SOLID WASTE MANAGEMENT IN INDIAN PERSPECTIVES: A COMPREHENSIVE REVIEW

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ABSTRACT: This research paper presents a comprehensive review on solid waste management from an Indian perspective. It provides an overview of the current status, challenges, and opportunities in the field of solid waste management, with a focus on environmental sustainability and public health. The study examines the types and composition of solid waste generated, existing waste management practices, and the legal and policy framework surrounding waste management in the country. It also explores the collection and transportation of solid waste, as well as disposal and treatment methods. The review identifies infrastructure and resource constraints, institutional and governance issues, and environmental and social impacts as major challenges. Moreover, it highlights opportunities for sustainable waste management, including integrated waste management approaches, technological innovations, and community engagement. The findings of this review contribute to the understanding of solid waste management in India and provide insights for policymakers and practitioners to develop effective and sustainable waste management strategies for the country.
KEYWORDS: *Environmental sustainability; Public health; Solid waste management; Sustainable waste management.*

1. INTRODUCTION

Solid waste management is a critical global concern, and India grapples with this issue as well. With its massive population exceeding 1.3 billion, India generates a staggering 62 million tonnes of solid waste annually, making it as the world's third-largest waste generator (Sharma et al., 2021). Rapid urbanization, population growth, and changing consumption patterns in India have magnified the challenge of solid waste management. Over the years, India's solid waste management practices have evolved. Traditionally, waste disposal involved open dumping and burning, leading to severe environmental contamination and health hazards. The inefficient management of solid waste has led to several environmental problems. Poor disposal practices and insufficient waste treatment contribute to pollution of air, water, and soil, causing harm to ecosystems and human health (Mohan and Joseph, 2021). Accumulation of waste in landfills and dumping sites emits greenhouse gases and contaminates groundwater, worsening environmental degradation. Additionally, improper waste disposal contributes to the spread of diseases, including vector-borne and respiratory illnesses (Mainul, 2019). The consequences are not only environmental but also social and economic, affecting the overall well-being and quality of life.

Addressing the challenges of solid waste management in India requires comprehensive strategies encompassing waste reduction, segregation, collection, treatment, and disposal. Sustainable waste management practices not only reduce pollution and health risks but also offer opportunities for resource recovery, energy generation, and employment (Sharma et al., 2021). These practices are vital for mitigating the adverse effects of waste on natural resources, ecosystems, and human health. By utilizing suitable waste treatment techniques, harmful pollutants can be prevented from contaminating air, water, and soil. This safeguarding of natural resources also extends to water bodies, air quality, and soil health. Moreover, sustainable waste management aligns with circular economy principles by promoting recycling and reuse, thereby conserving resources and reducing environmental impacts (Romero-Hernández and Romero, 2018).

Effective waste management also contributes to climate change mitigation. Technologies that convert waste to energy and methods to reduce methane emissions from landfills aid in reducing greenhouse gas release, mitigating climate change. Furthermore, proper waste management significantly impacts public health. Ensuring appropriate waste collection, treatment, and disposal minimizes risks associated with waterborne and vector-borne diseases, along with respiratory ailments linked to improper waste practices (Nor Faiza et al., 2019).

Overall, the significance of effective waste management for environmental sustainability and public health cannot be overstated. By reducing pollution, conserving resources, mitigating climate change, and safeguarding public health, sustainable waste management practices pave the way for a healthier and more sustainable future for India and its communities. Thus, to address the challenges and potential impacts of solid waste management in India, comprehensive research and analysis are necessary. This study aims to provide an in-depth understanding of the current state of solid waste management in India, identify key issues and challenges, and explore potential solutions for achieving sustainable waste management practices.

2. MATERIALS AND METHODS

The methodology employed in this comprehensive review on solid waste management in India involved a systematic approach to gather relevant data, analyze information, and draw meaningful conclusions. To achieve the objectives of the study, a thorough literature review was conducted. A comprehensive search strategy was developed to identify relevant research articles, reports, government publications, and other reliable sources of information related to solid waste management in India. Various online databases, including academic journals and research repositories, were searched to collect primary and secondary data.

