Chapter 10
Modern Landfilling Approaches for Waste Disposal and Management

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10.1 Introduction

The highly energetic and goods energy consumption coupled with rising population expansion and high living standards contribute to large municipal solid wastes (MSWs) production, which poses a serious environmental hazard if they are not efficiently disposed of or recycled. MSWs means a variety of solid waste mixture, disposed of every day as waste, garbage, and waste by the public and private communities (Sharma and Kumar 2021). There are currently an estimated 2 billion tonnes, of which over 33% are uncollected by municipalities worldwide MSWs (Waste Atlas 2018). The average per capita garbage produced per day is approximately 0.74 kg. The World Bank anticipates that the production of MSWs would climb "to 3.4 billion tonnes by 2050 (The World Bank 2020)". Of the municipal garbage collected, approximately 70% of the municipal solids are used in waste disposal, 19% are recycled, and 11% for fuel recycling. Almost 3.5 billion individuals "are deprived of basic waste management facilities" from the present global

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population of 7.6 billion (Waste Atlas 2018). Also, it is predictable that by 2050, 5.6 billion people might be reached without adequate access to basic waste management systems. The solid waste from offices, households, small-scale organizations, and trade firms is the main source of MSWs. The content and classification of MSWs vary greatly around the world across towns, while it comprises biodegradable as well as non-biodegradable fractions composed of inorganic compounds. MSWs are generally made from the waste yard, glass, cardboard, food waste, paper, rubber, plastic, inert materials, metal, electronic waste, and various scrap products. The waste from the kitchen and garden together constitutes the organic part of municipal waste. Miscellaneous waste, which comprises textiles, fabrics, biomedicinal products (shaves, glasses, for example), personal health products, cosmetic, pharmaceutical, pet weight, leather, rubber, and polymer residues, is the most heterogeneous of all components in MSWs (Sharma et al. 2021a, b). High concentration of heavy metals such as Cu, Zn etc are present in the MSWs (Long et al. 2011). Several authors reported that the removal of metals from different sources for the prevention of soil and aquatic pollution (Dixit et al. 2018; Sharma et al. 2021c, d; Tripathi et al. 2021).

Owing to its content, the MSWs management process involved among municipalities, towns, and nations around the globe. The main stages for MSWs management are (1) waste generation; (2) waste collection, processing, and transfer; (3) waste disposal, waste processing, and treatment. In all phases of the municipal waste management system, the sequential stages were taken in developing and developed nations. The well-organized managing of municipally-owned MSWs, i.e. disposal, disposal, depends significantly on a country's gross and population domestic. The waste-to-energy technology for the conversion of fuel, heat, and power of MSWs is well established in industrialized nations (Moya et al. 2017; Nanda and Berruti 2020a, b). In developing countries, when population density requires the capacity available for garbage, the transportation, collection, and disposal of MSWs is nonetheless successfully and hygienically managed. In developing countries, population density, cultural aspects, socio-economic issues, unplanned management, average livelihoods, and the absence of strong environmental legislation generally hinder the appropriate remediation of urban and solid waste. Under two sustainable development targets, for example, Goal 11, sustainable urban and community management, and Goal 12, responsible use and production, the United Nations has defined effective municipal solid waste management (United Nations 2020).

MSWs are a renewable and affordable source with great potential for recovery of energy and precious assets, through waste energy transformation and other recovery techniques. Various waste-to-energy methods are available to turn MSWs into strong, gaseous, and liquid fuels, such as biological conversion and thermochemical technology, to meet the growing need for energy. Including the burning of MSWs to generate power, vapor and heat, and combined energy. In addition, it considerably reduces trash' volume. The incineration of municipal solid waste can decrease the influence and capacity (RenoSam and Rambøll 2006). Pyrolysis liquefaction and gasification are some of possibly the best methods of thermochemical conversion to bio-oil products for MSWs (Munir et al. 2019; Nanda et al. 2016c; Saidi et al. 2020; Fang et al. 2018; Katakojwala et al. 2020). MSWs can their bio-conversion methods like anaerobic digestion and aerobic composting, be transformed into biogas or biomethane and fertile compost (Jain et al. 2015; Singh et al. 2020a, b; Shah et al. 2019).

