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Waste Management in Rivers State: The Role of the Mechanical Engineer

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Abstract

This paper discusses various waste management and disposal strategies and the role of the Mechanical Engineer in their implementation. For many decades, different research institutes of many countries, private organisations as well as individuals have been trying to develop or design effective methods of handling the solid wastes generated in their environment. This is because of the conspicuous effects of these wastes which have become a matter of great concern locally, nationally and even globally. The desire to control or handle these solid wastes and their attendant problems led to the different waste management methods which exist today. In spite of the expectations of the masses, cities in Nigeria still grapple with waste management problems, as some areas, particularly the satellite towns stink because of the refuse heaps by the streets and walkways. This paper proposes waste management and disposal strategies such as separation, compaction, shredding or pulverising and incineration, all of which can be aided by design and construction of various machines and equipment by Mechanical Engineers. The paper also proposes a number of maintenance strategies to ensure that waste management equipment and machines do not break down too frequently and result in excessive waste of time and loss of money. This research is significant because it proposes effective strategies that can be applied to solve solid waste management and disposal problems, especially in the environs of Rivers State.

Keywords: Waste Management, Waste Disposal, Environment, Machines, Engineering Strategies, Rivers State.

Introduction

Various forms of waste are evident in our daily lives (Wofuru-Nyenke, 2021b; Wofuru-Nyenke et al., 2019). The problem of solid waste management in Nigeria has become more complex in recent times due to high rate of population growth, urbanisation, and industrialisation, which have led to increased amounts of different kinds of wastes being generated. Changes throughout the urban centres in the country over the years, particularly in demographic expansion have brought about phenomenal increase in the volume and diversity of solid waste generated daily in Nigeria. The result of this is that heaps of refuse and garbage are common sights in our cities, urban areas and state capitals. The Rivers State Waste Management Agency (RIWAMA) is the government body of Rivers State responsible for the enhancement of the environment. The history of Rivers State waste management is replete with numerous difficulties, encountered during various waste disposal activities. The management had suffered lack of waste management equipment, lack of proper maintenance culture, inadequate funding and insufficient manpower to handle the various activities of the agency. The problems of the agency include: lack of important waste management equipment like excavators, bulldozers, payloader, tippers and compactors, insufficient dumpsters, insufficient funds and poor operational logistics. In fact, the available compactors cannot collect all the solid wastes being generated in the metropolis daily. Furthermore, the welfare of workers has not been properly considered during various regimes of government.

Despite several efforts at improving the incorrigible situation, the agency still has logistic problems which cause inefficiency in waste disposal in the metropolis. In essence, the compactors are overused which, coupled with their poor management, causes constant breakdowns, worn-out tyres, bursted hydraulic and air pipes, as well as engine knocks. This results in high maintenance cost and inefficiency. Despite all these problems, a good solid waste management approach will help to improve the efficiency of the agency. This solid waste management approach can include route optimisation for reducing the long distances travelled by the compactors, thereby aiding in reducing the exorbitant maintenance and operational costs; design and development of more resilient waste disposal equipment and machines to cope with the high intensity and frequency of waste disposal activities (Wofuru-Nyenke, 2020, 2024f); implementing the most appropriate machine maintenance strategies to ensure that machine breakdowns are minimal; as well as regularly training personnel on carrying out maintenance activities and improving their work methods. All of these are roles the Mechanical Engineer can handle to improve the deplorable state of waste management and disposal in Nigeria.

The aim of this research is to highlight the various waste management and disposal strategies and the role of the Mechanical Engineer in their implementation. The paper proposes waste management and disposal strategies such as separation, compaction, shredding or pulverising and incineration, all of which can be aided by design and construction of various machines and equipment by Mechanical Engineers. The research also discusses various maintenance strategies and proposes the most viable maintenance strategy for waste management agencies, based on the type of machines used for waste management and disposal.

