

## EVALUATION OF MUNICIPAL SOLID WASTE GENERATION PATTERNS DURING THE COVID-19 OUTBREAK

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### ABSTRACT

*Utilizing a combination of quantitative and qualitative methods, we examined the composition, quantity and disposal practices of municipal solid waste (MSW) across different phases of the pandemic. Our findings reveal nuanced changes in waste generation patterns, influenced by factors such as lockdowns, remote work, shifts in consumer behavior, and alterations in commercial activities. While certain waste streams, such as single-use plastics, experienced an increase due to heightened consumption of packaged goods, other categories, such as office-related waste, declined due to reduced physical occupancy in commercial spaces. We conducted state-wise comparisons of waste generation, collection, treatment, and landfill practices to understand the trends in waste management across India during the pandemic. The outcomes of this study may assist policymakers in promoting sustainable practices for the effective management of MSW throughout the country. Effective management of MSW could also contribute to achieving the Sustainable Development Goals (SDGs), including clean water and sanitation (SDG-6), sustainable cities and communities (SDG-11), and life on land (SDG-15).*

**Keywords:** - Municipal Solid Waste, COVID-19, Sustainable Development Goals (SDGs), Waste Management.

### INTRODUCTION

Government action to stop the spread of SARS-CoV-2 through lockdown and mobility restrictions was very effective and it had a positive impact on the environment-animal relationships. Stress, anxiety, depression, insomnia, denial, anger, and fear are the major mental health issues reported in children and older people-age groups during and post-pandemic period. The COVID-19 period saw a rise in the incidence of mental illness linked to suicide cases. The Indian government has announced state-specific intervention techniques, telepsychiatry consultations, and a toll-free number specifically to ameliorate the psychiatric and behavioural problems arising during the post-pandemic (25; 1).

The COVID-19 pandemic has disrupted routine waste management practices, leading to an increase in the generation of municipal solid waste (MSW). The crisis has exposed the vulnerabilities of existing waste management systems, with overburdened landfills, overflowing waste bins, and heightened risks of environmental contamination.

COVID-19 is a contagious disease that can be transmitted through direct and indirect contact with infectious things. A very high risk of spreading the coronavirus by touch and air in our daily behaviour and actions. Behavioural changes in waste

management during a pandemic are primarily driven by the need to prevent pollution transmission and disease spread. When household infectious waste is dumped in open bins or waste collection compactors, there is a high risk of contamination among municipal waste recycling workers. Waste recycling is significantly impacted, leading to a decrease in municipal solid waste recycling during pandemics (3).

The COVID-19 pandemic has caused changes in the quantity and composition of municipal solid waste, as well as waste recycling, medical waste management and littered waste composition, but recognizing these issues can help in planning MSWM more efficiently and reduce virus transmission risk through waste. A hybrid mathematical modeling approach for energy generation from hazardous waste during the COVID-19 pandemic was proposed, which showed that 34% of the total cost of collecting and transporting waste can be compensated, and useful managerial insights were obtained using the data of Kermanshah city as a real case (4).

### SOLID WASTE GENERATION IN INDIA

In 2021, a total of 160038.9 tons per day (TPD) of solid waste was produced in India, and out of it 152749.5 TPD waste was collected with a 95.4% collection efficiency rate (5). Out of the total

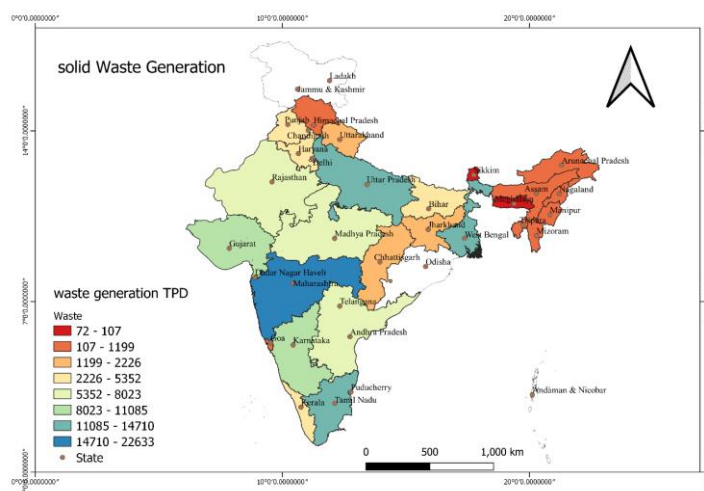
collected waste, about 50% of waste is treated and about 18.4% of waste is landfilled, while about 31.7% of the waste is left behind as unaccounted. The highest quantity of per capita solid waste generation in India is in Delhi, Lakshadweep, and Mizoram. Similarly, the lowest amount of waste generation is in Assam, Meghalaya, and Bihar (CPCB, 2022) (5).

