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Chapter- 4

Environmental Hazards Associated with the Disposal of Municipal Solid Waste

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Abstract:

Increasing urbanization, industrialization, and population growth result in increasing amounts of municipal solid waste (MSW), which proved to be one of the major threats to the environment and public health. This type of waste mainly comprises plastics, metals, organics, electronic waste, etc. As MSW contains various components such as microplastics, heavy metals, inorganic salts, and volatile organic compounds (VOCs), it is regarded as a mixed source of various contaminants. The mismanagement of these wastes subsequently causes increased pollution around an area, degrading air, water, and land. The heavy metals that accumulate in the ecosystem, which endanger humans and biota, are lead, cadmium, and mercury. These are often derived from industrial and electronic waste. Such nutrients above cause eutrophication and disrupt ecosystems with plastics and microplastic carriers of pathogenic bacteria and antibiotic resistance genes. MSW is well known for having VOCs and POPs about air pollution and public health, bioaccumulating along food chains. It is crucial to sink waste and to rehabilitate waste management. Recent approaches like recycling, energy recovery, and circular economy models emphasize cutting waste, recovering resources, and pollution prevention. Waste can also be tackled with energy production by incineration and anaerobic digestion methods. The ideals of sustainable development, which are concerned with environmental integrity, health risk reduction, and responsible consumption of resources, cohere with international efforts to shift sustainable practice. This synthesis stresses the urgent need for integrated approaches in the regulation-technical innovation-community combination to address the multifaceted challenges of municipal solid waste management and the welfare of people and the environment.

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Introduction:

The global production of municipal solid waste is increasing with industrialization, economics, and better living. The production of MSW is estimated at 2.1 billion tonnes per year, of which about 33% remain uncollected. This is causing environmental and health problems (Peng et al., 2023; Khan et al., 2022; Lino et al., 2023). Forecasts indicate that it will reach 3.4 billion tonnes by 2050 owing to accelerating urbanization as well as increasing population growth, especially in developing countries, where urban residency is expected to rise from 54% to 68% by the middle of the century (Statista, 2023; Kaza et al., 2018; UN DESA, 2018). The three major actors among countries that produce waste in large quantities are the USA, China, and India, illustrating that the more economic activities there are, the larger the waste volume (Gour and Singh, 2023). Waste characteristics and management differ greatly between income levels. Organic waste is highest in low- and middle-income regions, while high-income countries produce more recyclable materials such as metals and glassware (Kumar and Samadder, 2017). Poor waste management aggravates greenhouse gas emissions, water pollution, and plastic pollution, adding to the global environmental challenges (Vinti et al., 2023). Environmental hazards resulting from traditional methods of waste disposal such as landfilling, which accounts for more than half of waste disposal in countries such as the USA (52.6%) and Brazil (59.1%), including methane emissions, groundwater pollution, and disease spreading by vectors (Sun et al., 2019; Costa et al., 2019). The pathogenic and harmful gases CO_2 and CH_4 that leak from these organic fractions in landfills remain even after the landfill is closed (Chavan et al., 2019; Han et al., 2022). Moreover, the leachate from landfills, including chemicals from heavy metals, inorganic salts, and other toxicants, poses a future risk to water quality and public health for a long time (Mor and Ravindra, 2023; Abdel-Shafy et al., 2023). It included, for instance, changing from traditional disposal facilities to advanced waste management technologies such as incinerators, pyrolysis, and anaerobic treatment facilities that reduce the waste footprint, provide energy, and offer possible job growth (Singh et al., 2020; Waqas et al., 2023). Nowadays, NASA recycling and energy recovery are key components as global priorities shift toward reducing greenhouse gases toward desired resource utilization. This transformation echoes a greater, finer purview of sustainable development goals such as responsible consumption and production, sustainable cities, and environment conservation (Tamboli et al., 2024). The historical context of waste production discusses the linkage of population growth and urbanization with economic development since low-income countries are responsible for only 5% of the world's waste, unlike upper-middle and high-income countries contributing more than 65% to this figure (Maalouf and Mavropoulos, 2022). The two other major contributors were the Asia-Pacific region and Europe, as the dual forces of urbanization and rising GDP will come into play in waste generation (Hoornweg et al., 2013). In Asia, urban residents generate an estimated 760,000 tonnes of MSW a day and are print-listed to see this double Bwillhattopadhyay et al. (2009). Waste management is among those aspects of urban planning that need serious valiance because it has been shaped through policies like the Waste Framework Directive of the EU and CE models, meant to engender innovative initiatives aimed at waste reduction, reuse, and recycling (Kirchherr et al., 2017). On the legal frameworks prevalent in the European Union, waste prevention and recycling are emphasized, thus setting targets to recycle at least 55% of MSW by 2025, reducing landfill use to less than 10% by 2035 (European Commission, 2015). It gives a better insight into the gradual movement of resource extraction and disposal of wastes to a circular economy, with the capacity to prolong the lifetime of materials through these directives (Hobson et al., 2021). Some countries like Sweden have proven to be the best shift from this, with almost 47% recycling and composting rates and eliminating landfill waste by 2017 (EP, 2021). The US appears very poor in this aspect; its recycling rate for MSW is a paltry 23.6%. Challenges of waste globally demand technological innovation, the reform of laws, and people's participation. Further waste management strategies such as biogas production, value-added product development, and digitized systems could substantially make waste management effective in cities (Kurniawan et al., 2022; Norouzi and Dutta, 2022). The concept of a circular economy, building on sustainability and resource efficiency, is increasingly heralded as a strong pathway for relieving environmental and economic pressures from waste generation (Korhonen et al., 2018b). In waste management systems that include recycling, composting, and energy recovery, a nation can reduce its dependence on virgin materials, environmental degradation, and sustainable development (Erfani et al., 2023).

This article aims to consolidate all the emerging trends, challenges, and opportunities in municipal solid waste management worldwide in sustainable practice. It is meant to bring practical recommendations for policymakers, urban planners, and researchers to develop strategies to address one of the critical issues of the waste management problem in a way that would also consider the environment and people within it.

