

PROCEEDINGS

A Two day National Seminar on Multi-Disciplinary Research in Contemporary Era: Exploring Innovative Trends

20th & 21st February, 2025

Organized by
Department of Humanities
and
Internal Quality Assurance Cell (IQAC)

Editors

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Volume I



TERESIAN COLLEGE

Bannur Road, Siddarthanagar, Mysuru - 570 011

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ISBN: 978-81-948760-1-4

Published By

Teresian College

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20th Feb, 2025

Seminar Organized by Department of Humanities and Internal Quality Assurance Cell (IQAC),
Teresian College, Mysuru.

INR: 600

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ADVANCING WASTE MANAGEMENT PRACTICES FOR A GREENER FUTURE

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Abstract

Sustainable development and environmental protection are both heavily reliant on efficient waste management. With the increasing amount of trash generated worldwide, conventional disposal techniques like landfilling and incineration are not meeting the environmental and social problems related to waste. The paper explores novel approaches and cutting-edge techniques meant to make trash management a resource-efficient, sustainable system. The transition to integrated waste management, which prioritizes resource recovery, recycling, and waste minimization, is at the heart of the conversation. Due to their potential to increase productivity and reduce environmental impact, cutting-edge technologies such as artificial intelligence (AI), the Internet of Things (IoT), and bioconversion processes are emphasized. These developments will be examined in conjunction with neighbourhood-based programs that encourage local involvement and accountability, demonstrating the effectiveness of group efforts in tackling waste problems. This study also examines the role of policy and governance, highlighting the value of frameworks like landfill taxes and Extended Producer Responsibility (EPR) in encouraging sustainable activities. In order to create robust waste management systems that align with the tenets of a circular economy, public-private partnerships and community involvement are seen as essential components. This study links waste management practices with the Sustainable Development Goals (SDGs) of the United Nations, highlighting the need for innovative, integrated approaches to garbage management. By encouraging a future where waste is seen as a resource rather than an obstacle, it works to improve environmental resilience, economic sustainability, and social cohesion.

Key Words: Environmental Protection, Sustainable Development Goals (SDGs), waste management

Introduction

Rapid urbanisation, population growth, and consumption patterns have made the global waste crisis one of the greatest challenges of the twenty-first century. Basically 2.01 billion tonnes of municipal solid waste (MSW) are produced annually, and if current trends continue, this amount is predicted to increase to 3.4 billion tonnes by 2050 (World Bank, 2022). It is concerning to note that more than 33% of this waste is not managed in an environmentally safe manner, which has serious consequences for the environment and public health. Traditional waste management practices, such as open dumping and landfilling, exacerbate environmental degradation by contributing to pollution, greenhouse gas emissions, and the loss of valuable resources. For example, methane, a powerful greenhouse gas that contributes to climate change, is primarily released by landfills. Waste is a major emitter, contributing almost 3% of world emissions, according to the Intergovernmental Panel on Climate Change (IPCC, 2021). Additionally, informal garbage dumps proliferate as a result of insufficient waste disposal infrastructure in developing nations, endangering biodiversity and human health.

Economically, ineffective waste management imposes high costs on municipalities, particularly in low- and middle-income countries where waste collection and treatment can consume up to 20% of municipal budgets (World Economic Forum, 2020). Socially, marginalized communities often bear the brunt of waste mismanagement, facing increased exposure to pollution and unsafe working conditions in informal waste sectors.

The urgent need to adopt sustainable waste management practices is emphasized by the United Nations Sustainable Development Goals (SDGs), especially Goal 12, which calls for responsible consumption and production, and Goal 13, which addresses climate action. To meet these goals, it is imperative to transition from linear waste disposal models to circular systems that emphasize reduction, reuse, and recovery. By combining policy measures, community engagement, and technological advancements, this research aims to present a plan for transforming global waste management systems to secure a greener, more sustainable future. This paper examines the many facets of waste management, highlighting innovative approaches and technologies that offer sustainable solutions.

Challenges in Current Waste Management

1. Environmental Impacts

- a) **Greenhouse Gas Emissions:** Methane is a greenhouse gas that has a 25-fold higher potential for global warming than carbon dioxide over a 100-year period, and landfills are a major producer of this gas. A significant portion of climate change is caused by methane emissions from poorly managed or mismanaged trash (IPCC, 2021).
- b) **Leachate Pollution:** The liquid that percolates through landfills, known as leachate, often contains harmful chemicals and heavy metals. This poses severe risks to groundwater and surface water resources, affecting ecosystems and human health. Effective leachate management remains a critical challenge in waste management systems, particularly in low-income regions.
- c) **Loss of Biodiversity:** Uncontrolled waste disposal in habitats endangers biodiversity and degrades the soil. Wildlife frequently suffers direct harm as a result of ingesting or becoming entangled in garbage, especially plastics.