Solid Waste

A good number of authors have defined waste based on various perspectives. Tchobanoglous et al. (1977) defined waste as any unavoidable material resulting from domestic activities or industrial operation for which there is no economic demand and which must be disposed of. According to Odocha (1994), wastes are those materials which though may no longer be needed at a particular place, may become feedstock or raw materials elsewhere. It implies that what is a waste to someone may be a raw material for another person. Wastes do not, therefore, altogether apply to worthless substances around us. He also defines waste as those materials which are generated as a result of normal operations over which we have control in terms of their production, disposal or discharge. Therefore, waste is anything that is no longer of use to the owner, which must be disposed of, of which the owner may not attach any economic value to it. Furthermore, Karalam et al. (2024) explained that waste is any unavoidable material resulting from domestic activities or industrial operations of which there is no economic demand and which must be disposed of.

Wastes are generally categorised into solid, liquid and gaseous wastes. Solid wastes generated in a city or district is usually called municipal solid wastes (MSW). These wastes can be categorised as follows: hazardous or non-hazardous, combustible or non-combustible, decomposable or non-decomposable, reusable or non-reusable wastes etc. Solid wastes (SW) disposal is the disposal or careful removal of solid or semi-solid materials resulting from human and animal activities that are useless, unwanted or hazardous. Solid wastes (SW) may be classified as follows:

a) Garbage: Degradable wastes from food remains.
b) Rubbish: Non-decomposable wastes; combustible (such as paper, wood, clothes, plastics, rubber, leader etc) or non-combustible (such as metals, glass, stones, ceramics, bottles etc).
c) Ashes: Residues of the combustion of solid fuels.
d) Large wastes: Demolition and construction debris or trees.
e) Dead animals: Remains of bodies of animals.
f) Sewage-treatment solids: Material retained on sewage-treatment screens, settled solids and biomass sludge.
g) Industrial wastes: Such as chemicals, paints and sand, computer parts, textile materials, swarf (Wofuru-Nyenke, 2024a, 2024d).
h) Mining wastes: Slag heaps and coal refuse piles.
i) Agricultural wastes: Farm animal manure and crop materials (Wofuru-Nyenke, 2023b).

Solid Waste Generation

Solid wastes are being generated by the second all over the world. The rate at which these solid wastes are being generated depends on a good number of factors which include: the human population of the area under consideration, the living standards of the people, and their attitudes to waste prevention and control. This list of factors is by no means exhaustive, as there are several factors that affect the rate of generation of waste, which are particular to various climes. According to Tchobanoglous et al. (1977), solid waste products arise from our ways of life. Hoornweg and Bhada-Tata (2012) stated that when living standards rise, people consume more and waste increases. Several models can effectively be used for forecasting solid waste generation (Wofuru-Nyenke & Briggs, 2022; Wofuru-Nyenke, 2022). Table 1 shows the estimated daily municipal solid waste generation in Nigeria.

Table 1: Estimated daily municipal solid waste generation in Nigeria (Somorin et al., 2017).

S/No.	State	Metric Tonnes
1	Abia	2000
2	Adamawa	800
3	Anambra	2500
4	Akwa-Ibom	700
5	Bayelsa	600
6	Bauchi	900
7	Benue	800
8	Borno	900
9	Cross River	750
10	Delta	850
11	Ebonyi	600
12	Edo	900
13	Ekiti	800
14	Enugu	1000
15	Gombe	500
16	Imo	1000
17	Jigawa	600
18	Kaduna	1000
19	Kano	2000
20	Katsina	800
21	Kebbi	700
22	Kogi	500
23	Kwara	700
24	Lagos	6000
25	Nassarawa	400
26	Niger	700
26	Ogun	1000
28	Ondo	800
29	Osun	700
30	Oyo	1100
31	Plateau	700
32	Rivers	1500
33	Sokoto	900
34	Taraba	400
35	Yobe	400
36	Zamfara	400
37	FCT	3000

Solid Waste Composition

The composition of solid waste generated from any given area depends on what the people throw away as waste. Uchegbu (2002) stated that in industrialised countries, packaging of goods contributes about 30% of the waste, while 50% of the volume of household waste, food and yard scraps account for the remainder. Furthermore, he stated that in Nigeria, the average mass of waste disposed in big cities is 46kg/person/day. Ogwueleka (2013) has observed that household waste in Nigeria, especially Abuja, consists of 63.6% organic waste, 1.6% textile, 9.7% paper, 3.2% metal, 8.7% plastics, and 2.6% glass, while 10.6% is constituted by other unclassified wastes.