Some of the neighbourhood of the MSWs stored globally is transferred to waste treatment options like composting, biomass gasification and decomposition. The efficient way in which municipal and global solid waste is disposed of or treated is therefore essential, given that the patterns and practices of recycling programs vary from each country. Landfilling is a usual method used worldwide to bury non-recyclables, although garbage is disposed of in piles or disposed of in pits instead of covering with soil in some developing countries. Deposits seem to be a widespread structured municipal solid residue disposal method in the majority of developed countries but in developing countries are significantly less prevalent because of high population density, which has restrictions in an open area. Some deposits in underdeveloped countries also function as temporary garbage storage and feature waste consolidation, transmission, and processing containment facilities, including sorption, recycling, and treatment (Kour et al. 2021). Deposits can also be used as particular municipal garbage dumping sites that can be examined before tipping for waste sorting and processing of biodegradable substances. Although landfills are the chosen form of trash disposal in the municipality, there is a shortage of space for waste-to-energy recycling for municipal solid waste in emerging nations and exceedingly metropolitan regions. In addition to the existing state of the waste disposal treatment, dumping in soil-clothed pits. To discover prospects for efficient sustainable and implementation management techniques in MSWs, the existing status of waste technology has been assessed.

This chapter also examines the sites as a fresh version of traditional sites. Recent advances in the use of waste disposal leachates and upgrades of waste disposal gas to electricity and fuels have been tried. The advantages, constraints, and uncertainties of reclamation as a modern idea for improved energy recovery and material recycling from closed waste dumps are reviewed. The article also discusses the national and worldwide statistics on the generation, composition, management, disposal, and diversion of municipal solid waste. In addition, we evaluate the strengths, limitations, possibilities, and risks associated with municipal solid waste disposal and management strategies.

10.2 Solid Waste Composition

A World Bank compilation in 2012 indicated that three billion people in worldwide cities produced around 1.3 Gt of solid trash and projected an increase of 5.6 billion by 2015 to 2.2 Gt (Hoornweg and Bhada-Tata 2012). Furthermore, for many emerging and developed countries, national statistics on landfill tonnage and trash composition are severely imprecise. Eurostat tracks more than a dozen solid waste streams in the EU realistically, for example, industry, agriculture, forestry, and mining, one of which is frequently urban waste. For the USA, the annual estimate for deposited solid waste uses a material flow model is a well-known disparity compared to about twice the amount based on annual detection reports published by various regions (Bogner et al. 2008; Van Haaren et al. 2010). Most subsequently, a larger US estimate was also backed by the total yearly waste mass in 2011–2015 reported to the “USEPA Greenhouse Gas Reporting Program” by landfill proprietors (GHGRP) (Powell et al. 2016). Significant volumes of organically buried waste, dominated by lignocellulosic matter, are also stored in sites. Historically, the measured or presumed bulk organic carbon content of US garbage disposal ranges between 15 and 25%. Recent work favors the lower end of the spectrum (De la Cruz et al. 2013). Cellulosic (food plant debris, paper products, garden trash), lipids, and proteins in food waste are among key biodegradable components (Asnani 2006; Krishnamurthi and Chakrabarti 2013). But caution must be given to study waste data from nations that do not supply municipal systemic waste managing procedures. Different forms of industrial waste not dangerous, construction, demolition, bio-solids and other constituents commonly divided on single entrance weighbridges may be also available in MSW sites in the United States.

10.3 Management of Solid Waste

Landfilling supporting the disposal in a designated earth burial site or landfill of biodegradable and non-biodegradable garbage from suburban areas of a municipality. In many countries, garbage disposal has been a customary, most lucrative route. Incineration requires large investments in vast infrastructure, and extremely high-temperature conditions but requires expensive labor as well as the costs of operation and maintenance equipment, such as liquefaction, pyrolysis, anaerobic digestion, gasification, and composting. Because of its cost-effectiveness and lower workload methods, waste disposal is preferred over incineration of MSWs. In addition, a consolidated waste disposal system might also create money by using its waste gas and leachate for energy production. Connectivity of a waste dump with the recycling of leachates and upgrading of the waste gas to biogas followed by burning or flare to produce combined heat and electricity.

