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Energy and Resource Recovery Processes and Ecological Issues Related to Management and Disposal of Man-Made Specialty Waste

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Abstract - Issues because of informal administration of metropolitan strong waste (MSW) have arisen as the greatest ecological difficulties in many regions of the planet including India. In the urban communities of the agricultural nations including India, the greater part of the created squanders are manged informally through open unloading and landfilling.

Keywords: Energy Recovery, Resource recovery processes, Ecological issues, Management

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INTRODUCTION

The management and disposal of man-made specialty waste present complex challenges and opportunities in the context of modern environmental sustainability. Specialty waste, which includes electronic waste, hazardous industrial by-products, and medical waste, demands innovative approaches for effective handling due to its potential ecological and health risks. Traditional waste management practices often fall short in addressing the unique characteristics of these materials, necessitating advanced energy and resource recovery processes. These processes not only mitigate the environmental impact of waste disposal but also contribute to the circular economy by reclaiming valuable resources. However, the implementation of such technologies is fraught with ecological issues that must be carefully managed to ensure sustainable outcomes. This paper explores the various energy and resource recovery processes employed in the management of specialty waste, examines the ecological implications of these practices, and highlights the critical need for integrated, sustainable solutions in waste management.

ENERGY AND RESOURCE RECOVERY PROCESSES

Recycling the dry fraction, biologically treating the organic wet fraction, thermally treating the remaining waste, and finally disposing of the residues from these four processes in a landfill are the four essential components of an efficient and sustainable modern MSW management system. Thermal/thermochemical treatments are a crucial part of a sustainable waste management system in this paradigm. The primary benefits include: I reducing waste by more than 90% in volume and about 70% in mass; (ii) using waste for energy in a way that doesn't harm the environment; (iii) destroying organic contaminants; (iv) concentrating and immobilising inorganic contaminants; (v) using recyclable materials from thermal residues, including metals from bottom ash and slag; (vi) reducing methane emissions from anaerobic decomposition of organic wastes (Arena, 2011). As a result, it is obvious that landfills must only be used seldom and only for pre-treated garbage (Lombardi et al., 2015).

SOURCES OF MUNICIPAL SOLID WASTE

Zoning and land use regulations often dictate how much trash a certain area generates. Households, companies, institutions, wastewater treatment facilities, incinerators owned by cities, farms, and other commercial and industrial enterprises are common places to find trash. All garbage in a specific region is considered municipal solid waste, with the exception of waste produced by industry and agriculture (Tchobanoglous et al., 2021). Food scraps, paper, cardboard, textiles, rubber, leather, and garden trash from residences and commercial establishments are examples of organic waste. A few examples of inorganic components include glass, dishes, aluminium cans, ferrous metal, and pure soil.

COMPOSITION OF MUNICIPAL SOLID WASTE

The distribution and diversity of components that comprise a solid waste stream are described by composition, which is often stated as a percentage by weight. According to Deepa et al. (2002), there are several factors that may greatly influence the waste composition, such as dietary habits, way of life, economic status, weather patterns, and cultural standards. Both the quantity and composition of a country's municipal solid waste (MSW) are affected by its population and living standards. The average living standard, which indicates the range and accessibility of products accessible to consumers, demonstrates the capacity of a people to consume things. Consequently, this encourages the production of garbage. India produces three primary forms of municipal solid waste: ash materials, recyclable materials, and organic (biodegradable) matter.

DISPOSAL METHODS

Strong waste administration concludes with removal as its final practical component. Landfills are specifically designated places for the secure storage and disposal of different kinds of solid waste, such as refuse from private collections and transportation, scraps from materials recovery facilities (MRFs), compost, and other items made from solid waste. In contrast to the dumps common in most LDC cities, modern sterile landfills are purpose-built facilities for disposing of toxic waste on land or underground in a way that does not compromise public health or safety in any way, shape, or form (e.g., by encouraging the spread of disease or damaging underground water sources).