The Impact of Solid Wastes in Human Society

The impact of solid wastes in human society cannot be overemphasised. Land, water and air pollutions are all partly because of the accumulation of solid wastes, which also lead to disease spread, with consequent suffering and hardship, stunted economic development as well as diminished productivity. Khajuria et al. (2012) stated that in developing Asian countries, the municipal corporations are unable to handle the increasing amount of municipal solid waste, which has led to the uncollected waste being littered on roads and in other public areas leading to tremendous pollution and destruction of land as well as negative impacts on human health. Uchegbu (2002), in his research work stated that cholera outbreaks or spread in most parts of Nigeria have been as a result of accumulation of solid wastes in our society. According to Uchegbu (2002), the life expectancy in developing countries is fifty-three (53) years while that of developed countries is seventy-five (75) years, and the reason is that waste management is still very poor in our society when compared to that of developed countries.

Most drainage gutters are being blocked with solid wastes; resulting in flooding of many of our tarred roads, residential houses, farmlands, hospitals, schools etc. From observation, most streams in our society are no longer drinkable because of the contaminating solid wastes that get into it. Oloke and Olugboye (2014) have explained that water sources near waste dumps easily become contaminated, and a consequence is the spread of gastro-intestinal and parasitic diseases. Moreover, the bad odour that usually emanates from these wastes is irritating to the members of the society. In spite of all these problems associated with solid wastes in our society, there have been little or no measures to put a final end to the pollution from these wastes through effective waste management and disposal. Truly, if an appropriate waste management system is implemented, the various forms of pollution and environmental problems in the society will be assuaged, thereby making our living environment healthy, decent and enjoyable.

Different Approaches to Solving Solid Waste Management Problems

Solid waste management is borne out of the desire to control environmental pollution with its attendant health hazards. The topic has stirred up foreign and indigenous researchers to discuss on the waste management subject and proffer various solutions. As long as humans have been living in settled communities, solid waste, or garbage, has been an issue, and modern societies generate far more solid waste than early humans ever did. Daily life in industrialised nations can generate several kilograms of solid waste per consumer, not only in the home, but also in supply chains and factories that manufacture goods purchased by consumers (Wofuru-Nyenke et al., 2023). Solid waste management is a system for handling all of this garbage. Municipal waste collection is part of solid waste management, as are recycling programs, use of dumps, and incinerators.

Solid waste management is the systematic control of generation, collection, storage, transport, source separation, processing, treatment, recovery, and disposal of solid waste. In the world today, many countries approach solid waste management problems differently due to the kinds of waste they generate and the type of waste management equipment available in their countries. Therefore, a broad literature is available on studies that deal with different methods used in solid waste management. Some of these literatures include: optimisation of solid waste collection system (Agunwamba, 2003); fleet and truck size selection (Ojiako & Nwosu, 1989); solid wastes: engineering principles and management issues (Tchobanoglous et al., 1977); waste generation and management in a depressed economy (Odocha, 1994). Other ones are integrated solid waste management (Marshall & Farahbakhsh, 2013; Memon, 2010; White et al., 2001); vehicle routing and optimisation of solid waste collection routes (Chang & Wei, 2002; Hannan et al., 2018; Mojtahedi et al., 2021; Rahmanifar et al., 2023; Thakur et al., 2024) etc. Solid Waste management practices differ for developed, developing and underdeveloped nations, for urban and rural areas, and for residential and industrial producers. It is commonly observed that in most underdeveloped and developing countries like Nigeria, there are little or no mechanisms for dealing with the problem of evacuating or disposing all the solid wastes generated daily in their environment. While developed countries like the United States of America, Germany and Japan are better able, and still researching on how, to recover all the useful things from their solid wastes. Khajuria et al. (2012) support this view by explaining that the common problem faced by all developing Asian countries, is the disposal of municipal solid waste and availability of land fill site area. Based on the above statement, it is quite understandable that the waste management approach will be different for the two groups of countries.