It is reported that solid waste treatment has remarkably increased from 19% to 49.49% in the last six years. To manage the MSW and preserve the resources, a zero-waste concept for effective MSW has arisen in the past few decades (6).

Zero waste is defined as the preservation of resources through sustainable consumption, reuse, as well as recovery of any product or material without using the incineration process with no threat to the environment or human health (7). Based on the recovery of resources and the principles of the circular economy, a zero-landfill model is acceptable in terms of social acceptability. It calls for a continued effort to move away from the dependence of landfills on waste disposal. A zero-landfill city shall ensure that maximum volumes of waste are treated and recycled through scientific procedures, with negligible waste being produced as residual solid waste or rejects thus reducing the need to build new landfills.

The zero-landfill city model has been successfully implemented in Ambikapur (Chhattisgarh), Chandrapur (Maharashtra), and Taliparamba (Kerala), showcasing effective strategies for waste management that prioritize resource recovery, circular economy principles, and sustainable practices (8). The waste landfill trend has decreased from 54% to 18.4% in the last six years (2015-2021), with Rajasthan (73.68%), followed by Chandigarh (86.54%), Rajasthan (73.68%), Sikkim (71.69%), Punjab (50%), Tripura (3.8%), and Nagaland (2.27%) (CPCB 2022) (5).

The implementation of a zero-waste strategy can reduce the increasing amount of solid waste. Sustainable consumption and a proper waste management system are required to conserve natural resources and implement a zero-waste strategy (9). For constitutive solid waste management, different technologies have been adopted in the country such as bio-methanation plants in only 14 states and composting technology in practice in all states, while only 6 states have adopted waste-to-energy technology in India (CPCB 2022) (5). The COVID-19 impact on the municipal solid waste generation pattern. MSW pattern due to two major changes in our lives. During lockdown, packaging plastic, cardboard waste, PPE, face masks, single-use plastic, and household waste were increased (3).



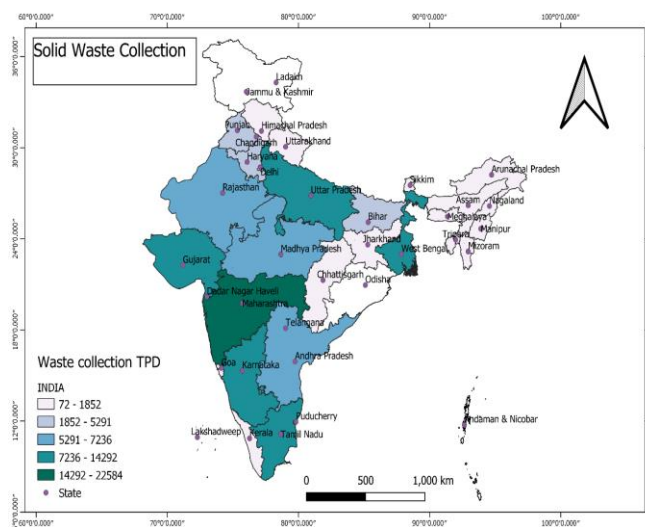
**Fig1**

As economic activity slowed in 2020 as a result of the COVID-19 crisis, plastic use fell by 2.2%; nonetheless, an increase in littering, food takeout packaging, and plastic medical equipment like masks has caused littering to grow. Only 9% of plastic garbage is recycled globally, and 22% of it is improperly managed. Besides it, the solid waste

of India has 46% mismanaged and uncontrolled litter, 36% is disposed of in landfills, 4% goes for incineration, and 13% is recycled (10). The COVID-19 pandemic has significantly altered our way of life, which makes it very important to re-evaluate the impact of human and environmental relationships on sustainable development (11). The

anaerobic breakdown of biodegradable waste at open landfills produces methane, a greenhouse gas that has been linked to several fires and explosions as well as major contributions to global warming (12). Composting is the most effective waste disposal method in Nepal, as Nepal produces more than 70% of total solid waste as organic waste (13). The comprehensive analysis of solid waste generation and collection across India provides significant insights into the ongoing waste management efforts within the country. The regions with smaller waste quantities, like Lakshadweep, Andaman and Nicobar Islands, and Chandigarh

