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Municipal Solid Waste Management in Nigeria: A SWOT Analysis and Potential for Biological-Based Treatment Systems

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Abstract
The uncontrolled discharge of substantial amounts of Municipal Solid Waste (MSW) has emerged as a major concern due to its profound impact on environmental contamination. The improper handling of municipal solid waste (MSW) is a worldwide problem that affects the environment, social equality, and economic stability. Addressing this issue requires comprehensive evaluations and all-encompassing strategies, particularly in developing countries where the unsustainable management of MSW is prevalent. This review makes an effort to summarize the municipal solid waste management (MSWM) practices in Nigeria. To suggest an administration of conceptual knowledge strategy for addressing the MSWM issues in Nigerian municipalities, the strengths, weaknesses, opportunities, and threats for MSWM in Nigeria were analyzed. The study reviews the existing research, knowledge, and regulations on Nigeria's MSWM. Inadequate awareness of the advantages of waste management, producer involvement in waste management, and ineffective application of government rules are all factors that contribute to ineffective waste management by individuals, households, consumers, and waste management firms. For MSWM in Nigeria, the review suggests a biologically based treatment system as a potential for solid waste management in Nigeria, offering a hopeful solution to the current challenges.

Keywords: Municipal Waste, Solid Waste, SWOT Analysis, Biological Treatment, Nigeria

Introduction

Solid waste is undesirable material produced by industrial, commercial, and residential activity aggregated in a certain area. It can be divided into categories based on its sources (household, industrial, commercial, building, institutional), its composition (organic material, glass, metal, plastic paper, etc.), or its potential for hazard (toxicity, non-toxic, explosive, radioactive, infectious, etc.). The proper management of solid waste contributes to economic growth, increased quality of life, and the reduction or elimination of harmful effects on the environment and human health. (Yadav, 2015). Solid waste mismanagement is an international issue that necessitates integrated assessments and all-encompassing solutions because of its detrimental impact on the environment, social inclusion, and economic sustainability (Bing et al., 2016). The management of solid waste in developing and transitional nations should be given special consideration. It is vital to draw attention to the distinctions between rising metropolitan cities and rural areas, where there are different management challenges, particularly about the volume of garbage produced and the available solid waste management (SWM) facilities (Ferronato & Torretta, 2019). Municipal solid waste is a resource that is both renewable and cost-effective, and it has a significant potential for the extraction of energy and valuable resources through the conversion of trash into energy or energy from waste, in addition to other methods of valorization (Nanda & Berruti, 2021). Municipal solid waste encompasses the wide array of waste materials consistently disposed of by urban and rural communities, such as garbage, junk, and refuse. Globally, around 2 billion tonnes of municipal solid trash are produced, of which nearly 33% were not properly collected, and the average amount of waste produced by an individual is 0.74 kg. MSWM in Nigeria is currently a big challenge due to the high incidence of garbage and poor management practices. All sources of unsorted waste, including business waste, waste from construction and demolition, garbage, electronic waste, and so on, are included in the category of municipal solid waste in Nigeria. These wastes are illegally deposited on roadsides, abandoned buildings, and any open pits that are available, regardless of the potential health risks to the general population (Nkwachukwu et al., 2010). In certain urban areas of developing nations like Nigeria, there is a prevalent practice of open-air, unregulated, and inadequately managed disposal of municipal solid waste. This practice gives rise to numerous environmental concerns (Nanda & Berruti, 2021).