The following sections present reviews of relevant literatures on approaches to solving waste management problems under the following sub-headings: fleet and truck size selection, minimisation of solid waste, and finally, integrated or combined solid waste management.

Fleet and Truck Size Selection

Wu et al. (2020) examined selecting the right vehicle for waste collection operation as the best way of optimizing the waste collection problem by considering factors like total weight, length, and types of collections and operators' productivity. Maimoun et al. (2016) utilised multi-criteria decision analysis for evaluating alternative fuels for waste collection vehicles in the United States. Arias-Melia et al. (2022) proposed a mixed integer-programming model to balance the crew size and the number of vehicles. However, the model lacks the features of a modern crew selection method. The procedure by Wofuru-Nyenke (2023a) can be adapted for crew and vehicle selection in waste management. According to Clark and Matharu (2013), collection of solid waste is much more expensive than its disposal. Most municipal collection fleets are made up of compactor trucks that service areas with dissimilar topography, population density, and waste generation rates. When vehicles are selected for solid waste collection fleets there is usually very little consideration given to providing the required service at minimum cost. One possibility for minimizing collection costs is to select a fleet of various-sized compactor trucks, while simultaneously satisfying the service constraints. To illustrate this approach, the waste collection system of a large metropolitan area is analysed for proper fleet size and type of compactor vehicle. Selection of the optimal fleet size and type of compactor truck is formulated and solved as a linear programming problem.

Agunwamba (2003) carried out a research on optimisation of solid waste collection systems in Onitsha, Nigeria. His focus was on the optimal combinations of collecting vehicles, containers and their distributions in each zone, which will ensure efficient collection at minimal cost. The work considered how best to assign different types of vehicles and containers to the six zones of Onitsha such that the waste disposal will be efficient and at a minimal cost. The problem was formulated as an integer problem with a cost objective function and constraints. The solution to the optimisation problem formulated from the data collected was obtained using TORA Optimization System. The results showed that the existing distribution and combination of waste collection vehicles require alteration in order to achieve optimality, and the optimality cost for effective and regular collection of waste was N 21,039,512.50.

Otti (2011) developed a model for solid waste management in Anambra State, Nigeria. His research was aimed at determining which type of integrated solid waste management option or programme will be used to implement minimised cost and maximised benefit (cost-benefit ratio) over a long planning period. He applied a linear programming model that considers the scheduling decision, benefits over-time, budget constraints and constraints on the number of equipment available to effectively implement the project.

Minimisation of Solid Waste

Solid waste disposal can be very expensive, especially in areas where the cost of purchasing a landfill site is very costly. The waste management process involves collection, segregation, recycling, treatment or disposal of discarded items, in order to achieve minimal to zero waste. Aiming for zero waste means designing products and packaging with reuse and recycling in mind. It means ending subsidies for wasting. It means closing the gap between landfill prices and their true costs. It means making manufacturers take responsibility for the entire life cycle of their products and packaging. Zero waste efforts, just like recycling efforts before, will change the face of solid waste management in the future. Instead of managing wastes, we will manage resources and strive to eliminate waste. The need to practice and apply some volume reduction techniques to the amount of solid waste that goes into the landfill site becomes necessary. These volume reduction techniques are refuse-processing techniques, which help to improve the efficiency of waste management operations, in order to recover useful resources and achieve energy recovery from wastes. Some of these techniques include component separation, compaction, shredding, incineration etc.

