POLITECNICO DI MILANO

SCHOOL OF CIVIL, ENVIRONMENTAL AND LAND MANAGEMENT ENGINEERING

MASTER OF SCIENCE IN ENVIRONMENTAL AND LAND PLANNING ENGINEERING

A material and energy from waste technology for developing countries

MASTER GRADUATION THESIS BY

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ACADEMIC YEAR 2018-2019

Contents

LIST OF TABLES

Abstract

Amid the most recent decades, there has been an increase in the generation of solid waste on the planet. In developing nations, the circumstance has been mainly essential since by, and large there is no sufficient treatment for the solid waste because of the shortage of the assets and to the weak heart of the exact circumstance and likely outcomes. This document presents the waste bio-drying coupled with a bioreactor landfill as an alternative proposal for the treatment of solid waste in developing countries, considering that its costs are affordable, and that the composition of the solid waste is mainly organic. The analysis was based on a current literature review and on the study of the solid waste situation in developing countries and especially Kenya; according to the results, a design and operational guideline for the development of a treatment plant based on both the aerobic bio-drying and the following anaerobic digestion in developing countries was proposed. The operational guideline's central core is the planning system; the planning system attempts to cover all the facets that are present during the planning and design process of a new treatment facility.

Keywords: bio-drying, bioreactor landfill, anaerobic digester, developing countries, municipal solid waste management, operational guideline, planning system.

Sommario

Durante gli ultimi decenni sì è verificato un incremento della produzione dei rifiuti solidi nel mondo. In particolar modo questo si può riscontrare nei paesi in via di sviluppo poiché in molti casi non esiste un trattamento adeguato a causa della scarsità delle risorse economiche, della limitata conoscenza della situazione reale e delle possibili conseguenze. Questo documento illustra una tecnologia basata sulla bioessiccazione, seguita dalla digestione anaerobica in discarica, come alternativa per il trattamento dei rifiuti solidi nei paesi in via di sviluppo, garantendo costi non elevati e tenendo conto che la composizione dei rifiuti è principalmente organica.

Le analisi si basano su una analisi della letteratura attuale e uno studio riguardante la situazione dei rifiuti solidi nei paesi in via di sviluppo e in particolare in Kenya. In base ai risultati è stata proposta una linea guida operativa per lo sviluppo di un impianto di trattamento che si occupa dello spreco dei rifiuti solidi urbani nei paesi in via di sviluppo utilizzando sia il bioessiccatore che il digestore anaerobico. In nucleo principale della linea guida operativa è il sistema di pianificazione. Quest'ultimo ha come scopo finale quello di coprire tutti gli aspetti che sono presenti durante il processo di pianificazione e progettazione di un nuovo impianto di trattamento.

Parole chiave: bioessiccazione, discarica bioreattore, digestore anaerobico, paesi in via di sviluppo, gestione dei rifiuti solidi urbani, linee guida operative, processo di pianificazione

Introduction

In the most recent years, the expansion of the generation of solid waste on the planet has broadened the enthusiasm for the advancement and utilization of clean innovations to deal with the solid waste properly. The particular setting of the developing nations produces a few limitations on the use of sufficient changes since the monetary assets are rare, the instruction of the populace is inadequate, and there is no still, small voice about the outcomes of poor management of municipal solid waste.

It is seen that there is a need for finding suitable alternatives to manage the solid waste in developing countries. Consequently, in this document, the bioreactor landfill with a bio-drying as a pretreatment technology is presented as a possible technology to handle the municipal solid waste if factors such as the cost, the composition, the flexibility on the size and technology and the ease of conducting the process are taken into account.

An overview of the problem, definition, and analysis of the context are developed in the first chapter. In the Second chapter, some summaries and analysis of the solid waste management situation in Kenya and Ngong city were carried out. The idea was to understand how the case is there, what they have done and the problems they are facing for no proper management of the waste; on this analysis, it was found that there was a lack of a specific guideline and adequate management solutions. Then, the presentation of possible technologies to deal with the raised problems with their most significant variables, advantages, and disadvantages are included in the third chapter.

Therefore, the design and operational guideline were designed based on the literature review and the analysis of the waste management situation. This operational guideline's central core is the planning system; the planning system attempts to cover all the facets that are present during the planning and design process of a new treatment facility.

Objectives and methodology

General objective

The general objective of this thesis is to develop an operational model for treatment plant by using the bio-drying and bioreactor landfill technologies in a developing country taking into account all the aspects and dimensions that should be considered when planning a treatment plant with the same features.