Classification and Composition of MSW:

The objectives of MSW categorization are increasing waste diversion, minimizing landfill volume, and lowering costs for waste disposal. Thus, the influence of MSW classification on the practical result of waste treatment, economic effectiveness, and environmental defense is important to identify. MSW is categorized by the source because the composition varies depending on the source. For example, kitchen waste may encompass perishable foodstuffs of animal or vegetable origin, as well as other kitchen residues such as tea leaves and coffee grounds (Zhang et al., 2021).

Branches, leaves, and charred wood are examples of natural yard waste. Waste paper and cardboard come from advertising fliers, office paper, and packing supplies. Bottles, packaging, and other types of plastic are examples of waste composed of rubber and plastic (Yang et al., 2018). Metal waste includes things like cans, cutlery, and food packaging. Bottles, lightbulbs, and food storage containers are examples of glass waste. Cell phones and PCs that are not working properly are considered electronic trash. Miscellaneous rubbish includes syringes, discarded clothing, pharmaceuticals, and pottery. Lastly, inert materials include inorganic waste, including furniture, ash, and construction waste. Each category highlights a different waste management challenge, from the breakdown of organic materials to the recycling and disposal of non-biodegradable materials (Nanda and Berruti, 2021).

Furthermore, waste is categorized based on income level. According to Hoornweg and Bhada-Tata (2012), waste is categorized into four groups, namely Lower Income (LI), Lower Middle Income (LMI), Upper Middle Income (UMI), and High Income (HIC). Figure 1 presents the waste composition by income group, showing how the types vary between low, lower-middle, upper-middle, and high-income countries.

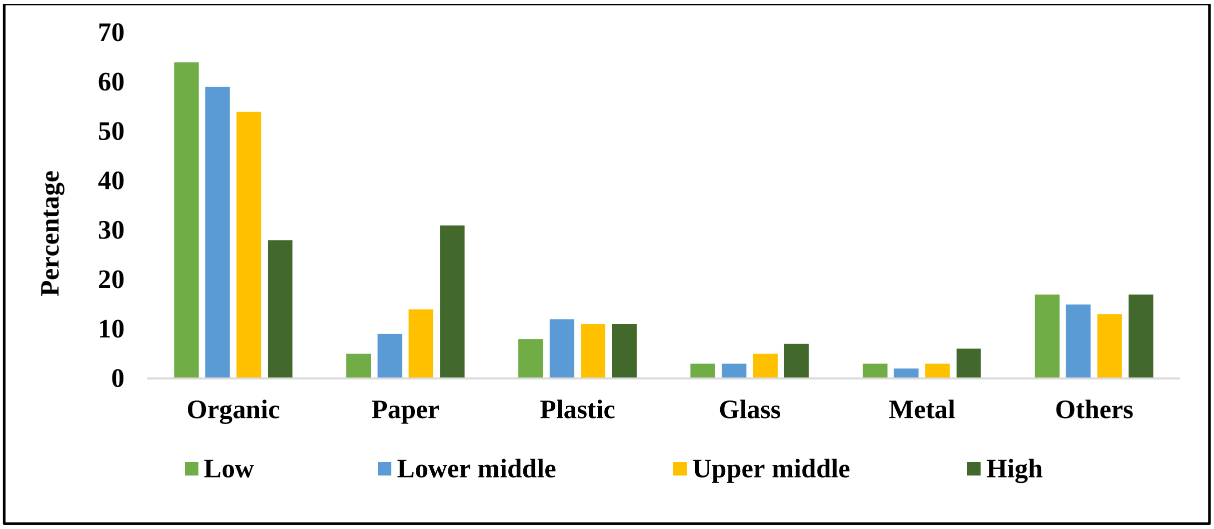

Figure 1: Composition of waste in percentage according to income (Hoornweg and Bhada-Tata, 2012).

It has been demonstrated that organic waste is lowest in high-income nations and most in low-income ones. Additionally, waste from paper and plastic grows as income rises. As income levels improve, the share of organic waste decreases, but the share of paper waste also increases considerably. The percentage of plastic waste is relatively consistent across all socioeconomic brackets. According to Feng et al. (2017) and Zhang and Yuan (2019), municipal solid waste (MSW) is frequently considered a porous media material since it exhibits the coexistence of solid, liquid, and gas phases, just like natural geotechnical materials. However, unlike natural geotechnical materials, which usually do not consider degradation-related changes in geotechnical properties, MSW shows notable time-dependent modifications (Ren et al., 2022). MSW's composition changes over time since most organic components undergo considerable biodegradation. According to Chen et al. (2016), this degradation is a complicated process that involves chemical, biological, and physical processes. The degrading process consequently significantly changes MSW's pore structure and composition, forming gases, leachate, and heat release (Zhou et al., 2024).

Environmental Contaminants present in MSW:

Many materials make up Municipal Solid Waste (MSW), such as plastics, metals, glass, and kitchen waste. Components carrying harmful contaminants can significantly affect the environment. Various pollutants, such as organic contaminants, plastics, synthetic materials, heavy metals, electronic waste, and several volatile organic compounds (VOCs), are common in municipal solid waste (MSW). MSW poses a primary ecological concern as it contains various contaminants, and these pollutants significantly affect ecosystems and human health.

Heavy metals are highly significant. In MSW, some common examples of heavy metals are arsenic (As), lead (Pb), mercury (Hg), and cadmium (Cd). A widely recognized ubiquitous heavy metal present in MSW is Pb which generally originates from the waste of electric products (e-wastes) and components of its, including cathode ray tubes, batteries, and circuit boards, etc. (Silvetti et al., 2017; Tucker et al., 2020; Madhu et al., 2022). Contamination in MSW is influenced remarkably by the disposal of waste-bearing As from drinking water treatment plants (Clancy et al., 2013). Another notable heavy metal is Cd found in MSW, often sourced from plastics and pigments (Ashfaq et al., 2022; Aendo et al., 2022). Improper disposal of items from the residential sector includes some cleaning agents, paints, and dyes containing Cr compounds, which contribute an efficient amount of Cr in MSW (Tumolo et al., 2020). Also, wastes from some industries and agricultural fields have a significant amount of Cr in them, adding to Cr in MSW. Jalali et al. (2011) studied the common source of another frequently detected contaminant, nickel (Ni), which is waste from stainless-steel utensils, batteries, and residues from electroplating.