Open dumping

Even in countries with low wages, the most common method of removal is open unloading. Sharholy et al. (2008) reports that over 90% of urban solid waste is informally thrown into the ocean. The proliferation of pests like rodents, flies, and mosquitoes, as well as contamination of the air, land, and water, and corruption of the soil, are just a few of the many negative ecological effects that may result from trash placed on open ground.

Sanitary Landfilling

Sanitary landfilling is an established and planned method of disposing of waste that poses no health risks. By carefully planning the spreading, compacting, and covering of the landfill site, clean landfilling prevents the damaging effects of uncontrolled offloading. We can lessen the effects of the site's leachates and gas production by careful site assessment, planning, and board duties. Waste can't be easily accessed by pests like rats and insects because to the reduced soil layer. (Surat et al., 2009).

ECOLOGICAL ISSUES RELATED TO MANAGEMENT AND DISPOSAL OF MAN-MADE SPECIALTY WASTE

Management of waste As a public service, the civil waste board provides a method for locals to dispose of their trash in an environmentally friendly and economically viable manner. Garbage The board is now a problem in urban, suburban, and rural areas alike. Garbage takes up space and remains the same even when no one is around. Not only does trash piled up on shoulders, in ditches and other low-lying areas, as well as outside seepages, ruin the aesthetic value of the area, but it also poses a significant health and environmental danger to people. Animals who feed on this garbage pose a significant threat to human health because they ingest the polythene and other harmful materials that are mixed in with food scraps. Despite the fact that solid waste management does exist in urban areas, it is distant from semi-urban and rural areas, posing environmental and health dangers to the people living there. Various harmful substances, such as carbonyls, poly aromatic carbonyls, dioxin, vinyl chloride, CO, CO2, SOx, NOx, hydrocarbons, and unexpected natural combinations, are released when household waste is consumed openly. Open, shallow discharge of hazardous waste accompanied by emissions of greenhouse gases such as CH4 and CO2, the latter of which has a tremendous potential that is many times more than that of CO2 (IEA, 2004). Therefore, the use of informal solutions for the disposal of toxic waste is a major health hazard. Lack of proper maintenance of MSW removal sites (landfills) increases the risk of contamination of ground water, the spread of disease vectors, rats, mosquitoes, and other insects.

INTEGRATED SOLID WASTE MANAGEMENT

By considering both direct effects (waste transportation, collection, treatment, and removal) and aberrant effects (energy and material utilization outside the waste administration framework), integrated solid waste management (ISWM) essentially unifies the waste administration order (Turner and Powell, 1991; Tchobanoglous et al., 1993). Both existing and future waste management systems may be improved with the use of a solid foundation (UNEP, 1996). Similarly, ISWM is a dynamic process that, with time, learns to handle waste in all its forms: solid, liquid, and gas (Ramachandra, 2011). ISWM encompasses a wide range of practices pertaining to burial as a means of controlling urban solid waste. Human welfare, natural insurance, public recognition, productivity, recycling, landfilling, soil remediation, and government assistance are some of the specialised and policy-centered themes covered. Here are the four primary areas that form the basis of ISWM: foremost, reducing waste at its source, which regulates the total quantity or toxicity of trash. It is most efficient to decrease waste production where it originates in order to reduce volume, care expenses, and environmental impact. Reusing then follows, which comprises gathering and sorting waste materials, preparing them for reuse, starting again, and eventually, remanufacturing. Recycling is a key component that may help reduce asset interest and rubbish sent to landfills. Waste transformation, the third phase, comprises physical, chemical, and organic MSW handling and transformation to recover recyclable and reuse materials, improve the efficiency of solid waste management activity frameworks, and convert it into compressed and combustible biogas for energy. The process of linked solid waste management (ISWM) includes landfilling as one of its intermediate steps. Everything that isn't directly used in energy recovery, materials recovery offices' leftovers, or strong waste recycling's trash falls into this category. "Landfilling" describes the method of disposing of solid waste in an organised and controlled way. Among ISWM's many benefits is its adaptability to many situations. Consider the potential tension between, say, the amount and average of trash created and the time spent focusing on waste reduction and avoidance. To get around this, you need to use different removal innovations and use real, accessible offices. ISWM is efficient and flexible, so the community may choose the best way to handle operations at every stage of waste management. An organized strategy helps the community choose a structure that will cost the least in the long run, which is smart.