exhibit higher collection rates, indicating efficient waste management practices even at lower scales. However, the disparity between waste generation and collection in certain states, such as Kerala, Maharashtra, and Tamil Nadu, signals the need for continued attention to waste management infrastructure enhancement. While several states exhibit commendable efforts in waste collection, some still face challenges in efficiently managing the solid waste generated. It is encouraging to observe states like Chhattisgarh, Goa, and Sikkim, which manage to collect the entire generated waste, reflecting effective waste management systems.



**Fig2**

**Source:** Status of Municipal Solid Waste Generation (Fig1) and waste collection (Fig2) tons per day in India (CPCB 2022) (5)

### COVID-19 AND MUNICIPAL WASTE GENERATION

Municipal Solid Waste Management (MSWM) in India is a complex system, that involves the planning, implementation and maintenance of a sustainable system for effective management and handling of MSW (14). The COVID-19 pandemic has posed significant challenges to municipal solid waste management (MSWM) worldwide. The rapid increase in medical waste, single-use items and changing waste composition has exacerbated the existing waste management issues. The coronavirus gets into contact with plastic products (eye shields, gloves, facemasks, and PPE) and can persist on their surfaces for 72 hours (15). The production of municipal solid waste (MSW) has significantly increased in developing countries as a result of urbanization and rapid population expansion (16). Madhya Pradesh and Goa have good environmental

performance in solid waste management across the nation (CPCB 2022) (5). The MSW has numerous detrimental effects on the environment, including its role in the escalating climate crisis, its effects on wildlife and the environment and its detrimental effects on people (11). In Bangladesh, COVID-19 medical waste increased from 658.08 tons in March 2020 to 16,164.74 tons in April 2021 (17).

The government's sudden action produced an increase in the huge amount of food waste. A large amount of food waste is produced by the closure of schools, cafes, offices, and malls (18). COVID-19 affected our daily lives and waste generation patterns. Plastic waste, food waste, biomedical waste, household waste, etc. are different types of waste that increased during the pandemic period. Despite India being the 9th largest food exporter globally (19), the sudden lockdown has had a significant impact on farmers and their crops. Developing countries like India have poor waste

management strategies and are at high risk of contamination. In developing countries, waste is directly dumped in open and poorly managed landfill sites, which act like a feeding ground for street dogs, cows, and goats. So, livestock and human relationships can exacerbate the spread of coronavirus.

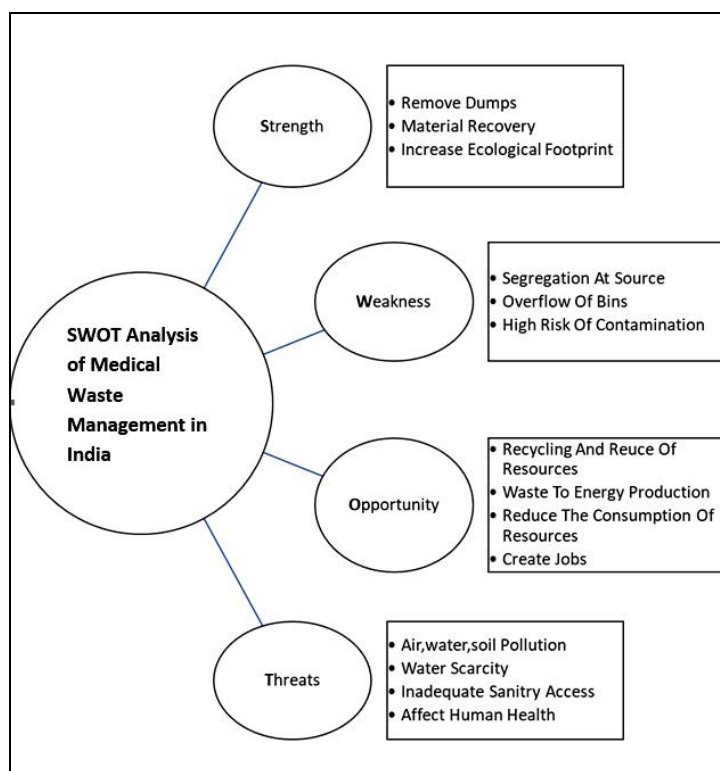
During the COVID-19 pandemic, co-incineration of clinical waste in municipal solid waste incinerators increased acid gas emissions and heavy metal content in air pollution control residues, which may cause serious health hazards in humans as well as living beings (20). Municipal solid waste (MSW) is a serious problem worldwide due to the increasing population and prosperity. MSW can be used as a resource for energy generation. In Dhanbad, (India) the MSW is used for energy recovery as it is a suitable feedstock for electricity generation through combustion (21).