Inorganic salts like sulfates (e.g., Na_2SO_4, $CaSO_4$), magnesium salts (e.g., $MgCl_2$), calcium chloride ($CaCl_2$), potassium chloride (KCl), and sodium chloride (NaCl) are another significant class of pollutants which are present in MSW (Meena et al., 2019). Food scraps, agricultural residues, industrial effluents, construction debris, and household litter are some of the primary sources from where the inorganic salts originate and get mixed with MSW. The presence of these slats in a high amount In MSW creates notable environmental challenges (Kim et al., 2022).

The existence of macro-nutrients in excessive quantity, especially nitrogen (N) and phosphorus in MSW, poses serious environmental risks. Organic materials, namely food wastes, paper and cardboards, sewage sludge agricultural wastes, are the major sources of these nutrients (Sultana et al., 2021; Kaur and Kaur, 2024). Accumulating these contaminants in MSW comes with nutrient pollution, which can harm the ecosystems (Meena et al., 2019; Das et al., 2022).

MSW is also known to contain various organic pollutants from numerous sources and processes. Due to the improper disposal of unused or expired medications, residual pharmaceutical compounds have been discovered in MSW and have been found in MSW (Bu et al., 2020). Volatile organic compounds (VOCs) are commonly found in MSW, often produced by the decomposition of organic matter and industrial activities (Wu et al., 2020; Majumdar et al., 2012). Another class of organic pollutants, aromatic compounds, frequently originate from aromatic detergents, chemical solvents, food additives, and paint coatings (Nie et al., 2018).

Plastics and microplastics (MPs) in MSW are an emerging environmental concern. Plastics and MPs enter MSW through various commercial, industrial, and construction activities. Various personal care products, plastic pellets utilized in manufacturing, and microfibers shed from synthetic textiles contribute to primary MPs, while the degradation of larger plastic items generates secondary MPs (Upadhyay et al., 2021).

Overall, the composition and contamination of MSW highlight the importance of managing waste effectively to minimize its environmental impact.

Potential Impact from the Contaminants on Environment and Biota:

The contaminants present in MSW have a profound impact on the environment and its living organisms. These pollutants can negatively impact the abiotic components, air, water, and soil, hamper human health and the ecosystems.

Contaminants from municipal solid waste, including heavy metals, inorganic salts, nutrients such as nitrogen and phosphorus, plastics, microplastics, volatile organic compounds (VOCs), and pharmaceutical residues, can leach into water bodies. By altering the physicochemical properties, such as pH, hardness, and nutrient concentrations, which can result in eutrophication and increased toxicity levels of the water bodies, these pollutants could significantly impact the quality of the water (Bhat et al., 2022).

Contaminants, such as pharmaceuticals, personal care products, and microplastics, are recognized for exacerbating risks by altering microbial communities, facilitating resistance transfer, and contaminating soil, water, and air (Anand et al.,2021). Microbes present in municipal solid waste (MSW), including bacteria, fungi, and algae, interact with heavy metals and play a crucial role in their uptake, accumulation, transformation, mobility, and bioavailability within landfills and contaminated soils (Sharma et al., 2022). MSW emits harmful air pollutants, such as particulate matter (PM), volatile organic compounds (VOCs), greenhouse gases (GHGs), and odorous compounds, which degrade air quality and pose health risks, including respiratory problems and headaches (Pekdogan et al., 2024). Various organic pollutants, such as polycyclic aromatic hydrocarbons (PAHs), phthalates, and persistent organic pollutants (POPs), present in composted municipal solid waste (MSW), can bioaccumulate in food chains and pose potential health risks to humans, including endocrine disruption, carcinogenicity, and toxicity, mainly when contaminated compost is applied to food production (Langdon et al., 2019). Microplastics in MSW landfill leachate serve as vectors, offering surfaces for the adsorption and proliferation of antibiotic resistance genes (ARGs) and pathogenic microorganisms, leading to contamination of soil, water, and potentially food chains (Jaafarzadeh et al., 2024).

Contaminants from MSW accumulate in animal bodies, causing toxic effects that disrupt reproduction, growth, and survival (de Titto et al., 2024). Additionally, open dumpsites serve as breeding grounds for disease vectors like mosquitoes and rodents, which can transmit pathogens to humans and increase the prevalence of vector-borne diseases. Pollutant introduction into different ecosystems can also alter species composition, disrupt the ecological balance, affect predator-prey dynamics, and potentially lead to the extinction of sensitive species due to habitat degradation (Abubakar et al., 2022).

Existing MSW Management Practices:

Effective Municipal Solid Waste (MSW) management is essential for maintaining environmental health and urban sustainability. Rapid urbanization and population growth have significantly increased waste generation, creating challenges for municipalities worldwide (Khan et al., 2022). This report outlines existing MSW management practices, highlights common challenges, and explores potential solutions to enhance efficiency and sustainability.

Screening of MSW:

A detailed review of studies was done to find examples of successful recycling or significant improvements through specific waste management methods. Many examples came from groups and projects that share best practices, like Zero Waste Europe, the Global Alliance for Incinerator Alternatives (GAIA), Regions for Recycling, and Pre-Waste. The Eurostat database was also used to find countries with high recycling rates, and towns or cities in those countries were studied further (Nanda and Berruti, 2021). In most cities in India, the collection is mainly done by community bins placed along highways, which might result in unlawful open collection stations; house-to-house collecting efforts are gaining momentum in megacities like Delhi, Mumbai, Bangalore, Madras, and Hyderabad, with the support of NGOs (Sharholy et al., 2008).

Identifying the Assessing Criteria:

Several criteria were applied to assess the chosen case studies. The case studies included in this paper were selected based on key factors aligning with current waste policies, laws, and the tools and strategies to encourage sustainable waste management. Different tools and methods can be used when creating a recycling program. These tools are divided into four main types: technical, economic, legal, and informational tools (R4R).

- Technical Tools
- Economic Tools
- Legal Tools
- Informational Tools

Technical Tools:

Household waste can be collected either through kerbside pickup near the property or by using designated drop-off locations; in property-close systems involve the use of various storage solutions such as bins, racks, sacks, and bags for effective collection (Dahlén and Lagerkvist, 2010).

Kerbside collection

Each household is given a waste container. Residents are responsible for storing waste in these containers, either inside or outside their homes. Some sources differentiate between door-to-door collection and yard collection. In door-to-door collection, the waste collector enters the property to pick up waste stored inside the house. In yard collection, the waste collector collects waste stored outside, usually in the yard (Kogler: Waste Collection., 2007).