The number of available and closed sites in the Union in which municipal solid trash is generated in Europe ranges between 150,000 and 500,000 (Jones et al. 2013). More than 150,000 deposits hold 30–50 billion cubic meters of municipal solid trash throughout Europe, in particular (Wagner and Raymond 2015). Over 33 million tonnes of municipal solid garbage in the United States are burnt, and over 136 million tonnes of urban solid waste are deposited annually (USEPA 2016). Consequently, MSWs landfills fell “from 89% in 1980 to less than 53% in 2014 in the USA” as a result of advances in recycling, composition, combustion, and energy recovery. Several estimates imply that there are over 2000 operational garbage disposal plants in both the US and Canada, whereas Canada has over 2000 active waste disposal plants (Giroux 2014; Peters 2016). Almost 97% of residual solid waste, i.e. recycling, composting, and energy recycling, is deposited each year in Canada and is about 24 million tonnes (Giroux 2014). Approximately 60% of MSWs created by the OECD or the OECD countries are also deposition-led (Hoornweg and Bhada-Tata 2012). Such landfills can also be changed, by implementing efficient integrated technologies that produce green power and secondary material, from trash storage to energy-energy powerhouses.

The proportion of energy input in municipal solid waste landfill and incineration. Deposit and waste incineration need substantially less human effort compared with other major energy supplies via diesel, power, and transport. Latest techno-economic analyses and lifecycle assessments in Tehran, Iran of 8500 tonnes, have shown that incineration has required a higher electricity percentage of 41% of total energy input in comparison to sites that demand 29% power (Nabavi-Pelesaraei et al. 2017). Additional exactly, 8500 tonnes of MSWs were incinerated and electrical input of 422.2 kWh, with an output of 3827.3 kWh, was needed. In other words, roughly 1 GJ of energy is used for every 1.99 tonnes of city MSWs burned for electricity, while more efficient methods and systems might boost energy output. Second, transport-based energy investment accounts for the majority of waste disposals, i.e., 21,600 t.km or 58% of total energy input, or 392 2 t.km, or 15% of the total energy supply. The use of shorter routes can lower the energy consumption generated by the transport sector in landfills by consuming fuel-effective rubbish vehicles collection with a greater waste assemblage or built-in garage compaction apparatus.

Deposits may be categorized as open dumping deposits, semi-controlled sites, and sanitary deposits (Narayana 2009). An open dump waste disposal area is terrain for the disposal in open-air environments of MSWs material. Landfill sites are frequent in all rising nations when MSWs is unilaterally thrown into low-lying open spaces. Subsequently these sites are not being achieved properly, they become a scavenging niche for worms, flies, vermin, mosquitoes, rodents, and pathogenic micro-organisms like vegetables, eagles, crowds, falcons, and other birds. Furthermore, due to oxygen-deficient circumstances, these operational problems are alleviated in anaerobic digestion. Open dumping is prohibited under regulatory law in many developed countries as illegal. Since 79% of municipal solid garbage is deposited in Canada, stringent waste disposal legislation and illegitimate removal can consequence in penalties, enforcement, and prosecution. Climate and Environmental Change Ministers apply the rules (Kelleher et al. 2005; Government of Ontario 2020). In addition, the U.S. Agency for Environmental Protection (AE) forbids open thrash dumping, burning, bans, and disposal of (bio) unsafe waste structure, devastation as well as refurbishment of garbage in open land or flowing water by law, with a penalty of US$1500–3000 (Illinois Environmental Protection Agency 2020).