Component separation technique

This technique, which can be mechanical or manual, involves sorting of solid wastes into its different components. This will help to separate solid wastes into combustible, non-combustible, decomposable, non-decomposable, re-usable and non-reusable wastes etc. Each component or category of waste will then be handled properly and this will help to reduce the amount of wastes that will be finally disposed of. Various optimal scheduling approaches have been developed for general engineering applications, as well as for solid wastes disposal and for proposing recycling options that will help in minimizing the amount of solid wastes that goes into the landfill sites (Fu et al., 2019; Linfati et al., 2021; Mohan & Kumar, 2016; Wofuru-Nyenke, 2024e). Models have been developed for routing optimisation that can be adapted to consider all the costs related to the collection, transportation and processing of recycled products, monitoring of the exhausted landfills and opening of new ones (Ismail et al., 2012; Nguyen-Trong et al., 2017; Tirkolaee & Aydın, 2021; Wofuru-Nyenke, 2024c).

Compaction Techniques

This is a mechanical volume reduction technique, which helps to increase the useful life of landfills. Here wastes are compacted with the help of high-pressure compacting systems to small volumes before disposing them into landfill sites. Compactors promote better housekeeping by providing a convenient place to dispose of trash. They reduce insect and rodent problems inside facilities by keeping pests out of trash and also allow retail companies to efficiently recycle paper and plastics by compressing them into bales that can be transported easily to recycling centres. Compacting equipment reduces large amounts of waste to smaller units by using powered rams to crush the garbage. It also makes waste disposal more efficient by compressing the waste so it requires less space in landfills, which reduces the garbage level in dump sites. Costs and economics are the primary metrics for determining which method or methods should be used. In some cases, operating costs and market economics may decree that little, if any, compaction is warranted. Standard landfill compaction is done with specialised earthmoving equipment designed for operations in waste. More extreme waste compaction can be achieved with mechanical waste bailers and dynamic compaction using impacts from heavy weights dropped from great heights. Counter-intuitive methods of air space minimisation include pre-shredding the waste (which initially fluffs up the waste and increases its volume) and mining the waste, an activity that reduces air space without any compaction at all. Compacting equipment reduces large amounts of waste to smaller units by using powered rams to crush the garbage. Three types of compactors are identified as:

a. Vertical compactors, which typically have material containers that can handle large volumes of waste material.
b. Stationary compactors, also called breakaway compactors, which have a removable material container, which can be picked up by the truck. Businesses use this type of compactor for solid waste or recyclable material.
c. Apartment compactors for residents of high-rise apartment buildings to dispose of solid wastes, such as metals, paper, cotton and cardboard boxes. The compactors compress these waste materials into bales that can be transported to disposal facilities or recycling centres.

Although compactors are majorly used by businesses ranging from manufacturing to retail, people also have them in their homes, according to the National Institute for Occupational Safety and Health.

Shredding or Pulverising Techniques

This is a mechanical size reduction technique, which helps to break down or shred the solid wastes into small pieces before disposing them. In shredding, organic materials can be grinded and used as manure, odour control of solid is improved and useful life of disposal landfill sites improved. The processing of solid waste for size reduction and uniformity will adopt the accepted interchangeable use of shredding and pulverizing. However, it should be noted that the end products of each of the processes are differentiated by the shredded or cut and torn shapes from the former process, and the pulverised or crushed and ground fine particles from the latter. There are basically four types of shredders used for the shredding or pulverizing of solid waste: hammer mills, drum pulverisers, crushers, and wet pulverisers. Each type of equipment has a variety of designs, advantages, and disadvantages. Major considerations in selecting a shredder are its capacity, speed, power requirements, maintenance needs, ability to produce the end product desired and, most importantly, reliability. These characteristics will differ significantly for various types of solid waste and differing end products. In choosing a type and particular design of a shredder, it is desirable to obtain information on the performance of the shredder in circumstances similar to those for which the machine is to be used.