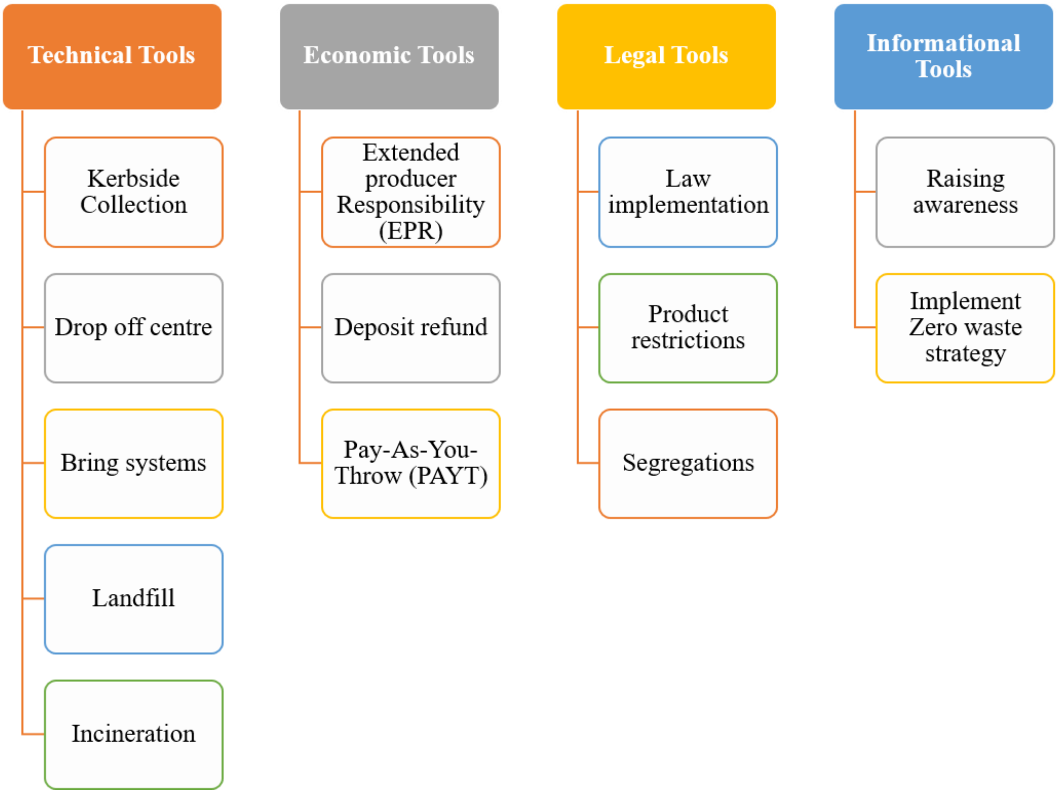

Figure 2: Methods used to improve MSW management (Xevgenos et al., 2015).

Drop off systems

Households are responsible for sorting their waste into different categories and taking it to nearby neighborhood containers. These containers come in various sizes and shapes. Families drop off their sorted waste at designated recycling or green centers (Gallardo et al., 2018).

Landfill Method

The most popular waste management technique worldwide is landfill disposal. Interest in landfill system innovation and progress has increased since these landfills operate as final waste receivers for municipal trash, industrial or agricultural leftovers, wastewater sludge, incinerator ash, recycling discards, and/or treated hazardous wastes. By choosing the best landfill location, residents' concerns may be addressed, and environmental harm can be minimized, leading to a more sustainable garbage lifecycle. Landfills are often built to contain or limit garbage to reduce exposure to the environment and people. Landfills generate methane gas in the atmosphere (Ayub and Khan, 2011).

Incineration

Incineration is one of the earliest techniques for handling and getting rid of solid waste, which has improved significantly in the past 20 years. At first, it only entailed burning garbage, seriously polluting the air. The primary benefits were illness management and waste volume reduction. Mass-burn incinerators are the most prevalent kind of incinerator. Before being transferred into the feeding chute, waste is kept in a pit and stirred using a crane arm to guarantee consistency.

Inside, the waste burns on grates, with oxygen levels controlled for efficient combustion. Extra fuel is added if needed based on the type of waste. The temperature in the incinerators varies between 980°C and 2000°C. Once filtering to remove metal particles, the remaining bottom ash is collected. A turbine attached to a generator generates electricity using steam created by hot gasses and particles from the combustion process that go through a boiler (Karim et al., 2019).

Economic Tools:

Extended Producer Responsibility (EPR)

General Extended Producer Responsibility (EPR) is a policy aimed at reducing the environmental impact of products by making them more eco-friendly. It requires producers and related businesses to pay fees that fund the recycling of materials they introduce into the market. These fees, which vary by country, can be based on the weight or type of material and reflect the industry's responsibility to manage waste (Hickle, 2014).

Deposit–refund systems

It is also called “Bottle Bills” or container deposit laws, which are economic tools designed to collect and recycle used packaging, like beverage bottles and cans. These systems have been used worldwide for decades, starting in the mid-1900s when the packaging industry shifted from reusable containers to single-use ones. The main goals of these systems are to reduce litter, cut waste disposal costs, recycle valuable materials, conserve energy and natural resources, and create new businesses and jobs. This is applied to glass bottles, plastic containers, cans, batteries, fluorescent lamps, and tires (US EPA, 2017).

Pay-As-You-Throw (PAYT)

A major reason for promoting sustainable waste management is to ensure that the costs are shared fairly among those generating the waste, based on the impact they create. The 'pay-as-you-throw' (PAYT) system, called variable-rate or unit pricing, applies the "polluter-pays" principle clearly and equitably. PAYT is an economic tool widely used worldwide that encourages better recycling practices. By linking waste disposal costs directly to the amount of waste generated, it provides a financial incentive to recycle more and produce less waste, while addressing social, environmental, and legal concerns (Morlok et al., 2016).