POSSIBLE ROUTES FOR WASTE TO ENERGY

Reasonable waste management innovations are absolutely necessary to sustain the generating scene's continued financial and current growth. It is currently critical to identify clean and sustainable alternative energy sources in light of the increasing global demand in energy, as well as a solution to the growing MSW age caused by rapid urbanization and population growth. Waste management methods that have been around for a long time, such as unsanitary landfills, open unloading, and cremation, are no longer relevant because of the damage they do to the environment and the energy they could have generated if used. Globally, politicians, corporate visionaries, and mainstream academics are increasingly prioritizing innovations that convert side-effects into useable energy, according to this perspective. There are a lot of techniques to get useful energy from waste. Waste products that cannot be recycled may be transformed into energy in the form of intensity, power, and filling via a number of different cycles. A waste-to-energy (WTE) innovation is any of a number of waste treatment procedures that convert various types of waste, such as solid, liquid, or vaporous waste, into usable energy, such as heat, electricity, and steam. WTE technology is a controllable way to generate energy; it is mostly used to recover energy from MSW. Canada, Singapore, and Turkey are just a few of the countries that have recently ramped up their education and strategy initiatives related to energy recovery from MSW, indicating that MSW has great potential as an environmentally friendly power asset and fuel for future WTE innovations. The idea of utilising WTE technology to extract energy from municipal solid waste (MSW) has been around for almost 1.5 years, but it wasn't until the 1990s that several countries, including the US, Japan (with 102 WTE plants), Germany, and the UK put it into practice. The US alone used 394 trillion Btu of MSW energy. There are three main categories of WTE innovations: (a) biochemical transformation cycles; (b) landfilling; and (c) heated transformation processes (such as cremation, pyrolysis, and gasification). As shown in Figure 1, a number of energy transformation pathways for MSW are shown schematically.

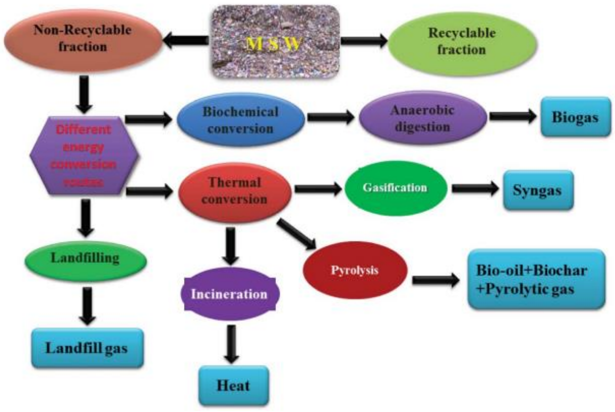

Figure 1: Various pathways for converting MSW into energy, shown schematically

ENERGY RECOVERY FROM WASTE IN INDIA

Wolfe and Mahadevia (2008) and Hornweg and Bhada-Goodbye (2012) state that out of India's 40 million tons of MSW, most is either deposited in dirty landfills or left visible after collection. Urban areas in India are still unprepared to meet regulations, and the situation is deteriorating as a result of fast urbanization and population growth, despite initiatives to enhance MSW management in the nation (e.g., the 2000 presentation of Taking Care of Rules and the MSW Board) (Talyan et al., 2008). Even though there is a lot of structural difference across rural and urban locations in India, the quantity of natural and latent materials contained in MSW is considerable. Fabric sorters often discover, during MSW recycling sorting, that there is a little amount of paper, plastic, glass, and metal (Unnikrishnan and Singh, 2010). Energy recovery from municipal solid waste (MSW) is becoming more popular in India as a way to reduce pollution, boost public health, and lessen the impact of harmful traditional waste management methods. The Asia-Pacific area is leading the way in waste-to-energy (WtE) with rapid improvements in China and India, making it the fastest expanding commercial sector in terms of market size, according to the World Energy Committee (2013). Growing concerns about the risks and environmental effects of MSW, together with increasing energy and land demands, have prompted modernization in these nations (Yang et al., 2013). Studies have shown that India has a 1.5 GW potential for MSW to energy conversion, although only 2% of that capacity has been investigated so far (EAI, 2013). Most landfills in India are already at capacity, and the estimated yearly acreage for landfills in metropolitan areas is about 1,240 hectares.

