (mswm) in India:

Municipal solid waste quantity and generation rate

In India, approximately 143,449 metric tonnes (MT) of municipal solid waste (MSW) is generated daily, with around 111,000 MT being collected and only about 35,602 MT undergoing treatment (S. Kumar et al., 2017). Waste generation varies significantly across cities, with per capita daily waste production increasing exponentially from 0.24 kg to 0.85 kg between 2001 and 2018, as reported by the Central Pollution Control Board (CPCB) in its 2018 annual report. This trend is expected to continue rising at an accelerated pace in the near future (CPCB India, 2018a; S. Kumar et al., 2017; Kumar Akhilesh & Agrawal Avlokita, 2020).

Table.1. Solid waste generation in 46 metrocities

Rank	City	Population (2011)[3]	Waste Generation (TPD)			
			1999- 2000	2004-05	2010-11	2015-16
1	Mumbai (Mh)	12,442,373	5355	5320	6500	11,000
2	Delhi i	11,034,555	400	5922	6800	8700
3	Bangalore (Krn)	8,443,675	200	1669	3700	3700
4	Chennai (TN)	7,088,000	3124	3036	4500	5000
5	Hyderabad (Tel)	6,731,790	1566	2187	4200	4000
6	Ahmedabad (Guj)	5,577,940	1683	1302	2300	2500
7	Kolkata (WB)	4,496,694	3692	2653	3670	4000
8	Surat (Guj)	4,467,797	900	1000	1200	1680
9	Pune(Mah)	3,124,458	700	1175	1300	1600
10	Jaipur (Raj)	3,046,163	580	904	310	1000
11	Luck now (UP)	2,817,105	1010	475	1200	1200
12	Kanpur (UP)	2,765,348	1200	1100	1600	1500
13	Nagpur (Mh)	2,405,665	443	504	650	1000
14	Visakhapatnam (AP)	2,035,922	300	584	334	350
15	Indore (MP)	1,960,631	350	557	720	850
16	Thane (Mh)	1,818,872	--	-	-	700
17	Bhopal (MP)	1,798,218	546	574	350	700
18	Pimpri-chinchwad (Mh)	1,729,359	-	-	-	700
19	Patna (Bhr)	1,683,200	330	511	220	450
20	Vadodara (Guj)	1,666,703	400	357	600	700
21	Ghaziabad (UP)	1,636,068	-	-	-	-
22	Ludhiana (Pb)	1,613,878	400	735	850	850
23	Coimbatore (TN)	1,601,438	350	530	700	850
24	Agra (UP)	1,585,704	-	654	520	790
25	Madurai (TN)	1,561,129	370	275	450	450
26	Nashik (Mh)	1,486,973	-	200	350	500
27	Vijayawada (AP)	1,476,931	-	374	600	550
28	Faridabad (Hr)	1,404,653	-	448	700	400
29	Meerut (UP)	1,309,023	-	490	520	500
30	Rajkot (Guj)	1,286,995	-	207	230	450
31	Kalian-dombivali (Mh)	1,246,381	-	-	510	650
32	Vasai-virar (Mh)	1,22,1,233	-	-	-	600
33	Varanasi (UP)	1,201,815	412	425	450	500
34	Srinagar (JK)	1,192,792	-	428	550	550
35	Aurangabad (Mh)	1,171,330	-	-	-	-
36	Dhanbad (Jh)	1,161,561	-	77	150	180
37	Amritsar (Pb)	1,132,761	-	438	550	600
38	Navi Mumbai (Mh)	1,119,477	-	-	-	675
39	Allahabad (UP)	1,117,094	-	509	350	450
40	Ranchi (Jh)	1,073,440	-	208	140	150
41	Howrah (WB)	1,072,161	-	-	-	740
42	Jabalpur (MP)	1,054,336	-	216	400	550

43	Gwalior (MP)	1,053,505	-	-	285	300
44	Jodhpur (Rj)	1,033,918	-	-	-	-
45	Raipur (Chh)	1,010,087	-	184	224	230
46	Kota (Rj)	1,001,694	-	-	-	-

India must enhance its municipal solid waste management system with a threefold objective: maximizing resource recovery, improving public health, and reducing the risks associated with anthropogenic greenhouse gas (GHG) emissions that contribute to global warming and climate change. The responsibility for assessing and implementing these improvements has been duly commissioned.