The collected data encompassed a wide range of aspects related to solid waste management in India and data were extracted and organized systematically for further analysis. The analysis of the collected data involved a combination of qualitative and quantitative approaches. Qualitative analysis was performed to identify key themes, trends, and challenges in solid waste management practices in India. This included synthesizing information from various sources, identifying common patterns, and critically examining the strengths and weaknesses of existing waste management systems. Quantitative analysis was conducted to assess waste generation rates, composition, and trends over time. This involved analyzing available data sets, conducting statistical calculations, and generating descriptive statistics to provide a comprehensive understanding of the quantitative aspects of solid waste management in India.

3. Overview of Solid Waste Management

3.1 Definition, types and composition of solid waste

Solid waste refers to any discarded or abandoned material that is not liquid or gaseous. In the context of solid waste management, it is important to understand the different categories of waste and their characteristics (Table 1). One of the major categories of solid waste is municipal solid waste (MSW), and the composition of MSW can vary significantly based on factors such as population density, socioeconomic conditions, and cultural practices within a region. Industrial wastes include hazardous substances, such as chemicals, heavy metals, and toxic materials, which require special handling and treatment to prevent environmental pollution and public health risks. Biomedical waste includes potentially infectious and hazardous materials, such as discarded medical equipment, sharps (needles and syringes), pathological waste, and pharmaceutical waste. Understanding the composition and characteristics of different types of solid waste is essential for designing appropriate waste management strategies and selecting suitable treatment technologies. Additionally, proper segregation, handling, and disposal of biomedical waste are crucial to prevent the spread of diseases and protect the environment.

Table 1: Types and composition of solid waste

Types	Composition of Solid Waste
Solid Waste	Refers to any discarded materials that are not liquid or gaseous and are managed as waste. It includes household, commercial, and industrial waste.
Municipal Solid Waste	Waste generated from households, hotels, markets, offices, institutions, and other non-industrial sources. It comprises organic waste, paper, plastics, glass, metals, and other miscellaneous items.
Industrial Waste	Generated by manufacturing and industrial processes. It includes hazardous and non-hazardous waste, such as chemicals, solvents, metals, and by-products from industrial activities.
Biomedical Waste	Waste generated from healthcare facilities, such as hospitals, clinics, and research centers. It includes infectious waste, pharmaceutical waste, sharps, and pathological waste.
Construction Waste	Generated during construction, renovation, or demolition activities. It includes materials like concrete, bricks, wood, metals, plastics, and packaging waste.
Electronic Waste	Also known as e-waste, it comprises discarded electronic devices such as computers, mobile phones, televisions, and other electrical equipment.
Hazardous Waste	Waste that poses substantial risks to human health or the environment due to its chemical or physical properties. Examples include toxic chemicals, pesticides, and radioactive materials.
Agricultural Waste	Generated from agricultural activities, such as crop residues, animal waste, agrochemicals, and packaging materials used in farming.

Source: Compiled by the researchers from different literatures.

3.2 Solid waste management practices

Solid waste management practices encompass a range of techniques and approaches aimed at minimizing waste generation, promoting resource recovery, and ensuring proper disposal of residual waste. These practices can be categorized into conventional and innovative waste management techniques. Conventional waste management techniques typically involve the collection, transportation, and disposal of waste. These include methods such as open dumping, landfilling, and incineration. Open dumping, the most basic and least environmentally friendly method, involves the uncontrolled disposal of waste in open areas, leading to environmental pollution and health hazards. In recent years, there has been a shift towards innovative waste management techniques that focus on the waste hierarchy principle. The waste hierarchy follows the order of priority for waste management, including reduction, reuse, recycling, recovery, and disposal. Innovative waste management practices focus on maximizing resource recovery and minimizing environmental impact. This includes advanced waste segregation techniques to separate recyclable materials from waste streams, decentralized composting and vermicomposting for organic waste treatment, and the promotion of circular economy principles to encourage the reuse and recycling of materials. Adopting innovative waste management practices aligned with the waste hierarchy is essential for achieving environmental sustainability and resource conservation. By prioritizing waste reduction, reuse, and recycling, countries like India can minimize waste generation, reduce dependence on landfills, conserve natural resources, and mitigate environmental pollution.