### MEDICAL WASTE GENERATION DURING COVID-19

Medical waste generation during COVID period was estimated that the USA (36,660.16 tons/day) is the greatest medical waste generator, followed by the UK (4,968.1 tons/day), Iran (2,462.13 tons/day), Mexico (1,561.3 tons/day), India (1,520.30 tons/day), Brazil (1,475.5 tons/day), Spain (1,104.5 tons/day), and France (1,097.2 tons/day) (22). Face

masks, gloves, and PPE daily usage depend upon the population of the country and the acceptance rate of using face masks or gloves per person on average daily. India is well behind in terms of COVID-19 waste management and requires comprehensive monitoring and implementation systems to enable the achievement of SDGs related to environmental health. In terms of sustainable development, India has fallen to 120 out of 165 countries and it is in critical condition. This is because of the lack of waste treatment provisions and facilities (23).

During the COVID-19 pandemic, medical waste generation increased by around 30%, and if not managed properly, it can pollute the environment and disturb health. Therefore, it is crucial to identify the potential of medical waste and review medical waste management in healthcare facilities, with incineration being one of the processing methods (24; 25). India generated over 32,996MT of COVID-19 waste between June and December 2020, and those states generating an average of 100MT/month should be considered a high priority for upgrading their Bio-Medical Waste (BMW) treatment capacity and implementing BMW rules (CPCB 2022) (5). The SWOT analysis of BMW showed that there are many challenges as well as opportunities in handling bio-medical waste (Fig 3).



**Fig2:** SWOT analysis of Bio-Medical Waste in India

A complex environment with strengths, weaknesses, opportunities, and threats is shown by the SWOT analysis of India's biomedical waste management. Strengths include expanding knowledge and regulatory frameworks, technological improvements, and effective therapeutic approaches. Inconsistent enforcement,

poor infrastructure, and a lack of public awareness of threats are examples of weaknesses. Opportunities include a thriving industry, work, and innovation. Disease outbreaks, environmental contamination, and detrimental effects on the safety of healthcare personnel are examples of threats.