2. Economic Constraints:

- a. **High Costs of Infrastructure:** Developing comprehensive waste management infrastructure, such as recycling plants and waste-to-energy facilities, demands significant financial investment. For instance, the capital cost of a modern waste-to-energy facility can range from \$500 to \$900 per ton of annual capacity (World Bank, 2022).
- b. **Inefficiencies in Collection and Segregation:** Inefficient collection systems and inadequate waste segregation at the source lead to increased operational costs and reduced effectiveness of recycling initiatives. The lack of standardized practices exacerbates these inefficiencies.
- c. **Informal Sector Challenges:** In many developing countries, waste collection and recycling are heavily reliant on the informal sector, which operates without access to financial or technical resources. This limits the scalability and efficiency of waste management efforts.

3. Social Issues

- a. **Health Hazards:** Workers in the informal waste sector face severe health risks due to exposure to hazardous waste, including medical and electronic waste. Respiratory diseases, skin conditions, and injuries are common among waste pickers.
- b. **Limited Public Awareness and Engagement:** Inadequate public understanding of waste segregation and recycling practices contributes to the inefficiency of waste management systems. Educational campaigns and incentives are often underfunded or poorly implemented.
- c. **Equity Concerns:** Vulnerable and marginalized populations often reside near dumpsites or landfills, exposing them to disproportionate environmental and health risks. Addressing these inequities is essential for achieving inclusive waste management systems.

Innovative Practices and Technologies

Circular Economy Approaches

The circular economy places a strong emphasis on system redesign in order to cut waste and improve resource efficiency. This concept promotes circular systems, in which trash is used as an input for new operations, as opposed to linear "take-make-dispose" systems.

The following are important tactics:

a. Product Lifecycle Extension:

Reducing the frequency of disposal by designing items for durability, repairability, and upgradeability. Industries implementing these strategies include, for instance, long-lasting apparel brands and modular smartphones (Ellen MacArthur Foundation, 2021).

b. Material Recovery Facilities (MRFs):

Advanced sorting systems are used in centralised facilities to separate valuable materials from mixed waste streams. Robotics and artificial intelligence are used in these facilities' automated sorting systems to increase productivity and lower pollution (European Commission, 2022).

c. Industrial Symbiosis:

Businesses collaborate to reuse waste or by-products of one industry as raw materials for another. For example, Kalundborg Eco-Industrial Park in Denmark demonstrates how shared resources and waste recovery systems contribute to sustainability ([Chertow, 2007](#)).

Technological Innovations

a. Artificial Intelligence (AI) and IoT:

Smart Waste Bins: Equipped with IoT sensors, these bins monitor fill levels in real time, enabling optimized collection routes and reducing operational costs ([Zhang et al., 2020](#)).

AI-Driven Sorting Systems: Employing machine learning algorithms, these systems identify and sort recyclable materials with high accuracy, improving recycling rates and reducing contamination.

b. Bioconversion Technologies:

Organic waste can be transformed into bioenergy or high-value products through anaerobic digestion and microbial technologies. For example, anaerobic digesters convert food waste into biogas and nutrient-rich fertilizers ([National Renewable Energy Laboratory, 2021](#)).

c. Plasma Gasification:

Advanced thermal technologies utilize high temperatures to convert waste into syngas (a mix of hydrogen and carbon monoxide) and slag, a non-toxic by-product used in construction. This process is nearly waste-free and offers a cleaner alternative to incineration (Weymouth et al., 2018).

d. 3D Printing with Recycled Materials:

Innovative startups are transforming plastic waste into filament for 3D printing, enabling localized manufacturing while reducing plastic pollution ([Parandoush et al., 2020](#)).

e. Blockchain for Waste Management:

Blockchain technology ensures transparency and traceability in waste management supply chains. It aids in monitoring compliance with recycling targets and preventing illegal dumping ([Kouhizadeh et al., 2021](#)).

Innovative Community Initiatives

a. Community-Led Recycling Programs:

Local initiatives, such as zero-waste communities, implement grassroots efforts to reduce, reuse, and recycle waste. Examples include San Francisco's Zero Waste initiative, which has achieved an 80% landfill diversion rate ([SF Environment, 2022](#)).

b. Pay-As-You-Throw (PAYT) Programs:

Citizens are charged based on the amount of waste they generate, incentivizing waste reduction and segregation. Such models have been successfully implemented in South Korea ([OECD, 2018](#)).

c. Decentralized Composting:

Urban and rural communities establish small-scale composting hubs to manage organic waste locally, reducing transportation emissions and generating valuable soil amendments. Examples include India's decentralized composting programs supported by NGOs ([TERI, 2022](#)).

d. Policy and Governance

Effective waste management policies and governance frameworks are crucial to addressing the global waste crisis. These systems aim to create robust regulatory environments, incentivize sustainable practices, and engage stakeholders at all levels.

Regulatory Frameworks

a) Extended Producer Responsibility (EPR):

EPR policies mandate that producers are responsible for the entire lifecycle of their products, including end-of-life disposal. This strategy incentivizes manufacturers to design products that are easier to recycle or repurpose. Countries such as Germany and Japan have pioneered EPR models to reduce waste and enhance recycling rates ([OECD, 2020](#)).

b. Landfill Taxation:

Governments impose taxes on landfill usage to discourage waste disposal in landfills. For instance, the UK Landfill Tax has successfully reduced landfill waste and promoted recycling ([HM Revenue & Customs, 2021](#)).

c. Plastic Bans and Restrictions:

Policies banning single-use plastics or imposing levies on plastic bags have been widely implemented to combat plastic pollution. Rwanda's ban on plastic bags has positioned the country as a leader in sustainable waste management in Africa ([UNEP, 2021](#)).