Legal Tools:

Law Implementation

Bans and restrictions on waste disposal help manage waste effectively. Landfill bans aim to reduce reliance on landfills and promote better waste management methods that follow the waste hierarchy. As highlighted in case studies, several countries have introduced statewide bans or restrictions on municipal waste. These rules differ based on waste types, including (i) untreated or unsorted waste, (ii) separately collected waste, and (iii) residual waste, considering factors like combustibility, biodegradability, and organic carbon content. In India, the Ministry of Environment, Forest, and Climate Change (MoEFCC) updated the Solid Waste Management (SWM) Rules in 2016, replacing the MSW Rules 2000. These updates aim to improve waste collection, sorting, recycling, treatment, and disposal in an eco-friendly way. Initiatives like the Hazardous Waste Management Rules (first issued in 1989 and revised in 2003) and the Swachhaa Bharat Mission (SBM) launched in 2014 also focus on promoting sustainable waste management (Sharma and Jain, 2019).

Separation of waste

One prescriptive policy tool that can support economical and effective recycling is separating waste based on its source. It can be sent directly to households or municipalities; they must be fined if they do not obey the regulations (Walls, 2011).

Informational Tool:

Informational tools are important in creating and implementing an integrated waste management plan. The goal of any informational tool about installing waste management systems should be to increase awareness among the public.

Zero Waste Strategy

Recently, more municipal, regional, and international governments started to include a "Zero Waste" goal in their waste management plans. Zero Waste is an ambitious idea rooted in the circular economy, focusing on more than just recycling. It involves redesigning products to save natural resources, reducing waste, encouraging reuse, and prioritizing resource recovery over incineration and landfill disposal (Zaman and Lehmann, 2013).

Conclusion and Recommendations:

Strategic approaches, technologies, and policies should be implemented to successfully separate and manage contaminants generated from Municipal Solid Waste (MSW). Handling those contaminants should be efficient. There are some recommendations given below:

Segregation at Sources: Encourage people to separate waste into categories like hazardous, residual, organic, and recyclable. Raise awareness through campaigns and introduce policies that motivate public participation in proper waste segregation.

Advanced Sorting and Processing Facilities: Invest in automated sorting systems, including screens, metals, and optical scanners to separate biodegradable and non-biodegradable garbage. Separate paper, glass, organic, and inert elements from combined garbage. There is much more emphasis on AI-powered sorting devices and recycling.

Containment of Hazardous Materials: Implement a separate collection system for hazardous waste (such as batteries, chemicals, and electronic waste). To avoid leakage and contamination, hazardous waste must be handled properly and securely.

Leachate Management: To prevent contamination of groundwater, landfills should be designed with suitable impermeable liners and leachate collecting systems. Reserve osmosis, activated carbon filtration, or biological treatment may be applied to treat leachate.

Air pollution control: Install landfill devices to capture methane and other harmful gases for energy use or safe disposal. Use scrubbers and advanced oxidation methods in waste-to-energy plants to lower pollutant emissions.

Biological Treatment for Organics: The biological treatment of municipal solid waste (MSW) can reduce its volume and turn organic waste into compost or biogas through processes like composting or anaerobic digestion. Ensure any byproducts meet environmental standards before disposal.

Recycling: Implement robust recycling programs for metals, plastics, paper, and glass to minimize waste contamination. Promote the reuse of recycled products through the reselling market, emphasizing the 3R (Reduce, Reuse, and Recycle) approach.

Community Engagement and Education: Organize workshops and awareness campaigns to teach communities about the harmful effects of improper waste disposal on the environment. Implement strict waste management regulations with penalties for illegal dumping.

References:

Abdel-Shafy, H. I., Ibrahim, A. M., Al-Sulaiman, A. M., & Okasha, R. A. (2024). Landfill leachate: Sources, nature, organic composition, and treatment: An environmental overview. *Ain Shams Engineering Journal*, *15*(1), 102293. https://doi.org/10.1016/j.asej.2023.102293.

Abubakar, I. R., Maniruzzaman, K. M., Dano, U. L., AlShihri, F. S., AlShammari, M. S., Ahmed, S. M. S., ... & Alrawaf, T. I. (2022). Environmental sustainability impacts of solid waste management practices in the global South. *International journal of environmental Research and Public Health*, *19*(19), 12717. https://doi.org/10.3390/ijerph191912717

Aendo, P., Netvichian, R., Thiendedsakul, P., Khaodhiar, S., & Tulayakul, P. (2022). Carcinogenic risk of Pb, Cd, Ni, and Cr and critical ecological risk of Cd and Cu in soil and groundwater around the municipal solid waste open dump in central Thailand. *Journal of Environmental and Public Health*, *2022*(1), 3062215. https://doi.org/10.1155/2022/3062215

An, E. U. (2015). action plan for the Circular Economy. *Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the Committee of the regions closing the loop. Brussels*, *2*.

Anand, U., Reddy, B., Singh, V. K., Singh, A. K., Kesari, K. K., Tripathi, P., ... & Simal-Gandara, J. (2021). Potential environmental and human health risks caused by antibiotic-resistant bacteria (ARB), antibiotic resistance genes (ARGs) and emerging contaminants (ECs) from municipal solid waste (MSW) landfill. *Antibiotics*, *10*(4), 374. https://doi.org/10.3390/antibiotics10040374

Ashfaq, A., Khan, Z. I., & Ahmad, K. (2022). Assessing the health risk of cadmium to the local population through consumption of contaminated vegetables grown in municipal solid waste–amended soil. *Environmental Monitoring and Assessment*, *194*(7), 468. https://doi.org/10.1007/s10661-022-10104-w

Ayub, S., & Khan, A. H. (2011). *Landfill practice in India: A review*.

Bhat, R. A., Singh, D. V., Qadri, H., Dar, G. H., Dervash, M. A., Bhat, S. A., ... & Yousaf, B. (2022). Vulnerability of municipal solid waste: An emerging threat to aquatic ecosystems. *Chemosphere*, *287*, 132223. https://doi.org/10.1016/j.chemosphere.2021.132223

Bu, Q., Cao, H., He, X., Zhang, H., & Yu, G. (2020). Is disposal of unused pharmaceuticals as municipal solid waste by landfilling a good option? A case study in China. *Bulletin of Environmental Contamination and Toxicology*, *105*, 784-789. https://doi.org/10.1007/s00128-020-03006-5

Chattopadhyay, S., Dutta, A., & Ray, S. (2009). Municipal solid waste management in Kolkata, India–A review. *Waste Management*, *29*(4), 1449-1458. https://doi.org/10.1016/j.wasman.2008.08.030.