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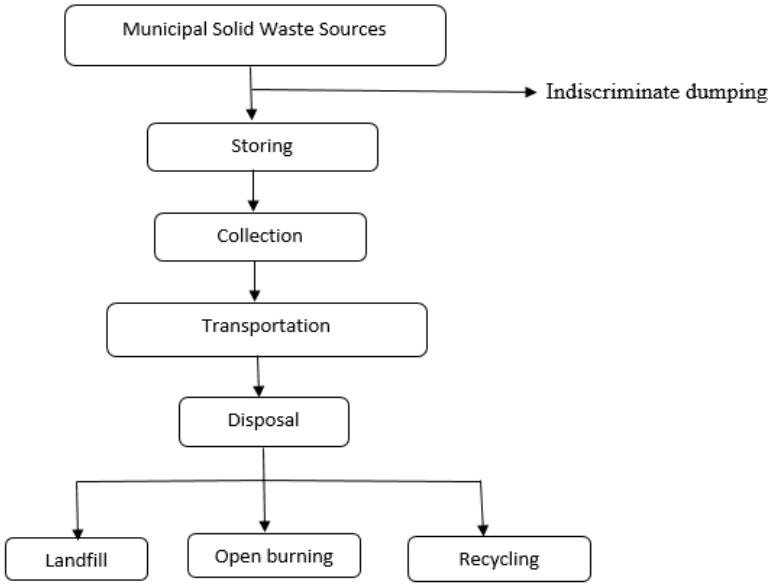
Nigerian practices for managing municipal solid waste do not adhere to international best practices. More frequently than any other method, including incineration, solid waste is disposed of in open dumping sites on land and in water bodies. Lack of adequate and qualified workers, specialized vehicles and facilities for transporting solid wastes, and specialized drop-off locations are the sector's main issues in Nigeria (Sarder, 2017). The most popular "treatment" option for solid waste disposal in developing nations is in open dump sites or unsanitary landfills, which poses a serious environmental and social challenge (Ferronato et al., 2019). It is important to implement sustainable policies that incorporate low-carbon emission technologies. The transition from a linear to a circular economy (CE) is a highly adaptable option which will protect the environment, spur new economic growth, and increase public ecological consciousness, it can be seen as the most flexible solution for enhancing present solid waste management globally. The increasing rates of energy and product consumption combined with the expanding population and rising standards of living result in significant thresholds of municipal solid waste production that, if not appropriately disposed of or recycled, will result in significant environmental hazards (Nanda & Berruti, 2021). A great tool for this approach is the SWOT analysis, which is among the optimal planning techniques for organizational management. It ensures that explicit objectives are acknowledged for a project and that all the aspects related to both favourable and unfavourable initiatives are acknowledged. By using this model, appropriate action plans can be created for public organizations to improve municipal solid waste management. SWOT analysis is a crucial tool for identifying the opportunities and strategies to launch and properly apply the MSWM programme, providing a comprehensive understanding and preparation for the task at hand (Lawínska et al., 2022). MSW is the waste products that are collected by a municipality from enterprises, houses, and other small-scale organizations. Municipal solid waste is comprised of these waste materials. The content and classification of municipal solid waste varies greatly from one municipality to another around the world despite the fact that it is composed of both biodegradable and non-biodegradable fractions, which are correspondingly composed of organic and inorganic components (Nanda & Berruti, 2021). In Africa's developing nations, especially Nigeria, the challenge of waste management is both ancient and ongoing. Nigeria's municipal waste management issues span issues with air, water, and land pollution as well as human health. Identification of the significant issues affecting the effective management of municipal garbage is critical for developing countries such as Nigeria to design a feasible solution (Abila, 2019). In certain towns, over 90% of the solid waste generated is immediately deposited in landfills that have inadequate management practices, resulting in unhygienic conditions. In the majority of developing countries, municipal solid garbage needs to be sorted at its origin. As a result, all forms of dangerous waste, such as infectious biological waste from healthcare facilities and toxic industrial remnants, are finally deposited in landfill sites for disposal (Nanda & Berruti, 2021).

The steps in managing municipal solid waste in Nigeria are storage, collection, transportation, and disposal at landfills (Fig. 1).



(Abila, 2019)

Figure 1: Showing the municipal solid waste management system in Nigeria

Municipal solid waste disposal can occur in a variety of ways, but the common disposal techniques include popular landfilling, burning, composting, anaerobic digestion, and recycling (Abila, 2019). While open dumping,

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landfilling, and open burning are commonly employed in Nigeria for municipal garbage management, incineration is infrequently utilized. In Nigerian hospitals, medical waste is often disposed of through small-scale incineration. However, the cost-effective option of incinerating municipal rubbish is hardly utilized (Ferronato et al., 2019). Landfilling is the easiest and least expensive way to dispose of trash. Although landfills have a significant negative influence on the environment, this impact could be reduced if sanitary measures are followed and trash reduction is promoted. Additionally, recycling, an environmentally desirable choice, is not adequately utilised. There are no recycling industries that are officially recognized in Nigeria. Scavengers are individuals who engage in the informal recycling of waste by purchasing the unwanted treasures of other individuals, going to both legal and illegal dumps, and searching for materials that can be recycled and reused (Abila, 2019). Nigeria's annual production of municipal solid garbage amounts to 25 million tons, with waste generation rates ranging from 0.66 kilograms per capita per day in urban areas to 0.44 kilogram per capita per day in rural parts, compared to 0.7 to 1.8 kilogram/cap/day in developed nations (Abila, 2019). Municipal solid waste generation is steadily rising from households, businesses, and other establishments. The urban and rural areas, as well as states, generate waste in different amounts and with different compositions. Population, socioeconomic class, and urbanization level all closely correlate with solid waste production in Nigeria (Taiwo, 2009).