4. CURRENT STATUS OF SOLID WASTE MANAGEMENT IN INDIA

4.1 Legal and Policy Framework

The effective management of solid waste in India is supported by a legal and policy framework that includes national and state-level policies and regulations. The central legislation governing solid waste management in the country is the Solid Waste Management Rules (SWM), 2016, enacted under the Environment (Protection) Act, 1986. These rules provide a comprehensive framework for waste management practices, including waste segregation, collection, transportation, treatment, and disposal. At the national level, the Ministry of Environment, Forest and Climate Change (MoEFCC) plays a crucial role in formulating and implementing policies related to solid waste management. The MoEFCC has released various guidelines and initiatives to promote sustainable waste management practices, such as the Swachh Bharat Mission and the National Clean Air Program. These initiatives aim to address the challenges associated with waste management and improve the overall cleanliness and environmental health of the country.

Despite the existence of a legal and policy framework, there are challenges in the implementation and effectiveness of solid waste management regulations in India. One of the major challenges is the gap between policy formulation and actual implementation on the ground. Inadequate infrastructure, lack of resources, and limited technical capacity pose significant hurdles in achieving the desired outcomes of waste management policies. Another challenge is the involvement of multiple stakeholders, including municipal authorities, waste collectors, informal waste pickers, and the general public. Coordinating and integrating the efforts of these diverse stakeholders is crucial for effective waste management but often requires capacity building and awareness programs.

4.2 Waste generation and composition

According to a study conducted by the Central Pollution Control Board (CPCB) in 2020-21, India generates approximately 58,406,468.5 tons of municipal solid waste (MSW) annually (Table 2) with per capita 119.07 gm/day solid waste generation (Table 3). This vast quantity of waste poses significant challenges for waste management infrastructure and systems across the country.

Table 2: Statistics of Solid Waste Management status in different states in India

Sl. No.	State	Solid waste generated (TPD) 2010	Solid waste generated (TPD)	Collected (TPD)	Treated (TPD)	Landfilled (TPD)	Growth Rate (%)
1	Andhra Pradesh	11500	6898	6829	1133	205	-40.04
2	Arunachal Pradesh	94	236.51	202.11	Nil	27.5	151.17
3	Assam	1146	1199	1091	41.4	0	4.62
4	Bihar	1670	4281.27	4013.55	Not provided	No	156.04
5	Chhattisgarh	1167	1650	1650	1650	0	41.34
6	Goa	193	226.87	218.87	197.47	22.05	17.53
7	Gujarat	7379	10373.79	10332	6946	3385.82	40.63
8	Haryana	537	5352.12	5291.41	3123.9	2167.51	896.86
9	Himachal Pradesh	304	346	332	221	111	13.82