Solid waste is shredded for several reasons, including volume reduction. Under certain circumstances, shredded refuse can be disposed of in a landfill without requiring as stringent compaction and cover procedures as would be applied to unprocessed refuse. If solid waste is to be converted to refuse derived fuel (RDF), shredding and/or pulverizing is an element of the RDF production process. Resource recovery plants that separate waste into recyclables often include one or more shredding operations to improve the mechanical separation characteristics of the waste. If solid waste is to be transported mechanically, pneumatically, or hydraulically, shredding is a desirable, if not essential, first step before transporting the waste.

Incineration Techniques

Incineration is the controlled process by which solid, liquid or gaseous combustible wastes are burnt and changed into gases, and the residue produced contains little or no combustible materials. This is a chemical reduction technique. It serves both for volume reduction and for power generation. Incineration can reduce the volume of waste by up to 80%. This is what makes it interesting. The technique is usually performed within an enclosure known as an incinerator. Moreover, the heat produced by an incinerator can be used to generate steam which may then be used to drive a turbine in order to produce electricity. However, incineration has its negative effects which include global warming and air pollution. Most often, in under-

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developed and developing countries like Nigeria, open air burning is usually practiced without considering the resultant air pollution and global warming. When wastes are incinerated at low temperatures or when plastics that contain polyvinyl chloride (PVC) are incinerated, dioxins and furans and other toxic air pollutants may be produced as emissions and/or in bottom or fly ash. Exposure to dioxins, furans and coplanar Polychlorinated Biphenyls (PCB) may lead to adverse health effects. Long-term, low-level exposure of humans to dioxins and furans may lead to the impairment of the immune system, the impairment of the development of the nervous system, the endocrine system and the reproductive functions. Short-term, high-level exposure may result in skin lesions and altered liver function. Moreover, exposure of animals to dioxins has resulted in several types of cancer.

Integrated or Combined Solid Waste Management

Many waste management options have been proposed and implemented during the last few years. Integrated waste management is a system of waste disposal that includes separating materials according to type, and finding the best use for discarded products, and may or may not include depositing useless items in a landfill. Figure 1 shows the components of integrated waste management. In California, as one example, the goal of the State's integrated waste management agency is to find alternative destinations for at least half of the waste collected. These alternatives will include recycling some materials through an approved program, and reusing some materials as well. The benefit of the integrated waste management system is that those picking up the discarded materials should know what they are picking up, if the consumer follows the rules. This not only helps sort things so that all discarded materials are not going to the landfill, it also helps keep the workers safe. Communities that do not have this system may find that everything is discarded into the same trash bags, including bio-hazardous materials. Furthermore, the pre-sorting of many materials makes the entire process easier and more efficient. It had been observed that none of these options mentioned above could solve the solid waste problems by itself. Therefore, intelligent combinations of these options help to improve the optimum solid waste management efficiency. This leads to a reduction in environmental and social impacts at an acceptable cost for the metropolis or community. United States Environmental Protection Agency (USEPA) defined Integrated Solid Waste Management (ISWM) as a comprehensive waste prevention, recycling, composting, and disposal program. An effective ISWM system considers how to prevent, recycle, and manage solid waste in ways that most effectively protect human health and the environment. ISWM involves evaluating local needs and conditions, and then selecting and combining the most appropriate waste management activities for those conditions.