The promotion of laws and regulations for the management of solid waste was done with the intention of preventing and reducing the continued dumping of solid waste into illegal dump sites. On December 30, 1988, the Federal Government of Nigeria passed Decree No. 58, which was made with the intention of establishing the Federal Environmental Protection Agency (FEPA) in order to accomplish a number of goals. Municipal, state, and federal governments in Nigeria are all responsible for waste management as their major responsibility. As well as having jurisdiction over municipal trash management at the state level, state environmental protection agencies and state waste management organizations are also responsible for this activity. At the moment, the environmental protection agency and the waste management agency of each state in Nigeria are in charge of overseeing the duty for the management of solid waste in the country's main cities and towns (Abila, 2019). Municipal solid waste is collected at the point of generation and then transferred to permitted dumpsites. As a consequence, the state environmental agency mandates that every household pay a charge to have their municipal solid garbage collected. When it comes to the distribution of waste collection fees, the size of a flat is the determining factor. Some households need help to afford the monthly payment due to their income situation. This financial constraint encourages such persons to discard waste indiscriminately. However, most rural residents need this opportunity. (Lawínska et al., 2022). SWOT analysis is a widely recognized strategic planning technique that evaluates an organization's internal strengths and weaknesses, as well as its external environment. It assists decision-makers in making the most informed decisions by providing valuable insights into the internal and external factors that impact the organization's development, both positively and negatively (Khan, 2018). The strengths, weaknesses, opportunities and threats of municipal solid waste management in Nigeria are summarized in Table 1 below:

Table 1- Showing the SWOT Analysis for MSWM in Nigeria

Strengths	**Weaknesses**
• High rate of waste collection. • Informal recycling/reuse activities. • Awareness campaign for waste management. • Strong training programs to promote waste management locally. • Enforcement of waste management law.	• Inadequate training in waste handling. • Roadside Construction Waste Deposition. • Lack of proper waste recycling facilities. • Poor enforcement of anti-littering behaviours by authorities. • Lack of financial resources and funding for implementing waste management systems.
Opportunities	**Threats**
• Employment opportunities. • Technological advancements. • Reduction in diseases and infections. • Receiving external support from government and industrial associations. • Availability of waste separation bins. • Increase in government revenue.	• Poor waste disposal techniques. • Rapid urbanization. • Lack of waste separation techniques. • Insufficient support from authorities. • Lack of standard method for waste recycling/reuse.

Strengths: The increased knowledge and awareness of solid waste and related issues are significant and can greatly help achieve the goal of a safer environment. The empowerment of regulatory entities such as NESREA

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and professional organizations like the Environmental Health Officers Registration Council of Nigeria (EHORECON) to supervise environmental health operations is highly commendable. In some locations, regular waste collection is another crucial part of MSWM. Another avenue being investigated is stakeholders' relative compliance with hazardous solid waste management laws. Environmental law enforcement in development projects in Nigeria would have a favourable impact on municipal solid waste management, particularly in the areas of collection and final disposal (Ehreth, 1991).

Weaknesses: Lack of regular training on waste handling, separation, and disposal are some of the issues plaguing municipal solid waste management in Nigeria, as they are frequently co-disposed with other waste streams. A key disadvantage is the need for proper solid waste recycling and collection infrastructure. Similarly, non-compliance with specified norms by enterprises and organizations, as well as non-adherence to international treaties, are concerns plaguing solid waste management in Nigeria. Another important issue is inadequate enforcement by the relevant authorities. In Nigeria, a serious issue is the low budgeting for solid waste research and development (Ehreth, 1991).

Opportunities: The creation of new job possibilities and the improvement of waste-to-wealth conversion will be welcomed developments. Collaboration with other international and development organizations on MSWM in Nigeria will have a good influence. Proper MSWM will result in less waste being dumped in municipal landfills. It is necessary to implement legislation to establish proper solid waste treatment facilities. This will result in better environmental management practices and reduce the occurrence of diseases and infections. Another possibility is to reduce the tapping, exploitation, and exploration of raw materials for manufacturing purposes, which results in the development of solid waste.