Half-measured sites are functioned facilities in which MSWs residues are shredded, sorted on-site, and compacted previously discarding at authorized dumping sites. Piles of rubbish are dispersed and straightened using bulldozers or rackets and covered every day with topsoil layers to prevent pollution, like birds breeding, animals, pests, and micro-organisms. While the semi-controlled sites due to their high soil cover are generally less malodorous, they are not designed to handle emissions of waste pipeline and leachate (Narayana 2009). On either hand, advanced forms of semi-controlled deposits are hygienic deposits. To collect liquid leachate and waste gas emissions, the sanitary waste fills have also been designed to provide the onsite waste sorting, segregations, reduction in size, densification, and top-soil cover. Sanitary landfills are distinguished by the routine placing of covered soil atop refreshingly dumped garbage inside a regional border away from residential areas, hence minimizing odour, fires, disease vectors, and scattering of MSWs. In industrialized countries, such kinds of sites remain communal with leachate intervention handling systems. Planned for a landscape extension are also sanitary landfills by excavating additional sites after saturation of existing sites has been limited.

10.3.1 Decentralization of MSWs Management

With active citizen contribution initiatives, a decentralized approach to MSWs management can be reached. The population becomes less dependent upon on waste collection/segregation system in the municipality that enhances the collection of main waste at the site. In developing and executing a decentralized managing approach for MSWs, consensus and strong cooperation among the community and management are essential (Srivastava et al. 2005). Even under a decentralized approach, economically feasible composting is incorporated to generate jobs by distributing the manure (Narayana 2009).

10.3.2 Separation of MSWs at Sites

In MSWs stream, non-biodegradable items, such as plastics and glass, present barriers in their procedures of treatment. This also raises the labor and operating costs associated with their separation and sorting at solid waste treatment facilities before waste-to-energy technologies are deployed and recycled. Such substances have a secondary level of market value, ideal for alternate recycling, including pyrolysis, liquefaction, or gasification. The finest MSWs organization schemes will not be implemented without the separation of MSWs into various streams, i.e. organic, metals, plastic, glass, inert materials, and papers. Give the first responsibility for MSWs segregation to the source. The downstream processing of solid waste could be reduced drastically. The separation of waste at the site could also increase the effectiveness and sanitation of the collection of MSWs. In addition, this technique promotes the decentralized MSWs management system. The transfer of organic and recyclable materials into domestic waste must be minimized. This method could be influenced by the novelty in garbage separation technologies and the application of restraints at the source.

The notion of waste management should be understood by residents: glass, paper, composites, recycling, non-recyclability, pharmaceuticals, non-flammable, flammable, inert, plastics, food waste, electronic waste, as well as building material and destruction and refurbishment trash. However, this innovation is not always known to large municipal garbage collection lorries and their built-in collection mechanisms. It will require intelligible inscriptions and pictograms on accommodating waste in different waste-collecting bags. The level of waste management is dependent on the municipalities in Canada and the United States. For instance, major urban areas are generally supplied with a garbage-retrieving service, and drop-off service is offered to small rural villages. It should also strengthen downstream technologies, product standards, customer relations, and the expansion of alternative products and by-product markets by the municipal recycling industry. Most MSWs administration companies in the industrialized nations, for example, offer housing MSWs, marketable and engineering waste management, and environmental solutions. They operate collecting operations, transfer stations, organic treatment plants, waste energy plants, and garbage disposal plants. It provides consumers with up-to-date evidence on waste disposal sites, collection schedules, waste pick-up, and container delivery for illustration of a recent MSWs disposal capability (Onishi 2005).

10.3.3 Disinfected and Secure Management of MSWs

MSWs comprise a range of opportunistic as well as harmful microbial communities. The faecal bacteria that typically occur in MSWs are *Enterobacter, Klebsiella, Escherichia coli, Salmonella, Streptococci, Shigella,* and *Yersinia* (Hassen et al. 2001). The waste manufacturers and farmers who use solid waste composts are quite contagious. Furthermore, the management of municipal solid trash and compost can cause bodily injury to organic contaminants, flammable, volatile, needles, shards, and sharp things. Even in some developing nations, workers in all sectors of work, including the management of municipal solid waste, have workplace-specific training duties in the area of work safety and awareness of health risks. Albeit in developing, nations such training on safety occurs, not strictly, which leads to a lack of adequate understanding and preparation for health hazards from operators' unsanitary MSWs treatment of waste.