Methodology

In order to develop an operational guideline, the methodology reported in Figure 1 has been followed.

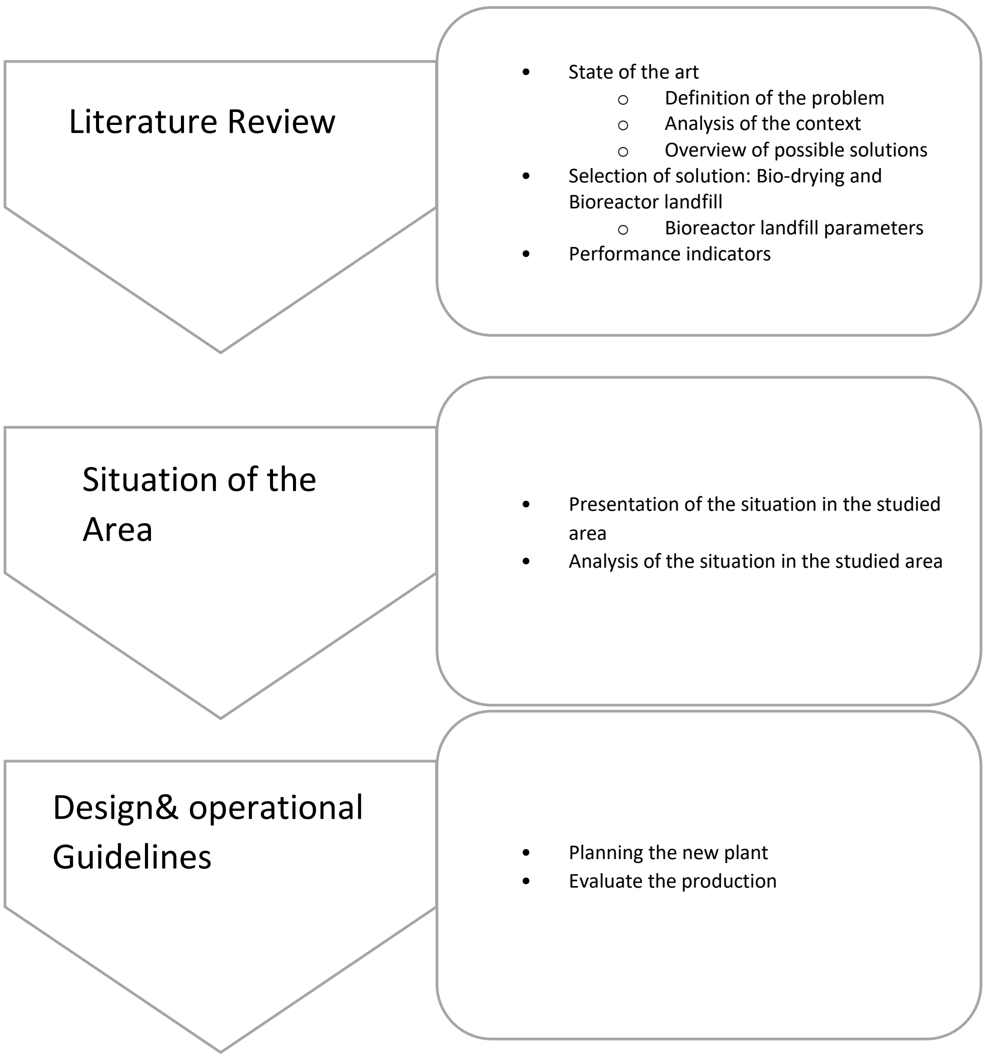

FIGURE 1 METHODOLOGY

1. The literature review: At first the typical scenario of the municipal solid waste was studied with a specific focus on developing countries, then the study and comparison of the treatments as possible alternatives permitted to verify the suitability of the proposed technology for the particular context of the developing nations. After it was discovered that bio-drying with a bioreactor landfill might be a plausible option, more inside and out research about bioreactor landfill was done, attempting to recognize the essential parameters and factors. Finally, when it was identified that there was a lack of evaluating the system for solid waste management, an investigation was performed to know and define some indicators that could be used or were being used for other purposes or technologies and that could be adapted to the proposed system. The whole process of the literature review was done through the investigation and research of several indexed papers and books.

2. Situation of the area: the study of the case of the area was done through the analysis of the solid waste management situation in developing countries, the main idea was to analyze them and understand the strength and weakness points for the technologies that are already used in developing countries, which would be used as reference for the design of the guideline model.