Threats: Toxic solid waste must be treated carefully to prevent the extensive spread of diseases and pollution of the environment. Municipal solid waste management is at risk since population increase is inversely correlated with garbage generation. Urban sprawl and haphazard development are crucial because they impede solid waste management and create the bioaccumulation of harmful compounds in the environment. It needs to be more sustainable and highly polluting to separate garbage at the sources in such an insufficient manner.

Potential for Biological-based Treatment System

The efficacy of the biological solid waste treatment system relies on microbial breakdown. According to numerous specialists, this method can be employed to extract energy from waste in an environmentally advantageous manner (Hijazi et al., 2020). Ideally, trash should have a significant proportion of biodegradable organic matter and a high amount of moisture. Anaerobic digestion and aerobic processes, such as composting, co-composting, and vermicomposting, are commonly employed for the biological treatment of municipal solid waste (Varjani et al., 2020).

Anaerobic digestion technique

Anaerobic digestion (AD) is a prevalent and significant waste management approach that effectively eliminates garbage while producing biogas (Bahreini et al., 2020). Biogas is an environmentally friendly energy source that consists of methane (CH4) and carbon dioxide (CO2). These have various practical applications, such as their use in baking, generating electricity, and transportation (Atelge et al., 2020). Anaerobic Digestion is a biological treatment of waste that utilizes microbes to degrade organic molecules in the absence of oxygen. It is a complex, multi-step treatment procedure that relies on biological activity. Anaerobic digestion consists of four distinct steps that take place in the absence of oxygen: Hydrolysis, Fermentation or Acidogenesis, Acetogenesis, and Methanogenesis (fig. 2) (Obileke et al., 2021). Hydrolysis which occurs in the presence of enzymes, is a chemical process that transforms complex organic compounds into simpler ones, such as sugars, long-chain carboxylic acids, and amino acids (Rasapoor et al., 2020). Fermentation or acidogenesis is a biological process wherein microorganisms are utilized to transform basic building blocks such as sugars and amino acids into byproducts such as ammonia, hydrogen, organic acids, and carbon. Acetogenesis is the biological process that transforms volatile fatty acids into NH_2, H_2, and CO_2. Methanogens employ ingested nutrients to generate methane and carbon dioxide during the biological process of methanogenesis (Arif et al., 2018).

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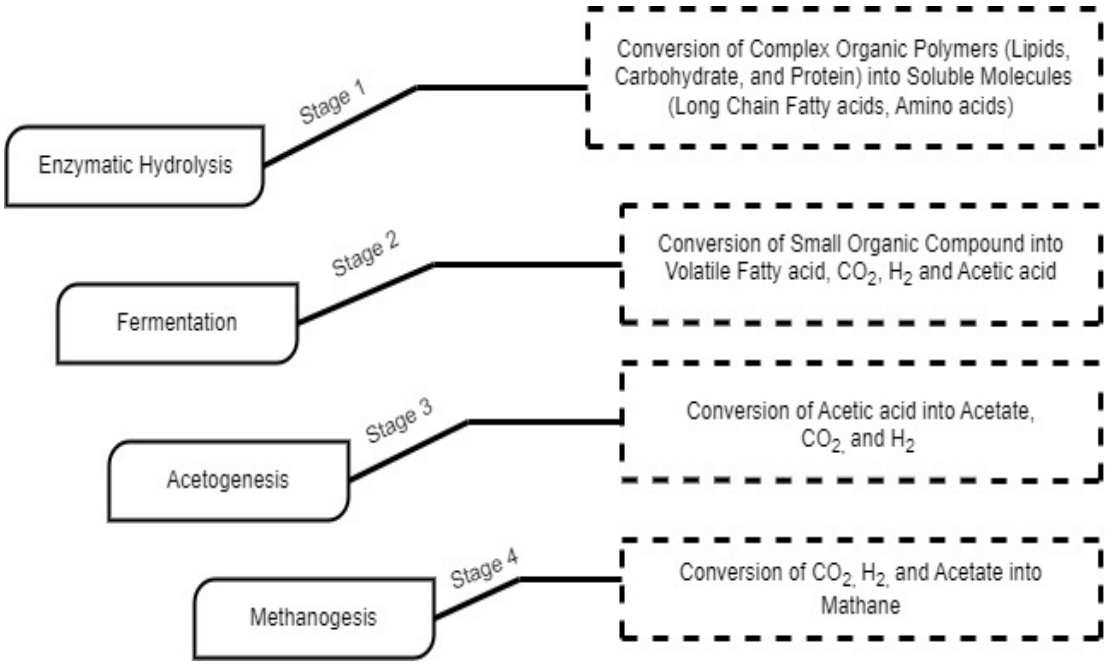