10	Jammu & Kashmir	1792	1463.23	1437.28	547.5	376	-18.34
11	Jharkhand	1710	2226.39	1851.65	758.26	1086.33	30.17
12	Karnataka	6500	11085	10198	6817	1250	70.54
13	Kerala	8338	3543	964.76	2550	Not Provided	-57.51
14	Madhya Pradesh	4500	8022.5	7235.5	6472	763.5	78.17
15	Maharashtra	19204	22632.71	22584.4	15056.1	1355.36	17.83
16	Manipur	113	282.3	190.3	108.6	81.7	149.20
17	Meghalaya	285	107.01	93.02	9.64	83.4	-62.58
18	Mizoram	142	345.47	275.92	269.71	0	143.92
19	Nagaland	188	330.49	285.49	122	7.5	75.54
20	Odisha	2239	2132.95	2097.14	1038.31	1034.33	-4.74
21	Punjab	2794	4338.37	4278.86	1894.04	2384.82	55.21
22	Rajasthan	5037	6897.16	6720.476	1210.46	5082.16	36.87
23	Sikkim	40	71.9	71.9	20.35	51.55	79.75
24	Tamil Nadu	12504	13422	12844	9430.35	2301.04	7.34
25	Telangana	NA	9965	9965	7530	991	NA
26	Tripura	360	333.9	317.69	214.06	12.9	-7.25
27	Uttarakhand	752	1458.46	1378.99	779.85	-	93.72
28	Uttar Pradesh	11585	14710	14292	5520	0	26.87
29	West Bengal	12557	13709	13356	667.6	202.23	9.19
30	Andaman and Nicobar Islands	50	89	82	75	7	78.00
31	Chandigarh	380	513	513	69	444	34.74
32	DDDNH	41	267	267	237	14.5	551.22
33	Delhi	7384	10990	10990	5193.57	5533	48.24
34	Lakshadweep	21	35	17.13	17.13	Nil	66.67
35	Puducherry	380	504.5	482	36	446	32.76
	TOTAL	127485	160038.9	152749.5	79956.3	29427.2	25.45

Source: CPCB 2010-11, 2020-21.

Table 3: Solid Waste Generation Per Capita

Year	Solid Waste Generation Per Capita(gm/day)
2015-16	118.68
2016-17	132.78
2017-18	98.79
2018-19	121.54
2019-20	119.26
2020-21	119.07

Source: CPCB 2020-21.

The composition of solid waste in India varies across regions and urban-rural divides. However, certain waste streams are consistently observed to make significant contributions. Organic waste, including food waste and garden waste, constitutes a substantial portion of the waste generated in India. It is estimated to account for around 50-60% of the total waste generated. This high percentage of organic waste highlights the potential for composting and biogas generation as sustainable waste management practices. Plastic waste is another major component of the waste stream. India has been grappling with a significant plastic waste problem, with single-use plastics and packaging materials contributing a significant portion of the waste generated. The study conducted by Ahluwalia and Patel (2018) reveals certain trends in waste composition based on population range. In cities with a population range of 0.1 to 0.5 million, paper constitutes the highest percentage at 2.91%, followed by compostable material at 44.57% and inert material at 43.59% (Fig. 1). Leather, rubber, and synthetics, glass, and metal have relatively smaller percentages in this population range (Table 4).

Table 4: Physical composition of municipal solid waste in India

Population Range (in million)	Number of Cities Surveyed	Paper (%)	Leather, Rubber, and Synthetics (%)	Glass (%)	Metal (%)	Compostable Material (%)	Inert Material (%)
0.1 to 0.5	12	2.91	0.78	0.56	0.33	44.57	43.59
0.5 to 1.0	15	2.95	0.73	0.56	0.32	40.04	48.38
1.0 to 2.0	9	4.71	0.71	0.46	0.49	38.95	44.73
2.0 to 5.0	3	3.18	0.48	0.48	0.59	56.57	49.07
5.0 and above	4	6.43	0.28	0.28	0.80	30.84	53.90

Source: Ahluwalia and Patel, 2018.