There are a total of only eight WtE facilities in operation in India as of 2014. But since 2012, the country has received 279 fertiliser plants, 172 anaerobic digestion plants, and 29 refuse-derived fuel (RDF) plants. India is home to many catastrophically unsuccessful large-scale soil fertilization, biomethanation, RDF, and WtE projects. Kalyananda and Pandey (2014) note that there have been prior attempts to employ RDF at 6.6 MW in Hyderabad, 6 MW in Vijayawada, and 500 tpd in Chandigarh. Located in Timarpur, New Delhi, Mijotecknik constructed a 3.7 MW WtE plant in 1987. This facility could handle 300 tpd of MSW. Nevertheless, the facility was forced to shut operations around six months later due to the poor calorific value (550-850 kcal/kg) of the MSW, together with its high moisture and inactive component content (Talyan et al., 2008). Similar problems forced the closure of MSW-burning plants in other developing countries (Abd Kadir, Sharifah Aishah Syed et al., 2013). Biomethanation facilities in India that have a more targeted approach have generally shown better results. There is currently only one WtE facility in India that is burning municipal solid waste (MSW). Soil treatment, cremation, landfilling, material recovery office coordination, burning, and gasification for the thermochemical removal of MSW are likely the most environmentally beneficial approaches (Nixon et al., 2013b). In India, nevertheless, these other approaches have shown more success than RDF (Erses Yahoo, 2015).

India is drastically different from developed countries when it comes to their well-established WtE sector. Despite certain difficulties in industrialized nations, waste treatment has seen considerable cycles of improvement. The European Commission (2006), Nixon et al. (2013a), and Tabasová et al. (2012) all list the following as potential issues: public resistance, high costs associated with vent gas treatment, increased air pollution control measures, and fouling and erosion of the evaporator heat exchanger surface. The WtE industry in India has a number of unique challenges due to cultural norms and economic variables that set it apart from other countries. The concerns in India pertaining to arrangement inadequacies, budgetary restrictions, technology issues, and strategy barriers have not been adequately addressed or acknowledged. To understand why waste-to-energy (WtE) facilities don't work, a few architects have researched waste-to-energy techniques in India. Inadequate development and support have led to the termination of MSW handling facilities, according to Kalyani and Pandey (2014). In their study, Chattopadhyay et al. (2009) identified inefficiencies in trash segregation, collection methods, and recycling infrastructure as the main problem with Kolkata's municipal solid waste (MSW). Because of its low energy content (3350-4200 kJ/kg), cremating MSW was likewise deemed an impractical option, and they estimated that a tipping price of 3900-5200 Rs./ton would be necessary to make WtE economically viable. According to Gupta et al. (1998), burning is not a viable option for India because of the country's inefficient segregation and gathering systems, which is the main difficulty. With the assistance of government organizations, academic institutions, and delegates from Lucknow, Srivastava et al. (2005) conducted a SWOT analysis of MSW executives in India, gathering assumptions about their business partners and identifying strengths, weaknesses, opportunities, and threats. They concluded that a lack of office space, inadequate transportation alternatives, and government awareness were the primary challenges encountered by MSW executives in India. In 2011, Singh et al. showcased a handful of operating facilities and proved that many technologies may be used to recover electricity from municipal solid waste in India. Still, nobody paid any attention to the problems these plants were having. The reference provides a more comprehensive analysis of the different waste collection services in India (Narayana, 2009). When evaluating WtE procedures, analysts in India often used optional data. Research on WtE in other developing countries has also used literature reviews to draw conclusions about the various challenges. Agunwamba (1998), Zhuang et al. (2010), Tsai and Chou (2006), and Cheng and Hu (2010) are among the many sources referenced. Quantitative data is lacking, according to Guerrero et al. (2013), who reviewed studies on waste management in developing nations in general. The authors state that more studies are required to determine the root causes by looking at the issues from the viewpoint of cities and analysing several major factors. The writers were unable to locate any evaluations that used the necessary data to comprehensively examine WtE plants in India, and there has been a propensity to focus on districts rather than the business's viewpoint when accumulating partner opinions on WtE in India (Srivastava et al., 2005). In addition, contemporary partners have arrived to different conclusions than India's local governments and academics about WtE matters. So, there is a lack of pertinent data on the problems that Indian enterprises and local governments have with WtE.