(Arif et al., 2018)

Fig. 2: Showing the stages involved in anaerobic digestion

Composting: Under carefully managed conditions, organic waste can break down through microbial action during the composting process in moist, warm, oxidative, and non-oxidative settings (Bohacz, 2018). The composting process is the predominant and economical approach for managing the organic portion of municipal solid waste. This technique is most suitable for managing the organic component of biodegradable municipal solid waste (MSW), which includes dairy waste, vegetable waste, food waste, and slaughterhouse waste (Abdel-Shafy & Mansour, 2018). Aerobic composting and anaerobic composting are the two primary methods of composting. Aerobic composting, unlike anaerobic composting, happens in the presence of oxygen and involves the decomposition of organic waste by microorganisms (Mengistu et al., 2018). The final result of composting, which is acquired following bacterial activity, has a big impact on agriculture. This compost can be used on farms as a suitable fertilizer because it is largely pathogen-free (Zamri et al., 2021). By using the composting method, waste can be reduced by 50 to 85%. Composting has many benefits, including its capacity to improve soil quality, improve the quality of soil, and serve as an organic input for agriculture, all of which help to lessen the burden on landfills (Prajapati et al., 2021).

Co-composting: The practice of co-composting involves combining multiple raw materials to speed up the composting process. The feedstock is combined with a specialized bulking agent during the co-composting process, which can offer the right particle structure and density to increase the activity of aerobic bacteria and so speed up the rate of decomposition. The co-composting technique can also be used to reclaim contaminated soils and sediments or degraded soils from internal crops. The breaking down of heavy metals and polluted soils can be used to remediate contaminated soils, restore soil structure, and increase the fertility of nutrient-dependent soils (Awasthi et al., 2018).

Vermicomposting: Vermicomposting is a process that was developed scientifically to create compost. It is an eco-friendly and less expensive method (Hannan et al., 2020). It is a highly effective technique for recycling organic waste. This method can transform organic solid waste and contaminants into valuable items that contribute to the environmentally friendly regeneration of soil. In the vermicomposting process, microorganisms and worms such as earthworms and other types of worms alter the biochemical structure of organic waste to produce fertilizer. The three steps of the vermicomposting process are mixing, digestion, and maturation. Bacteria and earthworms often break down the waste component during the mixing stage. At this stage, a minimum of 2 to 5 days must pass, and a temperature of about 15 ℃ must be maintained. However, due to the energy produced during this process, the temperature rises by around 50 ℃ (Kiyasudeen et al., 2019). By utilising fungi, actinomycetes, and earthworms during the digesting stage, semi-complex chemicals are biodegraded into a substrate (Nogales et al., 2020). This stage needs a minimum of 10 to 30 days and a temperature of about 60 ℃ (Nogales et al., 2020). The biodegradation of complex molecules into a substrate takes place at the mature and cooling stage, the last and

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most important step, and it takes 10–20 days (Rafieenia et al., 2017). Vermicompost contains micro- and macronutrients, as well as bacteria that can fix nitrogen and phosphate, as well as plant growth hormones. As a result, vermicomposting technology is highly helpful since organic waste is managed correctly, producing organic fertilizers of higher quality (Balachandar et al., 2021). Vermicomposting offers prospective pathways to sustainable agriculture, including crop production, serving as a carrier for biofertilizers, potting and layering medium, reducing pathogens, and removing antibiotics from biowaste (Yuvaraj et al., 2021).

Conclusion

The insufficient handling of municipal solid waste in Nigeria presents a substantial obstacle to both environmental components and public health. Solid waste is now transported to a single, inadequately designed land disposal site since there is a general lack of public awareness or concern regarding waste concerns. The current system is plagued by negative economic conditions as well as institutional, statutory, technical, and operational limitations. Hence, it is crucial to efficiently manage it in order to provide a more secure environment in Nigeria. The huge volume of municipal solid waste generated in Nigeria can be used for good through biological-based treatment systems or energy production through waste-to-energy conversion. Waste recycling with additional value should take precedence over open waste dumping.

Suggestions

1. The finest available technologies and an integrated approach be adopted to effectively and efficiently manage solid waste.
2. The informal sector will be more fully integrated, and the private sector will be more effectively involved.
3. There is a need for improvement in the areas of resource recovery, waste recycling, and composting of biodegradable solid wastes.
4. A biologically based treatment system as a potential source of solid waste management in Nigeria highly recommended.

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