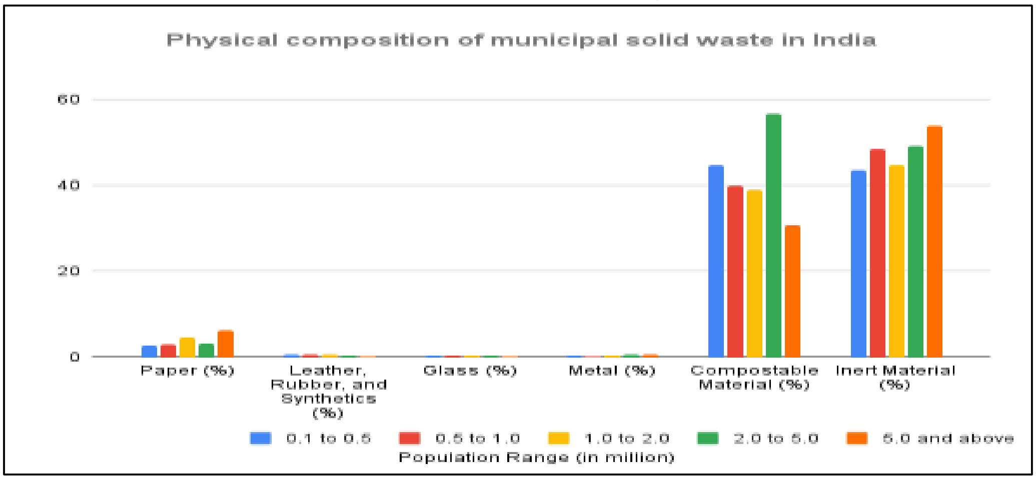

Fig. 1: Physical composition of municipal solid waste in India, 2018

4.3 Collection and Transportation

Efficient and systematic waste collection and transportation are crucial components of solid waste management. In urban areas, MSW collection is primarily carried out by municipal corporations or local government bodies. The collection process involves the deployment of waste collection vehicles, such as compactors, tricycles, or pushcarts, to collect waste from households, commercial establishments, and public spaces. The collected waste is then transported to transfer stations or directly to treatment and disposal facilities. The coverage and efficiency of waste collection systems in urban areas vary significantly across cities (Mainul *et al.,* 2019). Larger cities generally have more established waste collection infrastructure and better coverage compared to smaller towns and peri-urban areas. However, even in urban areas, challenges persist. Limited financial resources, inadequate infrastructure, and population growth pose significant challenges to achieving comprehensive waste collection coverage. Furthermore, the presence of narrow and congested streets, informal settlements, and high-rise buildings can make waste collection and transportation more challenging (Aijaz, 2019).

In rural areas, waste collection and transportation systems are often less organized and rely on decentralized approaches. The responsibility for waste collection is shared among households, local communities, or panchayats (village-level local self-government institutions). In some cases, waste collection is carried out by informal waste pickers who collect recyclable materials for their livelihoods. The collected waste is often transported to open dumping sites or disposed of in nearby open areas, posing environmental and health risks.

4.4 Waste Disposal and Treatment Methods

In India, various disposal and treatment practices are employed, including landfilling, incineration, composting, and recycling. Landfilling is the most common method of waste disposal in India, particularly in urban areas. However, the environmental impact of landfilling is a matter of concern. To mitigate these impacts, modern landfilling techniques such as engineered landfills with liners and leachate collection systems are being implemented in some regions. However, the adoption of incineration in India is limited due to concerns over air pollution, emission of toxic pollutants, and the high capital and operational costs associated with the technology. Composting is a widely practiced waste treatment method in India, particularly for organic waste. Community-level composting initiatives and decentralized composting facilities are being promoted in many cities and towns to encourage waste segregation at source and the utilization of organic waste for sustainable agriculture (Mandpe *et al.,* 2020).Recycling is an important component of solid waste management in India. The recycling industry in India has experienced significant growth in recent years. However, challenges such as inadequate collection systems, poor quality segregation, and lack of awareness among the public still persist. Each waste disposal and treatment method has its own environmental and social impacts.

5. CHALLENGES IN SOLID WASTE MANAGEMENT

5.1 Infrastructure and resource constraints

One of the significant challenges in solid waste management in India is the inadequate infrastructure and resource constraints. Many cities and towns in India lack adequate waste collection vehicles, waste treatment and disposal facilities, and recycling infrastructure. Insufficient infrastructure hampers the efficient collection, transportation, and treatment of waste, leading to inadequate waste management practices. Financial constraints play a significant role in limiting the development and maintenance of waste management infrastructure. Limited financial resources often result in delays or compromises in the implementation of waste management projects. Technical constraints encompass technological limitations and the need for specialized knowledge and skills. However, there is a shortage of skilled personnel and technical experts in the field of waste management posing challenges in adopting and implementing innovative waste management practices.