3. Design & Operational guideline: The design and operational guidance were designed based on the literature review and the situation of the solid waste management in the studied area; with the conclusions of both of them it was possible to identify the two central cores of the framework and its following aspects.

Municipal Solid Waste Management

Insufficient solid waste management (SWM) in urban settlements of low - and middle-income countries is an extreme environmental and health issue. Fast urban populace development and the consistent increment in waste generation escalates the test. Regularly over 50 % of the waste delivered is organic and biodegradable (Yvonne Vögeli, 2014). Subsequently, appropriate treatment alternatives for the organic fraction could help lighten the waste issue. In the meantime, the overall drive to discover spotless, sustainable power sources remains a fundamental need. At a national level, countries are keen to cut their reliance on fossil fuels due to concerns over the security of supply and to provide alternatives to wood fuel, the primary energy source for cooking and warming which is causing extreme deforestation. At the city level, residents, commerce, and industries want to reduce their dependency on unpredictable price fluctuations of fuels. Finally, from the waste management and environmental impact perspective, national and local governments are focused on the issue of global warming, trying to avoid the release of methane from landfills into the atmosphere.

State of the art

According to the first EU Framework Directive on Waste (75/442/EC), as cited by (Vasiljevic-Shikaleska A., 2014) waste is "any substance or object or, more generally, any movable good that the holder has discarded, intends to discard or must discard" because of, for example, its hazardous properties. Furthermore, waste is an inevitable result of every human activity that will continue until a conscious effort is made. In this sense, waste has always been a part of human history, especially given the fact that it cannot be destroyed but only transformed from one form to another (Rushbrook, 2014). It is important because society's proximity to waste dumping areas and sites has always had a negative impact on human well-being, a fact that had been ignored for many years because of the multiplicity of other factors that have had a more direct and influencing adverse effect on the life expectancy of the population. In this way, waste only became a cause for concern when communities started to develop into towns, and the population density increased, leading to the accumulation of waste in proximity to the people. It, in turn, led to the first efforts on human health protection, initiatives that were mainly focused on sewage and water treatment as the most explicit link between waste and health.

Concerning solid waste management though, the turning point only came by the end of the 19th century as public health laws were passed, and a more organized collection of wastes was instated (Rushbrook, 2014), and the treatment became systematic. Nevertheless, although this can be considered the turning point in refuse treatment, specific research on waste management only came years later.

The first thirty years of research on waste can be divided in three separate decades starting in 1970 with the Age of Enlightenment when a clear data collection plan over dumping sites was organized to understand the situation at the time. Based on this age, the second decade, the Age of Understanding, was characterized by the constant discovering of the processes of decomposition, contamination control and the involvement of technology in waste-specific operations. In turn, this knowledge gave way to the Age of Regulation in the 1990's when new rules and laws were passed to protect both the environment and the general population (Rushbrook, 2014).

Within these years of research several waste categories were established (i.e., municipal, industrial, hazardous, agricultural waste) with their specific characteristic and treatment methods. This paper, however, will focus only on Municipal Solid Waste (MSW), which is "generated by households, commercial activities and other sources whose activities are similar to those of households and commercial enterprises" as it represents the refuse generated in daily human activities.

Furthermore, it is worth noting that within the scope of this municipal solid waste there are also differences between urban and rural waste as the former is produced in greater quantity than the latter due to the higher population density in cities and the higher level of consumption. In this way, the wastes themselves also vary as rural waste is mainly composed of organic material, while urban waste has higher percentages of other materials such as plastic or metal. It is also because of the population density that urban areas count on a more established and well-run sanitation system than rural areas as the proximity of people to waste (especially non-organic) is considered a more significant hazard than on a low population density area.

The relation between public health and improper storage, collection, and disposal of solid wastes are quite clear. General wellbeing specialists have demonstrated that rats, flies, and other ailment vectors breed in open dumps, and besides in ineffectively built or inadequately looked after lodging, in nourishment storerooms, and in numerous different spots where sustenance and harborage are accessible for rats and the creepy crawlies related with them.