WASTE GENERATION GLOBALLY

In 2012, the worldwide MSW age rates from urban communities were approximated at 1.3 billion tons MSW each year at a pace of 1.2 kg per individual each day. They additionally assessed that this number would increment to 2.2 billion tons of MSW each year by 2025. (Hoornweg D, 2012) This makes a requirement for a superior waste administration in the days to come. Despite the fact that, in the previous 10 years, there was an expansion in squander; squander the board area has changed a ton as well. From being an area which manages essential treatment and the board of waste streams to an area which gives energy to the local area, The age rates are profoundly subject to the pay level of the country. Other major impacting factors in MSW age are pace of industrialization, urbanization, public propensities and neighborhood environment. (UNEP, ISWA, 2015)

WASTE RECOVERY

The waste arrangement influences, treatment as well as assortment of the waste. In the event that the waste is wetter and denser, it has a low calorific worth and subsequently the energy recuperation process turns out to be more troublesome. Likewise, the expense of waste transportation increments. The calorific worth of MSW likewise switches up the world going from 4-12 MJ/kg. (ISWA, 2013) Squander is overseen in view of its properties and consequently the energy recuperation techniques change appropriately. To maximise the use of waste, it is necessary to employ a combination of techniques such as material recovery, organic treatment, and energy recovery. (Avfall Sverige, 2008). In opposition to the customary burning advances, energy recuperation innovations' monetary presentation is decidedly impacted by the information squander fuel costs. Squander has a negative value and is managed frequently, shaping the premise of significant kind of revenue for the WtE plant proprietors. Aside from this, age of power and intensity is one more type of revenue. The significant expenses related with these plants are the speculation and maintenancecosts. As a general rule, the expense for WtE plant, contingent upon area, size and different elements is assessed at about $650 - $1000 per yearly ton limit (WTERT, Waste to Energy Worldwide 2015). In low pay nations this could cause unregulated unloading, which is seen a modest arrangement. The essential goal of energy recovery facility is to treat the waste in order to stay away from any chance of spreading of sickness and defilement because of it. The auxiliary goal is energy recuperation from the waste.

CONCLUSION

The effective management and disposal of man-made specialty waste are pivotal in mitigating ecological and health risks while promoting sustainable development. Energy and resource recovery processes offer significant potential for transforming waste into valuable resources, thereby supporting the principles of a circular economy. However, these processes must be implemented with a keen awareness of their ecological impacts to avoid unintended environmental consequences. By adopting a holistic approach that integrates advanced recovery technologies with stringent environmental safeguards, we can achieve a balanced strategy that addresses both the immediate challenges and long-term sustainability goals. Ongoing research, innovation, and policy support are essential to refine these processes and ensure they contribute positively to ecological health and resource conservation. As we move forward, the collaboration between industry, government, and academia will be crucial in developing and deploying effective waste management solutions that align with global sustainability objectives.

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