Human resource challenges also contribute to the constraints in solid waste management. The efficient management of waste requires trained personnel, including waste collectors, supervisors, engineers, and administrative staff. However, there is a shortage of trained personnel in many waste management departments. In addition, the lack of awareness and proper training among waste handlers and the public regarding waste segregation and proper disposal practices further complicates the waste management process. These infrastructure and resource constraints have a direct impact on the efficiency and effectiveness of waste management systems in India (Mir *et al.,* 2021).

5.2 Institutional and governance issues

Effective waste management requires clear roles and responsibilities for various stakeholders, as well as coordination and collaboration among government agencies, municipalities, and private entities. The roles and responsibilities of different stakeholders involved in waste management are often not well-defined or properly coordinated. The responsibilities for waste collection, transportation, treatment, and disposal are typically shared among multiple agencies, including municipal corporations, local bodies, and private contractors. Lack of clarity in roles and responsibilities leads to overlapping or fragmented efforts, resulting in inefficient waste management practices. Coordination and collaboration among government agencies, municipalities, and private entities are crucial for the successful implementation of waste management initiatives. However, challenges in coordination and collaboration persist. In many cases, inadequate collaboration leads to suboptimal waste management practices and missed opportunities for innovation and improvement (Robins *et al.,* 2011). Institutional and governance issues also include policy and regulatory frameworks. The effectiveness and enforcement of policies and regulations related to waste management vary across different states and regions in India. Moreover, the involvement of informal waste sector and ragpickers is an important aspect of waste management in India. Ragpickers play a significant role in waste collection and recycling, often operating in an informal and unregulated manner. Integrating the informal waste sector into formal waste management systems poses governance challenges, including issues of recognition, social security, and fair remuneration for their services.

5.3 Environmental and Social Impacts

Improper solid waste management practices in India have significant environmental and social impacts. Understanding and addressing these impacts are crucial for sustainable waste management. Improper waste management has adverse effects on public health. Open dumping and inadequate waste treatment facilities contribute to the spread of diseases and contamination of water sources. The presence of hazardous waste in unregulated landfills poses long-term health risks to nearby communities. Furthermore, the emission of pollutants from waste incineration and open burning degrade air quality, affecting the respiratory health of individuals living in close proximity to waste disposal sites (Sk *et al.,* 2020).

The impact of improper waste management extends beyond environmental concerns and affects social aspects as well. Inequitable waste management practices lead to marginalized communities bearing a disproportionate burden of waste-related issues. Landfills and waste disposal sites are often located near low-income neighborhoods, leading to environmental injustice. The stigmatization and marginalization of waste pickers, who play a critical role in informal waste management, also highlight social challenges in waste management systems. Moreover, inefficient waste management practices impact livelihoods, particularly for those engaged in the informal recycling sector.

6. OPPORTUNITIES FOR SUSTAINABLE SOLID WASTE MANAGEMENT IN INDIA

6.1 Integrated waste management approaches

To address the challenges in solid waste management, there are significant opportunities for implementing integrated waste management approaches in India. Integrated waste management focuses on adopting holistic strategies that prioritize waste segregation, recycling, and resource recovery, while minimizing the amount of waste sent for disposal (Hossain *et al.,* 2019). One key aspect of integrated waste management is waste segregation at the source. This segregation enables efficient handling and treatment of specific waste streams, facilitating recycling and resource recovery processes. Several cities in India have implemented source segregation programs, where households are encouraged to separate waste at the household level. In addition to waste segregation, recycling plays a crucial role in sustainable waste management. It helps conserve natural resources, reduces energy consumption, and mitigates the environmental impact of waste disposal. Promoting recycling initiatives, such as establishing recycling centers and engaging with the informal recycling sector, can enhance the recycling rates and reduce the amount of waste ending up in landfills. Furthermore, adopting circular economy principles is a promising approach for sustainable waste management. The circular economy aims to minimize waste generation and maximize the utilization of resources by promoting the reuse, repair, and recycling of products and materials (Sharma *et al.,* 2021). By designing products with recyclability and reusability in mind, and by creating closed-loop systems where waste is seen as a valuable resource, a circular economy can significantly reduce the environmental impact of waste management.