Discussion

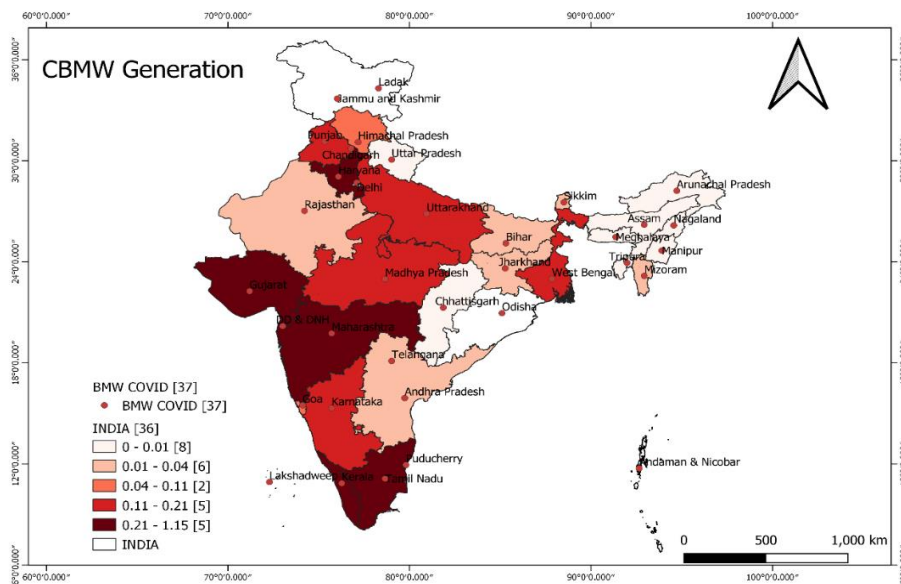


Fig4

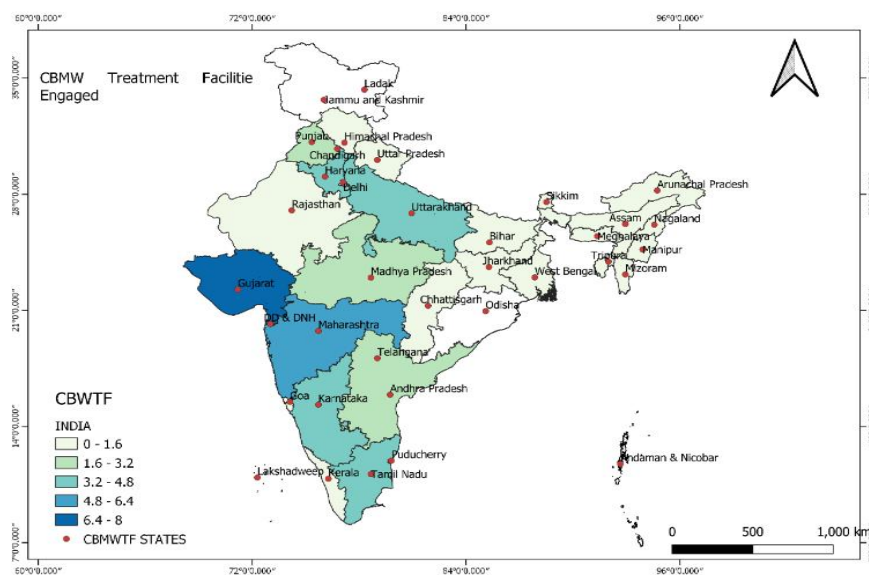
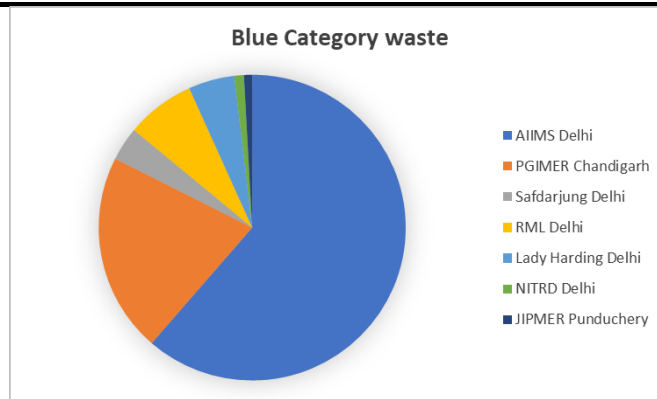


Fig5

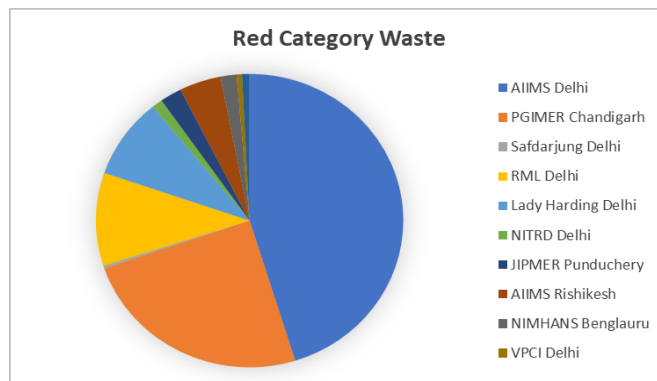
**Source:** Status of COVID-19 biomedical waste generation (Figure 4) and treatment facilities (Figure 5) involved in collection, treatment & disposal (CPCB 2022) (5)

The data shows that 5.08 tons per day of COVID-19-related biomedical waste (BMW) were generated daily across India, with regions like Kerala and Delhi contributing significantly. Factors like COVID-19 prevalence, healthcare infrastructure, population density, and waste management practices influence the generation.