Chavan, D., Lakshmikanthan, P., Mondal, P., Kumar, S., & Kumar, R. (2019). Determination of ignition temperature of municipal solid waste for understanding surface and sub-surface landfill fire. *Waste Management*, *97*, 123-130. https://doi.org/10.1016/j.wasman.2019.08.002.

Chen, Y., Guo, R., Li, Y. C., Liu, H., & Zhan, T. L. (2016). A degradation model for high kitchen waste content municipal solid waste. *Waste Management*, *58*, 376-385. https://doi.org/10.1016/j.wasman.2016.09.005.

Clancy, T. M., Hayes, K. F., & Raskin, L. (2013). Arsenic waste management: a critical review of testing and disposal of arsenic-bearing solid wastes generated during arsenic removal from drinking water. *Environmental Science & Technology*, *47*(19), 10799-10812. https://doi.org/10.1021/es401749b

Costa, A. M., Alfaia, R. G. D. S. M., & Campos, J. C. (2019). Landfill leachate treatment in Brazil–An overview. *Journal of Environmental Management*, *232*, 110-116. https://doi.org/10.1016/j.jenvman.2018.11.006.

Dahlén, L., & Lagerkvist, A. (2010). Pay as you throw: Strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. *Waste Management*, *30*(1), 23–31. https://doi.org/10.1016/j.wasman.2009.09.022

Das, A., Saha, A., Sarkar, S., Sadhu, S., Sur, T., Agarwal, S., Mazumdar, S., Bashar, S., Tarafdar, S., & Parvez, S. S. (2022). A multidimensional study of wastewater treatment. *Int. J. Exp. Res. Rev.*, *28*, 30-37. https://doi.org/10.52756/ijerr.2022.v28.005

de Titto, E., & Savino, A. (2024). Human Health Impact of Municipal Solid Waste Mismanagement: A Review. *Advances in Environmental and Engineering Research*, *5*(2), 1-37. https://doi.org/10.21926/aeer.2402014

EP, 2021. Waste management in the EU: infographic with facts and figures. https://www.europarl.europa.eu/news/en/headlines/society/20180328STO00751/eu-waste-management-infographic-with-facts-and-figures.

Erfani, H., Swetanshu., Singh, P., Madhu, N.R., & Jadoun, S. (2023). Evaluation of the performance of the compost plant for optimal operational evaluation. *Environ Monit Assess*, *195*, 1271. https://doi.org/10.1007/s10661-023-11810-9

Feng, S. J., Zheng, Q. T., & Chen, H. X. (2017). Unsaturated flow parameters of municipal solid waste. *Waste Management*, *63*, 107-121. https://doi.org/10.1016/j.wasman.2017.01.025.

Gour, A. A., & Singh, S. K. (2023). Solid waste management in India: a state-of-the-art review. *Environmental Engineering Research*, *28*(4) 220249. https://doi.org/10.4491/eer.2022.249.

Han, J., He, S., Shao, W., Wang, C., Qiao, L., Zhang, J., & Yang, L. (2023). Municipal solid waste, an overlooked route of transmission for the severe acute respiratory syndrome coronavirus 2: a review. *Environmental Chemistry Letters*, *21*(1), 81-95. https://doi.org/10.1007/s10311-022-01512-y.

Hickle, G. T. (2014). An examination of governance within extended producer responsibility policy regimes in North America. *Resources, Conservation and Recycling*, *92*, 55–65. https://doi.org/10.1016/j.resconrec.2014.08.007

Hobson, K., Holmes, H., Welch, D., Wheeler, K., & Wieser, H. (2021). Consumption Work in the circular economy: A research agenda. *Journal of Cleaner Production*, *321*, 128969. https://doi.org/10.1016/j.jclepro.2021.128969.

Hoornweg D., & Bhada-Tata P., What a waste: A global review of solid waste management, The World Bank, 2012.

Hoornweg, D., Bhada-Tata, P., & Kennedy, C. (2013). Environment: Waste production must peak this century. *Nature*, *502*(7473), 615-617. https://doi.org/10.1038/502615a.

Jaafarzadeh, N., & Talepour, N. (2024). Microplastics as carriers of antibiotic resistance genes and pathogens in municipal solid waste (MSW) landfill leachate and soil: a review. *Journal of Environmental Health Science and Engineering*, *22*(1), 1-12. https://doi.org/10.1007/s40201-023-00879-6

Jalali, M., & Arfania, H. (2011). Distribution and fractionation of cadmium, copper, lead, nickel, and zinc in a calcareous sandy soil receiving municipal solid waste. *Environmental Monitoring and Assessment*, *173*, 241-250. https://doi.org/10.1007/s10661-010-1384-9

Kaur, H., & Kaur, P. (2024). Factors Determining Household Waste Segregation Behaviour: An Indian Case Study. *International Journal of Experimental Research and Review*, *41*(Spl Vol), 83-95. https://doi.org/10.52756/ijerr.2024.v41spl.007

Karim, M., & Corazzini, B. (2019). The current status of MSW disposal and energy production: A brief review of waste incineration. *MOJ Ecology & Environmental Sciences*, *4*(1). https://doi.org/10.15406/mojes.2019.04.00129

Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). *What a waste 2.0: a global snapshot of solid waste management to 2050*. World Bank Publications.

Khan, S., Anjum, R., Raza, S. T., Ahmed Bazai, N., & Ihtisham, M. (2022). Technologies for municipal solid waste management: Current status, challenges, and future perspectives. *Chemosphere*, *288*, 132403. https://doi.org/10.1016/j.chemosphere.2021.132403

Khan, S., Anjum, R., Raza, S. T., Bazai, N. A., & Ihtisham, M. (2022). Technologies for municipal solid waste management: Current status, challenges, and future perspectives. *Chemosphere*, *288*, 132403. https://doi.org/10.1016/j.chemosphere.2021.132403.

Kim, H., Purev, O., Cho, K., Choi, N., Lee, J., & Yoon, S. (2022). Removal of Inorganic Salts in Municipal Solid Waste Incineration Fly Ash Using a Washing Ejector and Its Application for CO_2 Capture. *International Journal of Environmental Research and Public Health*, *19*(4), 2306. https://doi.org/10.3390/ijerph19042306

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221-232. https://doi.org/10.1016/j.resconrec.2017.09.005.