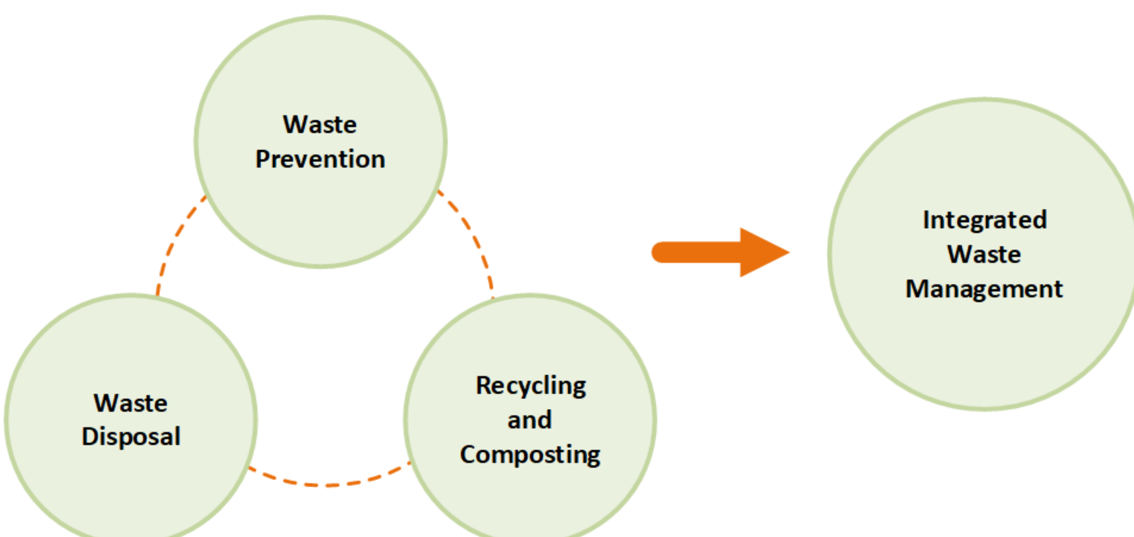

Figure 1: Components of Integrated Waste Management.

The major ISWM activities are waste prevention, recycling and composting, and combustion and disposal in properly designed, constructed, and managed landfills. Many cities are putting effort on waste diversion through an integrated solid waste management approach because of the increasing rate of consumption of landfill and the cost of siting new ones. Integrated solid waste management incorporates a number of factors with a general framework that includes collection techniques to be used, facilities to be adopted, level of service to be offered, complex interactions among other variables etc that will provide a holistic analysis of the solid waste problem. Integrated solid waste management is like an umbrella term that covers other waste management approaches in use. The option to be integrated for a particular kind of waste depends on the nature of the waste, the volume of the waste, the cost effectiveness of that option and its efficiency.

Waste Management Equipment Maintenance Strategies

Regular maintenance of the equipment and machines used in waste collection, transportation, processing and disposal is necessary to improve the reliability of the machines (Ugoji et al., 2022; Wofuru-Nyenke, 2024b). This is to avoid frequent unexpected machine breakdowns which can lead to increased costs and time wastage. The mechanical engineering discipline proffers some viable maintenance strategies that can aid waste management agencies cope with effectively maintaining their equipment and machines. These strategies include preventive maintenance, corrective maintenance, predictive maintenance and condition-based maintenance. Figure 2 shows the various maintenance strategies. Preventive maintenance refers to the routine, scheduled checks and actions to prevent equipment failure and breakdowns (e.g. cleaning, oiling, inspections etc.). Corrective maintenance refers to all the repairs performed after an equipment failure has occurred, for restoring the equipment to working conditions. Predictive maintenance refers to the use of real-time data, from sensors or monitoring tools, to predict and prevent failures. This maintenance strategy basically utilises sensor data to predetermine when an equipment is likely to fail, so maintenance can be done just in time (Wofuru-Nyenke, 2021a). Condition-based maintenance refers to maintenance that is carried out based on the actual condition of the machine or equipment, determined through sensors or diagnostics. This maintenance is performed when specific indicators like temperature or vibration reach a threshold.