2. Challenges Related to MSWM in India Environment, Ecosystem and health:

Environmental degradation has a profound impact on human health (Shukla et al., 2000). Formal and informal waste workers face direct health risks due to the lack of proper protective gear such as gloves, uniforms, and safety equipment (Kumar, 2020). Communities living near waste disposal sites are highly susceptible to gastrointestinal parasite infections (Giusti, 2009). Open dumps, under anaerobic conditions, release methane from decomposing biodegradable waste, often leading to fires and explosions, significantly contributing to global warming (Slagstad & Bratteb, 2013). Additionally, waste disposal sites generate odor pollution and leachate migration, contaminating soil and water sources (Unnikrishnan et al., 2006; Muhammad et al., 2020; Dasgupta et al., 2013).

Uncontrolled burning of waste at dumpsites emits fine particulate matter and smog, posing serious respiratory health risks (Sridevi et al., 2012; Annepu, 2012; Ghosh, 2016a). Poorly maintained landfill sites and unsanitary disposal methods further exacerbate groundwater contamination due to leachate production. Certain ecosystems, particularly marine and coastal environments, suffer from improper waste management and littering, leading to severe threats to marine species through ingestion and entanglement.

Waste also has indirect environmental and economic impacts. Materials that are not recovered or recycled represent a loss of valuable resources, increasing the environmental footprint across the entire product lifecycle, including production, transportation, and consumption. These life-cycle impacts far exceed the effects of waste management alone. Furthermore, waste pollution contributes to climate change through methane emissions, contaminates air and freshwater sources, degrades soil quality, and introduces toxic chemicals into the food chain. Illegal dumping, open burning, and improper waste exports further aggravate environmental and health risks, though the full extent of these impacts remains difficult to quantify. Solid waste also degrades urban aesthetics, leading to littered streets and declining environmental quality. Inefficient waste combustion—whether in open air or poorly managed waste treatment facilities—causes significant air pollution. Despite the expected rise in waste generation, municipal solid waste management (MSWM) services remain inadequate, with major gaps in waste collection coverage, scientific waste processing, and proper disposal methods. Addressing these challenges requires urgent improvements in waste management infrastructure, stricter regulatory enforcement, sustainable waste treatment solutions.

Waste as a resource

Waste can be a valuable resource, reducing the demand for extracting new raw materials. By maximizing the use of existing resources, the environmental impacts associated with material extraction, production, and disposal can be minimized. Unutilized waste represents a significant loss of potential value, emphasizing the need for efficient waste management. Ensuring high-quality recycling, restricting energy recovery to non-recyclable waste, eliminating landfilling, and preventing illegal waste shipments are crucial steps toward sustainable waste management.

Organic waste, particularly kitchen and garden waste, constitutes the largest portion of municipal solid waste. When collected separately, it can be converted into valuable resources such as energy or fertilizer. Anaerobic digestion, for example, generates biogas, which can be used as a renewable energy source, while the residual byproduct serves as a nutrient-rich fertilizer, similar to compost.

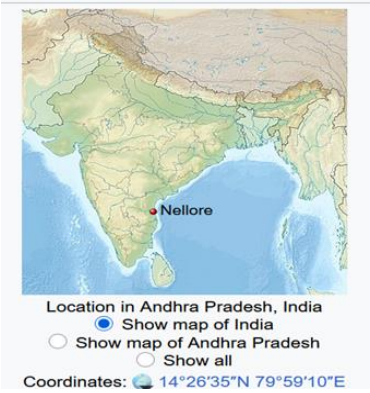
Both waste-to-energy processes and the circular economy offer multiple benefits beyond waste reduction. Transitioning from conventional disposal methods to energy recovery helps lower pollution, promoting better public health and a cleaner environment. Additionally, reducing reliance on raw material extraction mitigates the environmental and social impacts of mining, thereby benefiting both ecosystems and human communities.