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, *175*, 544-552. https://doi.org/10.1016/j.jclepro.2017.12.111.

Kumar, A., & Samadder, S. R. (2023). Development of lower heating value prediction models and estimation of energy recovery potential of municipal solid waste and RDF incineration. *Energy*, *274*, 127273. https://doi.org/10.1016/j.energy.2023.127273.

Kurniawan, T. A., Liang, X., O'Callaghan, E., Goh, H., Othman, M. H. D., Avtar, R., & Kusworo, T. D. (2022). Transformation of solid waste management in China: Moving towards sustainability through digitalization-based circular economy. *Sustainability*, *14*(4), 2374. https://doi.org/10.3390/su14042374.

Langdon, K. A., Chandra, A., Bowles, K., Symons, A., Pablo, F., & Osborne, K. (2019). A preliminary ecological and human health risk assessment for organic contaminants in composted municipal solid waste generated in New South Wales, Australia. *Waste Management*, *100*, 199-207. https://doi.org/10.1016/j.wasman.2019.09.001

Lino, F. A., Ismail, K. A., & Castañeda-Ayarza, J. A. (2023). Municipal solid waste treatment in Brazil: A comprehensive review. *Energy Nexus*, 100232. https://doi.org/10.1016/j.nexus.2023.100232.

Maalouf, A., & Mavropoulos, A. (2023). Re-assessing global municipal solid waste generation. *Waste Management & Research*, *41*(4), 936-947. https://doi.org/10.1177/0734242X221074116

Madhu, N.R., Sarkar, B., Slama, P., Jha, N.K., Ghorai, S.K., Jana, S.K., Govindasamy, K., Massanyi, P., Lukac, N., Kumar, D., Kalita, J.C., Kesari, K.K., & Roychoudhury, S. (2022). Effect of Environmental Stressors, Xenobiotics, and Oxidative Stress on Male Reproductive and Sexual Health. © The Author(s), under exclusive license to Springer Nature Switzerland AG 2022, S. Roychoudhury, K. K. Kesari (eds.), Oxidative Stress and Toxicity in Reproductive Biology and Medicine. *Advances in Experimental Medicine and Biology*, *1391*, 33-58. https://doi.org/10.1007/978-3-031-12966-7_3

Majumdar, D., & Srivastava, A. (2012). Volatile organic compound emissions from municipal solid waste disposal sites: A case study of Mumbai, India. *Journal of the Air & Waste Management Association*, *62*(4), 398-407. https://doi.org/10.1080/10473289.2012.655405

Meena, M. D., Yadav, R. K., Narjary, B., Yadav, G., Jat, H. S., Sheoran, P., ... & Moharana, P. C. (2019). Municipal solid waste (MSW): Strategies to improve salt affected soil sustainability: A review. *Waste Management*, *84*, 38-53. https://doi.org/10.1016/j.wasman.2018.11.020

Mor, S., & Ravindra, K. (2023). Municipal solid waste landfills in lower-and middle-income countries: Environmental impacts, challenges and sustainable management practices. *Process Safety and Environmental Protection*, *174*, 510-530. https://doi.org/10.1016/j.psep.2023.04.014.

Morlok, J., Schoenberger, H., Galvez-Martos, J.-L., & Zeschmar-Lahl, B. (2016). *The Impact of Pay-As-You-Throw Schemes in the Management of Municipal Solid Waste: The Case of the County of Aschaffenburg, Germany*. https://doi.org/10.20944/preprints201611.0025.v1

Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. *Environmental Chemistry Letters*, *19*(2), 1433-1456. https://doi.org/10.1007/s10311-020-01100-y.

Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: A review. *Environmental Chemistry Letters*, *19*(2), 1433–1456. https://doi.org/10.1007/s10311-020-01100-y

Nie, E., Zheng, G., Shao, Z., Yang, J., & Chen, T. (2018). Emission characteristics and health risk assessment of volatile organic compounds produced during municipal solid waste composting. *Waste Management*, *79*, 188-195. https://doi.org/10.1016/j.wasman.2018.07.024

Norouzi, O., & Dutta, A. (2022). The current status and future potential of biogas production from Canada’s organic fraction municipal solid waste. *Energies*, *15*(2), 475. https://doi.org/10.3390/en15020475.

Pekdogan, T., Yildizhan, H., & Ameen, A. (2024). Unveiling the air quality impacts of municipal solid waste disposal: An integrative study of on-site measurements and community perceptions. *Atmosphere*, *15*(4), 410. https://doi.org/10.3390/atmos15040410

Peng, X., Jiang, Y., Chen, Z., Osman, A. I., Farghali, M., Rooney, D. W., & Yap, P. S. (2023). Recycling municipal, agricultural and industrial waste into energy, fertilizers, food, and construction materials, and economic feasibility: a review. *Environmental Chemistry Letters*, *21*(2), 765-801. https://doi.org/10.1007/s10311-022-01551-5.

R4R_online_tool_starting_guide.pdf. (n.d.). Retrieved November 27, 2024, from https://www.acrplus.org/media/origin/images/project/R4R/R4R_online_tool_starting_guide.pdf

Ren, Y., Zhang, Z., & Huang, M. (2022). A review on settlement models of municipal solid waste landfills. *Waste Management*, *149*, 79-95. https://doi.org/10.1016/j.wasman.2022.06.019.

Sharholy, M., Ahmad, K., Mahmood, G., & Trivedi, R. C. (2008). Municipal solid waste management in Indian cities – A review. *Waste Management*, *28*(2), 459–467. https://doi.org/10.1016/j.wasman.2007.02.008

Sharma, K. D., & Jain, S. (2019). Overview of Municipal Solid Waste Generation, Composition, and Management in India. *Journal of Environmental Engineering*, *145*(3), 04018143. https://doi.org/10.1061/(ASCE)EE.1943-7870.0001490

Sharma, P., Dutta, D., Udayan, A., Nadda, A. K., Lam, S. S., & Kumar, S. (2022). Role of microbes in bioaccumulation of heavy metals in municipal solid waste: Impacts on plant and human being. *Environmental Pollution*, *305*, 119248. https://doi.org/10.1016/j.envpol.2022.119248

Silvetti, M., Garau, G., Demurtas, D., Marceddu, S., Deiana, S., & Castaldi, P. (2017). Influence of lead in the sorption of arsenate by municipal solid waste composts: metal (loid) retention, desorption and phytotoxicity. *Bioresource Technology*, *225*, 90-98. https://doi.org/10.1016/j.biortech.2016.11.057

Singh, A. D., Upadhyay, A., Shrivastava, S., & Vivekanand, V. (2020). Life-cycle assessment of sewage sludge-based large-scale biogas plant. *Bioresource Technology*, *309*, 123373. https://doi.org/10.1016/j.biortech.2020.123373.