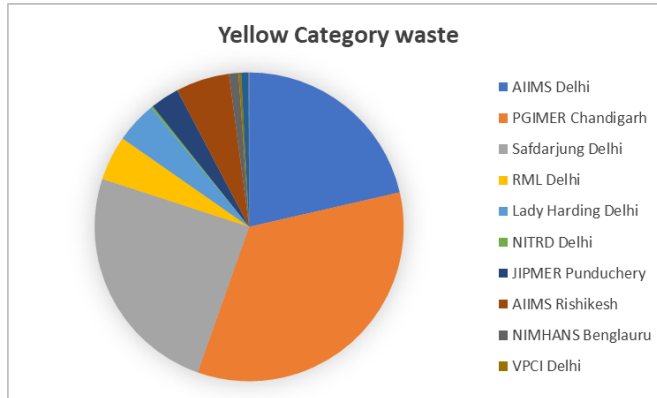
States with higher CBWTFs are better equipped to manage waste, aligning with World Health Organization guidelines. However, gaps in waste management practices in regions like Arunachal Pradesh, Ladakh, Lakshadweep, and Nagaland require increased attention and resources.



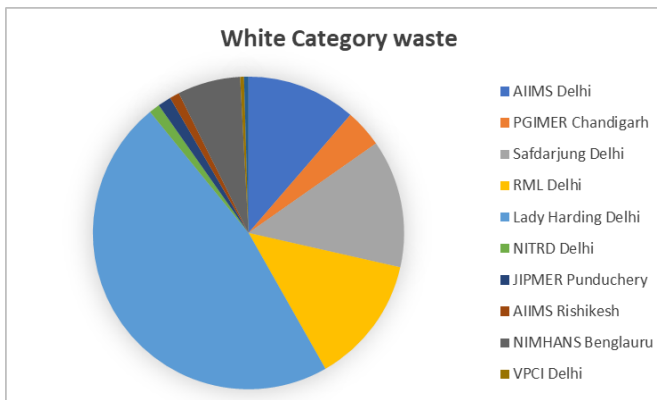
**Fig6**



**Fig7**



**Fig8**



**Fig9**

**Fig 6, 7, 8, 9** Bio-medical waste (category-wise weight percentage) generated by some major Central Government Hospitals as of February 2021 (23)

The analysis of waste categories based on weight percentages in prominent healthcare institutions across India provides a comprehensive overview of waste composition and management practices. Notably, the highest percentage of blue category waste, indicating general waste, is observed at 61% in AIIMS Delhi, emphasizing the need for efficient waste segregation to divert non-hazardous waste from disposal sites. The identification of the highest yellow category waste, related to infectious and hazardous waste, at 34% in PGIMER Chandigarh, emphasizes the importance of proper waste classification and targeted management practices to minimize environmental and health implications. Additionally, the identification of white category waste, including sharp objects and anatomical waste, at the highest proportion of 47% in Lady Hardinge Medical College, Delhi, highlights the necessity of specialized disposal methods and safety measures to safeguard healthcare workers and the public.

### CONCLUSION

The study highlights the interconnectedness of environmental, social and economic factors. While the decrease in certain waste streams might initially seem positive for the environment, it is essential to consider the broader implications, such as potential impacts on livelihoods within the waste management sector. As societies recover from the pandemic and adjust to new norms, long-term waste management strategies should be developed with a holistic view, incorporating sustainability principles, public awareness campaigns and policies that encourage responsible waste behavior. In developing countries like India, the COVID-19 epidemic has highlighted the critical need for robust and sustainable municipal solid waste management systems. This analysis shows a notable change with increased single-use plastic in the waste generation pattern and a fall in conventional office-related garbage. This highlights the significance of adaptive waste management strategies in efficiently handling these emergencies. It is advised to incorporate sustainable waste management techniques into national and local policies to address the pandemic's effect on the environment and human health. Sustainable waste practices such

as waste-to-energy technologies, enhancing waste segregation, and reducing dependency on landfills through a circular economy. To reduce the threats to the public's health, biomedical waste management procedures must be strictly enforced. Global cooperation is necessary to exchange innovations and best practices, and developed countries may learn a lot from successful waste management systems. Long-term sustainability requires aligning waste management procedures with the Sustainable Development Goals (SDGs). The outcomes represent the interdependence of environmental, social, and economic aspects in waste management, emphasizing the pressing requirement for data-driven, robust waste management systems to tackle present obstacles and get ready for upcoming emergencies, protect public health, and accomplish global sustainability objectives.

### STATEMENTS AND DECLARATIONS

#### Data Availability

No datasets were generated or analyzed during the current study.

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#### Author Contributions

P.P. wrote the manuscript, prepared all the tables and figures, and conducted literature collection and table data organization. P.D.C. revised the manuscript. All authors reviewed the manuscript.

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### ETHICS DECLARATIONS

#### Conflict of Interests

The authors declare no competing interests.

#### Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.

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