Public-Private Partnerships

Public-private partnerships (PPPs) facilitate investment, innovation, and expertise sharing in waste management. Key examples include:

a. Infrastructure Development:

Partnerships have enabled the development of modern waste treatment facilities, such as waste-to-energy plants in Singapore and Sweden ([World Bank, 2020](#)).

b. Recycling Initiatives:

Collaborations between municipalities and private companies, such as Coca-Cola's World without Waste initiative, aim to increase recycling rates and reduce environmental footprints ([Coca-Cola, 2022](#)).

c. Innovation Funding:

Governments and private sectors co-fund research and development projects focused on advanced waste management technologies, such as bioconversion and AI-powered sorting systems ([European Commission, 2022](#)).

Community Engagement

a. Awareness Campaigns:

Educating citizens about waste segregation, recycling, and composting is a cornerstone of effective waste management. Campaigns such as India's Swachh Bharat Abhiyan have successfully mobilized public participation ([Ministry of Housing and Urban Affairs, 2022](#)).

b. Incentive Models:

Reward-based systems, such as deposit-return schemes for beverage containers, encourage consumers to recycle. These schemes have shown success in countries like Germany and Norway ([Container Recycling Institute, 2021](#)).

c. Local Governance Support:

Strengthening local governance systems enables municipalities to implement tailored waste management solutions. Decentralized governance in countries like Japan allows for community-specific waste segregation and treatment programs (JICA, 2021).

International Collaboration

a. Global Alliances:

Organizations like the Basel Convention facilitate international cooperation on the trans boundary movement of hazardous wastes, ensuring environmentally sound disposal practices (UNEP, 2020).

b. Knowledge Sharing Platforms:

Initiatives like the Global Partnership on Waste Management (GPWM) promote the exchange of best practices, technologies, and policies across countries (UN-Habitat, 2022).

Recommendations for Strengthening Urban and Rural Innovations in Waste Management

a) Technology Adoption

Encourage Investment in AI, IoT, and Advanced Waste Processing Technologies:

To enhance efficiency in both urban and rural waste management, governments and organizations should invest in cutting-edge technologies like Artificial Intelligence (AI) and the Internet of Things (IoT). These technologies can enable smart sorting, waste tracking, and real-time monitoring of waste collection systems, leading to optimized waste processing and energy recovery. Furthermore, advanced waste processing technologies such as mechanical-biological treatment (MBT) and anaerobic digestion can increase the recovery of valuable materials and convert waste into useful resources like biofuels and fertilizers.

b. Policy Alignment

Integrate Waste Management Policies with Sustainable Development Goals (SDG) Targets:

Waste management policies in both urban and rural areas should be aligned with the global Sustainable Development Goals (SDGs), particularly Goal 11 (Sustainable Cities and Communities) and Goal 12 (Responsible Consumption and Production). Aligning

policies with SDG targets ensures a comprehensive approach to waste management that focuses on reducing environmental impact, enhancing resource efficiency, and supporting sustainable economic growth. Governments should also create incentives for cities and rural communities that successfully implement sustainable waste practices.

c. Capacity Building

Train Waste Management Personnel and Support Informal Sector Workers:

Investing in human capital is critical for the success of any waste management program. Training waste management personnel — both in formal and informal sectors — in modern techniques, technologies, and safety practices will improve waste collection, sorting, and recycling processes. Informal sector workers, who play a significant role in waste collection in many developing countries, should also be recognized, supported, and provided with the necessary tools, skills, and protective equipment to ensure safe and efficient waste handling.

d. Research and Development

Foster Innovation through Funding and Cross-Sector Collaborations:

Governments and organizations should promote robust research and development (R&D) in waste management by providing funding for pilot projects, academic research, and start-ups working on innovative waste solutions. Cross-sector collaborations between waste management experts, environmental scientists, technology developers, and the private sector can lead to the development of sustainable and scalable waste solutions. Encouraging multi-stakeholder partnerships can drive forward innovations such as new waste-to-energy technologies, improved recycling processes, and eco-friendly packaging materials.

These recommendations aim to create a sustainable and efficient approach to waste management that leverages technology, policy, capacity building, and research. By adopting these strategies, both urban and rural communities can work towards reducing waste, improving resource recovery, and contributing to sustainable development.

Conclusion

Advancing waste management practices is crucial for tackling global environmental challenges and driving sustainable development. Through the integration of cutting-edge technologies, effective policies, and active community engagement, societies can shift towards a circular economy that minimizes waste and optimizes resource efficiency.

This paper highlights the need for collective action, collaboration across sectors, and systemic change to build a more sustainable future. By adopting these strategies, we can create lasting solutions that protect the environment, promote economic resilience, and ensure a healthier planet for future generations.

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