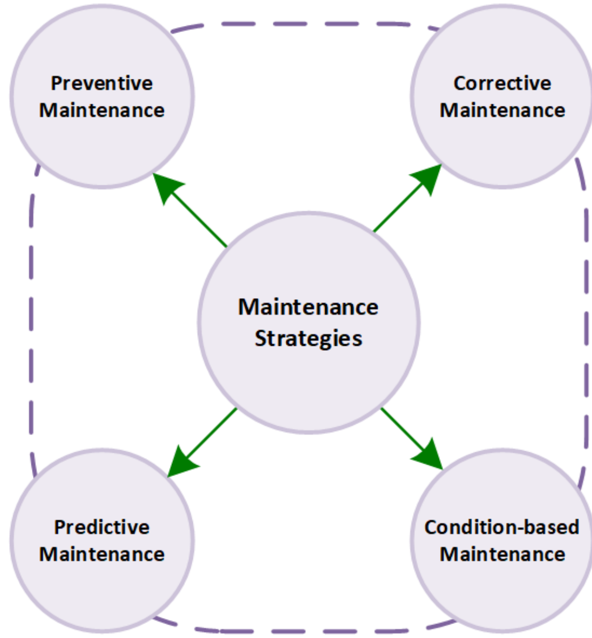

Figure 2: Maintenance strategies.

These maintenance strategies are some of the techniques that waste management agencies in various countries, can adopt and combine to improve their waste management and disposal operations. Of these strategies, the corrective maintenance strategy is the least appropriate for maintaining the equipment and machines of waste management agencies. This is because the strategy involves restoring a machine to normal working conditions after downtime and possible large expenses have been incurred from machine failure.

Conclusion

This paper has discussed the concept of solid waste and its classifications; solid waste generation; solid waste composition in Nigeria; the impact of solid wastes in human society; different approaches to solving solid waste management problems, including fleet and truck size selection, minimisation of solid waste and integrated or combined solid waste management. The paper discussed some techniques for solid waste minimisation which include component separation, compaction, shredding or pulverising and incineration. The paper has also identified some equipment maintenance strategies that are common in the field of Mechanical Engineering, and proposes some of these strategies for maintaining the equipment and machines involved in waste management and disposal within various municipalities, especially those of Rivers State. Therefore, it is recommended that the Rivers State Waste Management Agency (RIWAMA) should implement the findings of this research in order to improve their operations across the municipalities of the state.

Further research can handle the development of mathematical and simulation models for routing of compactor trucks between dump sites, waste processing plants, as well as landfills or incineration centres. Moreover, researchers can design and develop more efficient equipment and machines that aid the waste management and disposal process, such as waste collection, segregation, recycling, organic waste management, hazardous waste management, landfill management, waste-to-energy, and e-waste recycling equipment. The collection equipment can include garbage bins and containers for collecting and storing waste temporarily; compactors for compressing waste to reduce volume and transportation costs; as well as garbage trucks for collecting and transporting waste. The segregation equipment can include conveyor systems for sorting waste materials by type e.g. plastic, metal, organic; magnetic separators for extracting ferrous metals from waste; as well as optical sorters which use sensors for identifying and separating recyclable materials. The recycling equipment can include shredders for reducing large items into smaller pieces for easier recycling; bailers for compressing recyclable materials like cardboard, plastics, and metals into compact bundles; as well as crushers for breaking down glass, concrete or stone for reuse. The organic waste management equipment can include composters for converting organic waste into compost for agricultural use; as well as biogas plants for treating organic waste to produce methane for energy. The hazardous waste management equipment can include incinerators for safely burning hazardous waste materials; autoclaves for heating and pressurising medical waste in order to sterilise them; as well as chemical neutralisation systems for treating hazardous chemicals for safe disposal. The landfill management equipment can include bulldozers for spreading and compacting waste at landfill sites; leachate collection systems for managing liquids produced in landfills; as well as gas extraction systems for capturing methane gas generated in landfills. The waste-to-energy equipment can include pyrolysis units for converting waste into usable energy through thermal decomposition; as well as gasification systems for generating energy from waste using controlled combustion. The e-waste recycling equipment can include circuit board shredders for breaking down electronics for material recovery; as well as precious metal extractors for recovering valuable metals like gold and silver. These machines will aid the waste management and disposal process, while helping to reduce the drudgery, costs and time required to carry out waste management operations.

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