Biological marvels, for example, water and air contamination have additionally been credited to the ill-advised management of solid wastes. For example, liquids from dumps and ineffectively designed landfills have polluted surface waters because they contain harmful components, for example, copper, arsenic, uranium, or it might debase water supplies with undesirable salts of calcium and magnesium. Although nature can dilute, disperse, degrade, absorb, or otherwise reduce the impact of unwanted residues in the atmosphere, in the waterways, and on the land, ecological imbalances have occurred where the natural assimilative capacity has been exceeded. Solid waste management might be characterized as the teach related with the control of generation, stockpiling, gathering, exchange and transport, handling, and transfer of solid waste in a way that is as per the best standards of general health, financial aspects, building, protections, and that is likewise receptive to open states of mind. The nature and activity of solid waste management change fundamentally from country to country. Distinctions such as these are not limited to the national scale however and can be seen at the city and neighborhood level. Regardless of size, these differences are to some extent attributable to prevailing socio-economic, financial, legal and political variables at that level. There is a manifest necessity to accommodate the requirement for more viable waste management with the imperatives that are looked by neighborhood districts or national governments.

The international aid and development community increasingly recognize the identification of waste management as integral to sustainable urban development. The United Nations Conference on Environment and Development (2005) stressed that '...solid waste production should be minimized, reuse and recycling, maximized, environmentally sound waste disposal and treatment promoted, and waste service coverage extended'. The United Nations Centre

Human Settlements Programme (UNCHS Habitat, 2005) stresses naturally stable and asset productive ways to deal with the issue of developing solid waste amounts and thinks about waste administration as a vital part of human approaches and projects. What these cases delineate is the rising significance that solid waste management has among promoters of sustainable advancement.

Solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the solution to all problems of solid wastes. The answers may affect complex interdisciplinary relationships among such fields as political science, city, and regional planning, geography, economics, public health sociology, demography, communications, and conservation, as well as engineering and material science. Numerous individuals feel that strong waste management is a straightforward issue - only placing waste into a vehicle and emptying it at a dump. If this was valid, at that point for what reason do as numerous such towns experience the ill effects of uncollected decline blocking boulevards and channels, harboring flies and rats, and corrupting urban conditions? Without thought, exertion and much gaining from botches, it is uncommon to accomplish effective solid waste management. The planning and management of a decent solid waste management framework require contributions from a scope of orders and careful thought of nearby conditions.

Waste Hierarchy

In order to continue with the progress towards an improved waste management system in the world, a waste hierarchy, first introduced by the EU in the Waste Framework Directive (75/442/EEC) has been created to protect the environment and protect natural resources. Although different countries have differences in the specifics of their waste hierarchy, the basic idea is maintained: the approach seeks to reduce the quantity of refuse generated throughout all of its lifecycles, starting with the extraction and use of natural resources, the production process, and ending in the recycling or final disposition stage (US EPA, 2013). It sets the fundamental definitions regarding waste management such as clarifying the ideas of waste, recycling, and recovering; it requires to refuse to be handled in a way that protects human health and the environment (European Commision, 2016).

FIGURE 2, WASTE HIERARCHY (EUROPEAN COMMISION, 2016)

Prevention

Prevention and minimization of waste generation are first and preferred in the waste hierarchy context as it aims towards the reduction of waste generation itself and. Therefore, the avoidance of all of the subsequent steps (Vasiljevic-Shikaleska A., 2014); prevention of waste generates a general consciousness towards sustainability and creates a suitable global scenario to stimulate SWM evolution towards improved operations as it seeks the minimization of quantities and the optimization of quality.

Re-use

Re-use refers to the process of utilization of a product without reprocessing or modification, either for its original purpose or a different one. By doing so, the raw material and energy consumed in the product's production or its reprocessing are conserved (Vasiljevic-Shikaleska A., 2014).

Recycling

The process of recycling is a useful tool to manage waste once it has been generated and cannot be used any longer in its production form. The primary process consists of collecting, processing, and remanufacturing the refuse that is destined towards final disposal. In this way, recycling becomes highly valuable as it reduces the use of raw material and landfill use, conserving natural resources, preventing the emission of greenhouse gases and water pollutants, and stimulating the development of greener technologies (US EPA, 2013).

Other Recovery

After having undertaken all of the previous steps, when waste cannot be reused or recycled anymore because of technical, environmental, or economic factors, it is desirable and promoted to recover any possible value left in the object before moving to the disposal process. This idea has resulted in financial investment in waste management technologies for extracting energy from waste which will be discussed in more details in the following chapters. (UNEP, 2013)

Treatment and Disposal

Disposal represents the least preferred option in the waste hierarchy as it represents the end of the refuse's value lifecycle and the necessity for final disposition. There are several disposal methods and treatments with different health and environmental impacts, like waste-to-energy incineration or sanitary landfills or bioreactor landfills, which depend strictly on the country's or cities' financial and technological capabilities and their ability to maintain them.