10.3.4 Combustible Gases from Landfills

Deposits are composed unevenly in pockets that can sprinkle finished the covering of the ground, liner, or accumulated garbage. In addition, in underdeveloped nations, compaction and leveling of solid waste at the dump and the soil area are rarely followed (Sharholy et al. 2008). Deposits and anaerobic digesters cause gas emissions that potentially endanger operators by excessive CO_2, CH_4, and CO levels. Such gases can cause solid waste operators or persons living close to the local disposal facilities to asphyxiate, suffocate, asthma, and other respiratory and pulmonary problems. Furthermore, deposit gases may increase pressure to make them highly inflammable through uncontrolled flames or explosions.

MSWs disposal sites should have fine-appointed waste gas, lixiviation, and urgent prevention systems in place to prevent any vulnerabilities. MSWs incineration also results in air pollution and fly ash including dioxins, heavy metals, volatile organic carbons, furans, and dangerously toxic chemicals, and particle matter. The capturing and recuperation of particles and fly ash can reduce their atmospheric propagation persistence. Additionally, appropriate defensive procedures to prevent health dangers for municipal garbage handlers should be established. Environmental monitoring should also be carried out to inspect the leachate, landfill soil, and gases for the instant protection of the operators of the landfill and routine and seasonal chemical analysis (Sharma 2021; Sharma et al. 2020; Sharma and Singh 2021; Sharma and Rath 2021).

10.3.5 Soil Salinity from Compost Application

Agricultural farmlands can apply MSWs compost to boost organic matter, fertility, and demand for nitrogen, carbon, and other microelements (Suyal et al. 2021). In addition, the use of fertilizer can improve metal substances dramatically in the soil that represents poor environments for plant development (Dash et al. 2021; Kumar et al. 2021). The manure can contaminate the soil water by permeability through the soil profile by refractory organic components and other heavy metals. High salt concentrations may also define municipal solid waste-derived compost which may cause salinization when used in soil (Hargreaves et al. 2008). Water stress can have a detrimental effect on the soil's qualities such as pH, fertility, texture, capacity for cation exchange, conductivity, plant development, water retention, and success (Nanda and Abraham 2013). Municipal solid waste compost has also been observed to raise salt and chlorine levels in plants for those with low sodium dietary constraints (Hargreaves et al. 2008). Besides agricultural measures like irrigation, lamination, and application of "plant-growth-promoting rhizobacteria", the synthesis of critical phytohormones and antioxidants in plants can minimize salt and osmotic stress. Pre-treatment and refinement of municipal solid waste can help to lower compost heavy-metal concentrations.

10.4 Sustainable Landfill Management

Passing open dumps typical to sanitary waste disposal sites in underdeveloped and third world countries is a direct way to sustainable waste disposal management. Furthermore, the rehabilitation of closed sites and waste disposal sites through the phytoremediation process might also help to minimize the erosion of covering topsoil from sites and heavy metal and plant adsorption. For remediation and phytoremediation of contaminated soils around the landfill areas, energies like hybrid poplar, olive seed, and grass species can be used. The plantation of energy crops on shut-off waste is highly preferable because of some of these characteristics such as (i) low-price growth; (ii) fast growth; (iii) short-term harvesting of high biomass yields; (iv) non-seasonal available crops; (v) marginally-degraded soils growth (Singh et al. 2020a, b; Nanda et al. 2016b).

Biochar is recognized as a potential approach for landfill site rehabilitation, pollutant immobile treatment, and carbon sequestration, and especially for surface landfill cover (Kumar et al. 2011; Gunarathne et al. 2019; Gopinath et al. 2020). Gasification, pyrolysis, torrefaction, carbonization of biomass, and other waste products, such as MSWs, sewage sludge, and wastewater (Azargohar et al. 2019). Biochar is very mesoporous and carbon-rich, which works as an adsorbent in soil pollution and nutrient immobility material and as a habitat for critical plant growth-focusing micro-organisms (Nanda et al. 2016a). This seeks to improve plant growth, soil fertility, soil nutrients, and humidity bioavailability. Modification of biochar to sites of deposition can greatly improve pathway engineering, especially soil weight, internal friction angles, and cohesiveness (Kumar et al. 2011). In addition, biochar is a cost-effective and eco-friendly adsorbent material to remove both organic pollutants, such as aromatic, fungal substances, colorants, polycyclic, pesticides, and inorganic pollutants, such as metal ions and anions (Han et al. 2014; Singh et al. 2021).