Sustainable waste management models, such as decentralized waste management systems and community-based initiatives, also offer opportunities for improving waste management practices in India. Decentralized systems involve treating waste at or near the source of generation, reducing the need for long-distance transportation and centralized facilities. Community-based initiatives foster active community participation, creating a sense of ownership and responsibility towards waste management. Implementing integrated waste management approaches requires collaboration among various stakeholders, including government agencies, local municipalities, private sector, and community organizations. It necessitates the development of supportive policies, capacity building, and awareness campaigns to drive behavioral changes in waste management practices.

6.2 Technological innovations

In addition to integrated waste management approaches, there are significant opportunities for utilizing technological innovations to improve solid waste management practices in India. One notable technological innovation is waste-to-energy conversion, which involves the conversion of solid waste into energy forms such as electricity or heat. Technologies like incineration and gasification can convert non-recyclable waste into useful energy sources, reducing the reliance on fossil fuels and mitigating greenhouse gas emissions. Waste-to-energy projects have the potential to generate clean energy and address the challenge of waste disposal simultaneously. Bioremediation is another innovative approach that utilizes microorganisms or plants to degrade and detoxify waste materials. This biological process can be employed to treat organic waste, contaminated soil, and other types of hazardous waste. Technologies like pyrolysis and hydrothermal processing can efficiently convert plastic waste into valuable products, such as fuel or feedstock for manufacturing. By promoting advanced recycling methods, the circular economy can be further strengthened, reducing the dependence on virgin resources and minimizing waste generation.

Furthermore, the advent of smart solutions and digital platforms has the potential to revolutionize waste management practices. Smart waste management systems incorporate the use of sensors, data analytics, and Internet of Things (IoT) technologies to optimize waste collection, monitor bin levels, and improve operational efficiency. Digital platforms can facilitate citizen engagement, providing platforms for waste reporting, awareness campaigns, and efficient communication between stakeholders. These technologies enable real-time data monitoring, optimization of waste collection routes, and effective resource allocation, leading to improved waste management practices (Mdukaza *et al.,* 2018).

6.3 Community engagement and awareness

Community engagement and awareness play a vital role in promoting sustainable solid waste management practices. Community-based initiatives have emerged as effective models for waste management. These initiatives involve the active participation of local residents, non-governmental organizations (NGOs), and community-based organizations (CBOs) in waste collection, segregation, and recycling activities. By empowering communities and providing them with the necessary knowledge and resources, these initiatives promote waste management as a collective responsibility. Community engagement not only enhances the efficiency of waste management systems but also fosters a sense of ownership and pride among residents. Awareness campaigns and behavioral change programs are essential in promoting waste reduction and segregation practices. These initiatives aim to educate and inform citizens about the importance of proper waste management, the environmental impact of waste, and the benefits of recycling and composting. Through various communication channels such as workshops, seminars, social media, and public awareness campaigns, these programs raise awareness about the adverse effects of improper waste disposal and highlight the need for sustainable practices. Citizen participation is encouraged through educational materials, training sessions, and the provision of appropriate waste management infrastructure. Furthermore, the integration of waste management education in school curricula can play a pivotal role in shaping the attitudes and behaviors of future generations.