Statista (2023). https://www.statista.com/topics/4983/waste-generation-worldwide/#topicOverview.

Sultana, M., Jahiruddin, M., Islam, M. R., Rahman, M. M., Abedin, M. A., & Solaiman, Z. M. (2021). Nutrient enriched municipal solid waste compost increases yield, nutrient content and balance in rice. *Sustainability*, *13*(3), 1047. https://doi.org/10.3390/su13031047

Sun, W., Wang, X., DeCarolis, J. F., & Barlaz, M. A. (2019). Evaluation of optimal model parameters for prediction of methane generation from selected US landfills. *Waste Management*, *91*, 120-127. https://doi.org/10.1016/j.wasman.2019.05.004.

Tamboli, S., Imam, A., Mishra, U., Kumar, K., Mishra, S., Ray, M., Kumar, P., & Yadav, N. (2024). A Research on Fresh and Hardened Concrete Residences with Partial Replacement of Recycled Coarse Aggregates Obtained from Demolition and Construction Waste. *International Journal of Experimental Research and Review*, *42*, 343-350. https://doi.org/10.52756/ijerr.2024.v42.030

Tucker, E. L., Chickering, G. W., Spreadbury, C. J., Laux, S. J., & Townsend, T. G. (2020). A componential approach for evaluating the sources of trace metals in municipal solid waste. *Chemosphere*, *260*, 127524. https://doi.org/10.1016/j.chemosphere.2020.127524

Tumolo, M., Ancona, V., De Paola, D., Losacco, D., Campanale, C., Massarelli, C., & Uricchio, V. F. (2020). Chromium pollution in European water, sources, health risk, and remediation strategies: An overview. *International Journal of Environmental Research and Public Health*, *17*(15), 5438. https://doi.org/10.3390/ijerph17155438

United Nations Department of Economic and Social Affairs (UN DESA) (2018) https:// www. un. org/development/ desa/ en/ news/ population/2018-revision-ofworld-urbanization-prospects.html. Last accessed 18 December 18.

Upadhyay, K., & Bajpai, S. (2021). Microplastics in Landfills: A Comprehensive Review on Occurrence, Characteristics and Pathways to the Aquatic Environment. *Nature Environment & Pollution Technology*, *20*. https://doi.org/10.46488/NEPT.2021.v20i05.009

US EPA, O. (2017, August 31). *The United States Experience with Economic Incentives for Protecting the Environment (2001)* [Reports and Assessments]. https://www.epa.gov/environmental-economics/united-states-experience-economic-incentives-protecting-environment-2001

Vinti, G., Bauza, V., Clasen, T., Tudor, T., Zurbrügg, C., & Vaccari, M. (2023). Health risks of solid waste management practices in rural Ghana: A semi-quantitative approach toward a solid waste safety plan. *Environmental Research*, *216*, 114728. https://doi.org/10.1016/j.envres.2022.114728.

Walls, M. (2011). *Deposit-Refund Systems in Practice and Theory* (SSRN Scholarly Paper No. 1980142). Social Science Research Network. https://doi.org/10.2139/ssrn.1980142

Waqas, M., Hashim, S., Humphries, U. W., Ahmad, S., Noor, R., Shoaib, M., ... & Lin, H. A. (2023). Composting processes for agricultural waste management: a comprehensive review. *Processes*, *11*(3), 731. https://doi.org/10.3390/pr11030731.

WASTE COLLECTION (Kogler) PDF | PDF | Waste Management | Municipal Solid Waste. (n.d.). Retrieved November 27, 2024, from https://www.scribd.com/document/381418308/WASTE-COLLECTION-Kogler-pdf

Wu, C., Shu, M., Liu, X., Sang, Y., Cai, H., Qu, C., & Liu, J. (2020). Characterization of the volatile compounds emitted from municipal solid waste and identification of the key volatile pollutants. *Waste Management*, *103*, 314-322. https://doi.org/10.1016/j.wasman.2019.12.043

Xevgenos, D., Papadaskalopoulou, C., Panaretou, V., Moustakas, K., & Malamis, D. (2015). Success Stories for Recycling of MSW at Municipal Level: A Review. *Waste and Biomass Valorization*, *6*(5), 657–684. https://doi.org/10.1007/s12649-015-9389-9

Yang, R., Xu, Z., & Chai, J. (2018). A Review of Characteristics of Landfilled Municipal Solid Waste in Several Countries: Physical Composition, Unit Weight, and Permeability Coefficient. *Polish Journal of Environmental Studies*, *27*(6) 2425–2435. https://doi.org/10.15244/pjoes/81089.

Zaman, A. U., & Lehmann, S. (2013). The zero waste index: A performance measurement tool for waste management systems in a 'zero waste city.' *Journal of Cleaner Production*, *50*, 123–132. https://doi.org/10.1016/j.jclepro.2012.11.041.

Zhang, J., Zhang, Z., Zhang, J., Fan, G., & Wu, D. (2021). A quantitative study on the benefit of various waste classifications. *Advances in Civil Engineering*, *2021*(1), 6660927. https://doi.org/10.1155/2021/6660927.

Zhang, W. J., & Yuan, S. S. (2019). Characterizing preferential flow in landfilled municipal solid waste. *Waste Management*, *84*, 20-28. https://doi.org/10.1016/j.wasman.2018.11.023.

Zhou, W., Chai, J., Xu, Z., Qin, Y., Cao, J., & Zhang, P. (2024). A review of existing methods for predicting leachate production from municipal solid waste landfills. *Environmental Science and Pollution Research*, *31*(11), 16131-16149. https://doi.org/10.1007/s11356-024-32289-y.

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