Site Descrpition

Nellore, a city in Andhra Pradesh, India, is geographically positioned at approximately 14.44°N latitude and 79.99°E longitude, with an average elevation of 18 meters above sea level. As of the 2011 Census, Nellore had a population of 505,258, which increased to 558,548 following the merger of 15 gram panchayats into the Nellore Municipal Corporation. The literacy rate stands at 83.59%, surpassing the state average of 67.35%. Andhra Pradesh, the state encompassing Nellore, had a population of 49,577,103 according to the 2011 Census, with a density reflecting its diverse demographic distribution. The state's literacy rate is 67.35%, and it has a sex ratio of 997 females per 1000 males.

The climate in Nellore is classified as tropical savanna, characterized by hot, humid summers and warm winters. The city experiences its highest temperatures in April and

May, while December through February are the coolest months. Proximity to the Bay of Bengal, approximately 24 kilometers away, moderates the climate due to sea breezes. Nellore receives minimal rainfall from the southwest monsoon, with the majority occurring between October and December during the northeast monsoon, a period also prone to cyclones and flooding. In terms of environmental initiatives, Nellore was ranked as the 18th best "National Clean Air City" in India for cities with populations between 300,000 and 1 million, according to the Swachh Vayu Sarvekshan 2024. For a visual representation, refer to the map of Nellore city below:



Nellore, a city in Andhra Pradesh, India, has been experiencing rapid urbanization and industrialization, leading to increased solid waste generation. The waste produced encompasses various types, including biodegradable, non-biodegradable, construction debris, metals, and plastics. To address this, the Nellore Municipal Corporation (NMC) has implemented several waste management initiatives:

3. Waste Generation and Collection

The city generates approximately 200 metric tons of solid waste daily. Efforts are underway to enhance waste collection efficiency, including the establishment of wet waste management plants with a capacity of 15 tons each.

- **Waste Segregation**: NMC is promoting waste segregation at the source, aiming for 97% segregation at the point of generation.
- **Biomedical Waste**: The management of biomedical waste is a critical concern, with ongoing efforts to ensure its proper handling and disposal.
- **Landfill Sites**: The status and management of landfill sites are under scrutiny to prevent environmental hazards.
- **Public Awareness and Participation**: Recognizing the importance of community involvement, NMC is actively raising awareness about proper waste disposal practices and encouraging residents to cooperate with waste collection services.

In terms of administrative structure, NMC is divided into two zones and comprises 54 election wards. The corporation's functions include urban planning, approving new constructions, improving economic and social status, water supply management, fire contingency planning, solid waste management, public health, urban forestry, and development of weaker sections.

Financially, as of 2011, NMC's annual expenditure on solid waste management was approximately INR 3,941.66 million, with over 70% allocated to waste collection and only 5% dedicated to final disposal.

To further enhance waste management, NMC plans to establish additional wet waste management plants and an integrated solid waste management plant within the city limits. These initiatives aim to improve waste processing and reduce environmental impact.

Overall, while Nellore faces challenges in solid waste management due to its growing population and urbanization, the municipal corporation's initiatives reflect a commitment to improving waste management practices and environmental sustainability.

Solid waste management in Nellore is aimed to solve the challenges faced by local authorities in managing solid waste. Advanced technology, illegal dumping and management skills on disposal and landfill system. The concessionaires are expected to improve and ensure high-quality services in solid waste management, and provide recommendation and implementation policies and strategies pertaining to solid waste management services, as well as promoting participation and awareness among the public.

The study revealed some problems from Municipality that affected implementation like Inadequate Human & Financial Resources, Lack Of Integrated Solid Waste Management Plan, Public unawareness, inadequate land for final disposal of waste, lack of integrated solid waste management plan, public unawareness, lack of availability of modern technology and poor enforcement of Solid Waste Management Rule, 2016. Providing adequate resources, encouraging workers, developing a strong policy, incorporating technological innovations, providing monetary incentives for recyclable items, support from political leadership, encouraging waste reduction, composting and recycling techniques have been recommended for effective and successful waste management in the Nellore city.