7. CONCLUSION

This comprehensive review of solid waste management in India has shed light on various aspects related to the current practices, challenges, and opportunities in waste management. The findings reveal that while progress has been made, there are still significant gaps and obstacles that hinder effective waste management in the country. The review highlighted the increasing waste generation rates and the composition of solid waste in different regions of India. It identified the dominant waste streams and their proportionate contribution, emphasizing the need for targeted interventions. The analysis of waste collection and transportation systems revealed challenges in terms of efficiency, coverage, and infrastructure limitations. Additionally, the review examined the different waste disposal and treatment methods, highlighting the environmental and social impacts associated with each approach. The implications of this review are significant for sustainable waste management practices in India. It underscores the urgent need for policy reforms, improved infrastructure, and increased investment in waste management systems. While this study provides valuable insights into solid waste management in India, there are several areas that warrant further investigation. Future research should focus on evaluating the effectiveness of specific waste management interventions, such as community-based initiatives and technological innovations. Additionally, studying the socio-economic impacts of waste management practices and their implications for vulnerable communities would contribute to a more inclusive and equitable waste management system. The review also highlights the need for longitudinal studies to assess the long-term effects of waste management policies and interventions on the environment and public health.

REFERENCES

[1] Ahluwalia, I. J.; & Patel, U., (2018). Solid waste management in India: An assessment of resource recovery and environmental impact (No. 356). Working paper.

[2] Aijaz, R., (2019). India's peri-urban regions: the need for policy and the challenges of governance. ORF Issue Brief, 285.

[3] CPCB (2010-11). Consolidated Annual Review Report on Municipal Solid Wastes, Central Pollution Control Board. Retrieved from https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2010-11.pdf

[4] CPCB (2020-21). Annual Report on Solid Waste Management, Central Pollution Control Board. Retrieved from https://cpcb.nic.in/uploads/MSW/MSW_AnnualReport_2020-21.pdf

[5] Hossain, M. U.; Ng, S. T., (2019). Influence of waste materials on buildings' life cycle environmental impacts: Adopting resource recovery principle. Resources, Conservation and Recycling, 142, 10-23.

[6] Mainul, S. (2019). Challenges in the management of single-use plastic carrier bags in Aligarh City: A study on sellers and consumer attitude. International Journal of Research in Social Sciences, 9(7), 732-750.

[7] Mandpe, A.; Kumari, S.; Kumar, S., (2020). Composting: A Sustainable Route for Processing of Biodegradable Waste in India. Organic Waste Composting through Nexus Thinking: Practices, Policies, and Trends, 39-60.

[8] Mdukaza, S.; Isong, B.; Dladlu, N.; Abu-Mahfouz, A. M., (2018, October). Analysis of IoT-enabled solutions in smart waste management. In IECON 2018-44th annual conference of the IEEE industrial electronics society (pp. 4639-4644). IEEE.

[9] Mir, I. S.; Cheema, P. P. S.; Singh, S. P., (2021). Implementation analysis of solid waste management in Ludhiana city of Punjab. Environmental Challenges, 2, 100023.

[10] Mohan, S.; Joseph, C. P., (2021). Potential hazards due to municipal solid waste open dumping in India. Journal of the Indian Institute of Science, 101(4), 523-536.

[11] Nor Faiza, M. T.; Hassan, N. A.; Mohammad Farhan, R.; Edre, M. A.; Rus, R. M., (2019). Solid Waste: It's Implication for Health and Risk of Vector-Borne Diseases. Journal of Wastes and Biomass Management (JWBM), 1(2), 14-17.

[12] Robins, G.; Bates, L.; Pattison, P., (2011). Network governance and environmental management: conflict and cooperation. Public Administration, 89(4), 1293-1313.

[13] Romero-Hernández, O.; Romero, S., (2018). Maximizing the value of waste: From waste management to the circular economy. Thunderbird International Business Review, 60(5), 757-764.

[14] Sharma, H. B.; Vanapalli, K. R.; Samal, B.; Cheela, V. S.; Dubey, B. K.; Bhattacharya, J., (2021). Circular economy approach in solid waste management system to achieve UN-SDGs: Solutions for post-COVID recovery. Science of The Total Environment, 800, 149605.

[15] Sk, M. M.; Ali, S. A.; Ahmad, A., (2020). Optimal sanitary landfill site selection for solid waste disposal in Durgapur city using geographic information system and multi-criteria evaluation technique. KN-Journal of Cartography and Geographic Information, 70, 163-180.