Goals and policies

The primary objective of the municipal SWM refers to the protection of the health of the population. Taking into account that poor management of solid waste might cause some diseases, the United Nations Environment Programme (UNEP) refers to this issue:

"The organic fraction of MSW is an important component, not only because it constitutes a sizable fraction of the solid waste stream in a developing country but also because of Its potentially adverse impact upon public health and environmental quality… Unless an Organic waste is appropriately managed, its adverse impact will continue until it has fully decomposed or otherwise stabilized" (UNEP, 2013).

Regarding the environment, “Uncontrolled or poorly managed intermediate decomposition products can contaminate air, water, and soil resources” (UNEP, 2013).

Concerning the SWM impacts on the environment, UNEP declares:

"In an attempt to accelerate the pace of its industrial development, an economically developing nation may fail to pay adequate attention to solid waste management. Such a failure incurs a severe penalty at a later time in the form of resources needlessly lost and a tremendous adverse impact on the environment and public health and safety. In summary, the effort to preserve or enhance environmental quality should at least be commensurate with that afforded to the attainment of advance in development” (UNEP, 2013)

According to this, one of the goals of the municipal solid waste management should be to improve and preserve the conditions of the environment. In general, the solid waste management systems not only aims to provide a good service to the people, reducing the risk of diseases and to improve or preserve the natural environment in the long term "due to the implementation of modern solid waste management practices, both the public health and the quality of the environment are benefited directly and substantially," (UNEP, 2013) but also aims to develop a sustainable process and to provide support to economic productivity. It is important to remember that a sustainable municipal solid waste management should also "reduce Greenhouse Gas (GHG) emissions and improve the quality of life, promote public health, prevent water and soil contamination, conserve natural resources and provide renewable energy benefits” (Cherubini, 2009). Knowing that this is a difficult task for developing countries due to the lack of resources and priorities, an effort should be made to be as near as possible of achieving the ultimate goal.

SWM in developing countries

One of the main difficulties of SWM in developing countries in the past, as mentioned by Agunwamba in 1998 , is the lack of adequate policies or legislation, which enables the promotion of proper management (Agunwamba, 1998). Even though in many countries the laws governing municipal solid waste disposal, revenue collection, and project implementation and management exist, they are not sufficiently enforced (Boadi, 2003).

Besides, there is an absence of proper environmental pollution control and monitoring. In most of developing countries, corruption is an important issue to take into account when addressing a project. Besides using an inefficient centralized solid waste management approach, local authorities in Kenya maintain an inflated workforce, perpetuating redundant jobs for political reasons. In general, the political interest and the profits often take priority over the environment (Agunwamba, 1998).

Another problem related with SWM is that in most of the low and middle-income countries there is no policy about the reuse or recycling of materials. Additionally, there are no significant incentives to encourage the people and the enterprises to reuse materials, such as the ones that exist in high-income countries. In Nigeria, for example, there are no recycling programs in all the cities, and if there are, they are not comprehensible for the public, making it every day for the municipal solid waste to be mixed with heavy metal and hazardous wastes (Agunwamba, 1998) mainly due to the weak economic growth and the mismanagement of resources. As a result, it is challenging to acquire facilities for the sector (Boadi, 2003) or to expand and improve the municipal solid waste handling and building capacity. Additionally, the low-income levels of these populations are not enough to sustain successful programs since. Usually, the users do not have the economic capacity to pay for these kinds of services.

Inappropriate technology is also a problem when SWM is in low and middle-income countries. Generally, the facilities and the equipment do not meet the specific requirements of the country since they are designed or developed outside the country and then imported (Agunwamba, 1998). The main issue is related to vehicles and their inadequacy, as there are poor settlements or neighborhoods where the vehicles cannot physically gain entry access (Boadi, 2003). Moreover, many containers are not adequate regarding volume, quantity, and placement. For example, in Ghana, the compaction process is not appropriate since waste is mainly composed of organic materials and this process squeezes the leachate out of the waste, generating possible health threats (Boadi, 2003).