Composting is a process of controlled decomposition of the organic waste, typically in aerobic conditions, resulting in the production of stable humus-like product, i.e., compost. Considering the typical composition of wastes and the climatic conditions, composting is highly relevant in India and should be considered in all municipal solid waste management (MSWM) concepts.

Integrated Solid Waste Management:

The Integrated Solid Waste Management (ISWM) hierarchy prioritizes waste minimization, emphasizing reduction at the source and reuse as the most effective waste management strategies. The hierarchy suggests that all waste reduction options should be maximized before

selecting and implementing appropriate treatment technologies.

- **At-source reduction and reuse**: Encouraging waste minimization and sustainable use of products, such as reusing carry bags and packaging jars.
- **Recycling**: Processing non-biodegradable waste to recover commercially valuable materials, including plastic, paper, metal, glass, and e-waste recycling.
- **Composting**: Converting biodegradable waste into compost using methods like windrow composting, in-vessel composting, and vermicomposting.
- **Waste-to-energy**: Extracting energy from waste before final disposal, including RDF (Refuse-Derived Fuel), biomethanation, co-processing of combustible non-biodegradable dry waste, and incineration.
- **Landfills**: Safe disposal of inert residual waste in sanitary landfills after maximizing recycling and reuse.

The **reduce, reuse, and recycle (3R) approach** is a preferred method for waste management, offering numerous environmental benefits. These practices help lower greenhouse gas emissions, prevent pollution, conserve resources, save energy, and reduce the need for extensive waste treatment and landfill space. It is crucial to incorporate these strategies into the waste management framework.

Different cities in India have adopted various strategies for managing municipal solid waste (MSW). Solid waste management in Nellore aims to address the challenges faced by local authorities in handling waste. To ensure efficient and sustainable MSW management, it is essential to enhance service quality, implement effective policies and strategies, and promote public participation and awareness.

In Nellore, some of the key challenges in MSWM include:

- Lack of waste segregation at the source.
- Limited public awareness about waste management practices.
- Poor segregation and recycling of plastic waste.
- Littering and improper waste disposal.
- Blockage of drains and sewerage systems due to unmanaged waste.
- Open burning of waste, especially in rural areas, leading to environmental pollution.

Sustainable Solid Waste Management in Nellore City

Population growth and urban development have significantly increased waste generation in India, making solid waste management (SWM) a critical challenge. Many cities, including Nellore, face inadequate waste management infrastructure and improper waste disposal practices. Public participation in waste management remains low, and there is a general lack of responsibility toward waste within communities. Raising community awareness and changing public attitudes toward waste is essential for developing sustainable and effective waste management systems. A successful and economically viable SWM system must prioritize resource recovery while ensuring safe disposal of residual waste through engineered landfills and waste-to-energy facilities.

A decentralized approach is one of the most effective methods to address waste management issues in India. This approach has the potential to reduce waste generation by changing public behavior, lowering transportation costs, reducing traffic congestion, minimizing air pollution, decreasing road maintenance costs, and preventing groundwater contamination caused by leachate seepage. Most importantly, it reduces the volume of waste reaching landfill sites, which is crucial given the constraints on land availability for waste disposal.

For Nellore City, improving public awareness is essential, but awareness alone is not enough to drive active community participation in waste management. Strengthening the capacity of municipal authorities is key to fostering long-term sustainability and encouraging public involvement. A strategic approach should include:

- Promoting waste segregation at all levels.
- Implementing a city-wide litter awareness and prevention plan.
- Enforcing a ban on open waste burning.
- Establishing door-to-door waste collection services in rural and urban areas.
- Providing regular training for waste management workers.
- Adopting advanced waste management techniques, such as composting, waste-to-energy conversion, recycling, and repurposing plastic waste for road construction.

4. Conclusion

Effective solid waste management in Nellore City requires a combination of public participation, strong municipal capacity, and sustainable policies. A shift toward decentralized waste management, improved resource recovery, and strategic policy implementation will help mitigate environmental pollution, enhance urban cleanliness, and promote a circular economy. By integrating technological advancements, encouraging community involvement, and adopting eco-friendly waste disposal methods, Nellore can develop a more efficient, sustainable, and long-term waste management system.

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