10.5 Optional Marketing of Products from MSWs

Specific fuel products like bio-oils, gas, syngas, methane, and biology are produced by waste-to-energy processes like liquefaction, pyrolysis, gasification, and anaerobic composting. Bio-oil production is regarded as profitable, pyrolysis and liquefaction charcoal yield are minimized. Syngas and methane are also more profitable than charcoal and bio sludge for gasification and anaerobic digestion, respectively. The average bio-oil and biochar expenses are calculated at US$740 per tea and USD500 per tonne (Nanda et al. 2016a). Catalytically, organic oils can be transformed into synthetic transport fuels, while biochar can be used as solid fuel, adsorbing substances, specialized materials production, and applications in soil. The recovery of valuable compounds also includes bio-oils and MSWs leachate.

On a commercial basis, approximately 96% of hydrogen is synthesized by steam reform of gas or methane due to its low cost of production of 1:5 to 3:7 dollars (Balat and Kırtay 2010; Nanda et al. 2017). Hydrogen is a potential source of energy and energy to replace fossil fuels through the methane reform (Singh et al. 2018). In a steam reform process for the production of hydrogen fuel, a new market for highly concentrated methane derived from municipal sites and anaerobic digestion is possible. Given its high energy content, deposit gases can also be used to fire flares or to generate electricity with motors or turbines. Disposable gases create 4–5 kWh/m^3 of energy and can provide around 0.5–2 MW of electricity for medium waste disposal.

10.6 Application of "Pay as You Throw" Scheme

"Pay as you throw" is a waste metering and costing concept for domestic, commercial, and industrial garbage disposal. The 'pay as you toss' model is founded upon the two environmental policy guiding concepts, in particular, the 'polluter pays' and the 'common responsibility notion' (Batllevell and Hanf 2008). Following this approach, the inhabitants are charged a price based on the number of waste generated by the town or local authority for collection. The costs, limitations, and regulations differ according to the municipality. The waste collected is quantified by tags, size, bags, weight, garbage, waste containers, or other advanced techniques like the identification of radio frequencies. Hughes ID Devices or HID Global, Austin (USA), is a manufacturer of safe identifiers and waste management identifying tags for radiofrequency identifying (HID Global 2020). The waste collection truck scans the RFI tag implanted in the waste bin of the customer during the pick-up process. Three different ways can be implemented: partial price unit, full-price, and variable price systems (Kelleher et al. 2005). Further bags or containers for waste are nonetheless subject to extra fees. The waste management system is financed through the fees paid to the citizen by buying waste bags, tags, and particular sizes and numbers of containers or bins, through the full-unit pricing system. Residents are nevertheless advised to hire the smallest basket to minimize their garbage and save the cost of "pay as you lance". In most of Canada's cities, the excess amount of rubbish, recyclables, and waste is also paid for individually. It can lead to illegal dumping of waste, which in many countries is outlawed by law.

10.7 Conclusion

Successful management of MSWs and selecting the appropriate material recycling, landfilling choices, is required to understand the features, contents, and diversity of the waste discharged. The disposal of MSWs is one of the most favoured procedures. In addition, the scarcity of space for new waste disposal sites in highly urban areas has led to waste-to-energy recycling solutions for solid wastes being implemented. Conversion of MSWs energy waste is significantly higher than waste disposal because of less environmental implications, like poor greenhouse gases, great potential for energy harvesting, and emission reduction. Despite being a long-term geological storage facility for trash, deposits also raise environmental concerns concerning air emission, contamination by groundwater, global warming, and health repercussions. Monitoring procedures like depositary liner installations, flaring installations, soil coverage, gas recovery, leachate collection systems, and the rehabilitation of closed deposits are therefore necessary. Landfills also generate landfill gases and volatiles, that cause health risks to the disposal workers. Deposits of gas are very often fuel for their high concentration of gas, but their energy recovery has not been addressed properly. The incorporation of site mining in new site designs is extremely important to ensure that the stabilized waste can easily be accessed in time for mining, recovery of resources, and reclaiming.

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