On another hand, in Kenya, the roads' conditions are not weatherproof, making it impossible for the vehicles to circulate during the rainy season, resulting in uncollected refuse. It is common that the operation is canceled or delayed (Agunwamba, 1998). For instance, in Palestine, significant amounts of waste are accumulated between collection periods, generating problems with animals and increasing the risk of diseases for the population (Agunwamba, 1998). In Ghana, the situation is almost the same with the disadvantage that in low-income areas waste is mixed with human waste because of the inadequate sanitation facilities (Boadi, 2003), increasing the risk for its habitats. In Kenya, the operation has failed since the capacity to collect and safely dispose of the municipal solid waste has not increased at the same rate of the municipal solid waste generation, causing a delay in the discharge of services.

According to specific case studies and investigations such as the one carried out in Nigeria by (Agunwamba, 1998), the attitude of the workers towards SWM in low and middle-income countries is not appropriate. This is a consequence of several factors such as the poor remuneration, which might affect the low morale of the workers and lead to low efficiency (Agunwamba, 1998) or the lack of competent, adequately trained personnel, with technical background and with suitable carriers (Boadi, 2003); local authorities in Kenya, especially in Mombasa, Nairobi and Kisumu, hire overstaffed poorly trained workers. Besides, people working on SWM present a higher incidence of sick days, work-related accidents, and mortality than the average workers in most of the countries (Boadi, 2003).

Usually, the general public sees these kinds of jobs as low-rank or menial, contributing to the idea that it is not an essential contribution to the development of a society. Moreover, society's attitude does not correspond with the importance of SWM. in many situations; the public does not cooperate with the waste workers, making them work harder and decreasing the efficiency of the process. The population is not concerned about its waste (Agunwamba, 1998) and usually forget about it after itis no longer visible, ignoring that after the collection there is a critical process to be done, not only to maintain the population away from risk, but also to diminish the impacts on the environment. Another problem that governments must face is the adherence of the people to customs that do not comfortably fit into the modern world the knowledge and technology that are available now. Usually, the countries do not have effective participatory programs, and people are not involved in the SWM process.

Regarding the planning process of SWM. The difficulty comes when it is time to find data about generation and disposal. As most of the cities do not keep records about solid waste, leading to poor designs: because the knowledge about the composition, characteristics, generation and actual disposal of the municipal solid waste is reduced (Boadi, 2003). It is harder for the experts to design and adequately forecast future behavior. Because governments are not aware of the importance of this information, there are few efforts to document SWM data. It is then important to note that, consequently, the data presented itself must be interpreted as indicative. Due to this lack of planning, the location of dumping sites is decided because of convenience or through random solutions, and not as a part of a long-term planning process. Many sites are located according to access to the collection vehicles, disregarding public health or environmental considerations. This kind of choice might generate the contamination of water bodies, underground aquifers, or consumption of water if the location is in a flooding area. (Boadi, 2003)

As an example, the location of the dumpsites in Kenya did not take into account environmental impacts, prioritizing convenience, and nowadays none of the dumpsites meet the requirements to protect the water bodies and underground aquifers from the pollution by leachate.

The lack of planning is also seen in uncontrolled urbanization, as many developing countries see how their cities grow unrestrained as people from the rural areas migrate to the city searching for opportunities or are forced to leave their land because of conflict or threat. This migration has resulted in unplanned settlements with high population density, absence to excellent infrastructure (sanitary services, water access, etc.), and inaccessibility to social services and amenities. In Accra's metropolitan area (Ghana), for example, waste collection vehicles cannot access some areas because the streets are too narrow and not correctly laid down, resulting in additional costs. Uncontrolled waste is one of the problems related to municipal solid waste management in developing countries. Although this activity starts from the people's need for monetary income and the lack of opportunities to get formal employment, it generates high risk due to the high probability of making contact with hazardous materials or healthcare waste while working with refuse that is not separated. When the scavenging activity is undertaken without the proper instruments and an adequate place, the scavengers might get injured or acquire infections through contact with contaminated wastes. In Nigeria, not only uncontrolled scavengers but also children and animals can be seen within the borders of the waste disposal sites and, as in Ghana, the informal sector such as waste recyclers, waste pickers, waste carriers, and scavengers have not been recognized as relevant parties or integrated into the SWM system (Boadi, 2003).

Presentation of the case study

The contextual investigation will manage SWM in Ngong, a residential area in Kajiado District. It is situated in the southwest of Nairobi, in southern Kenya. The number of inhabitants in Ngong is 157,188 territories. Ngong was the central town of Ngong division while Kajiado Area was a district.

Design of a Municipal Waste Recycle and Treatment plant in Ngong, Kenya

The Ngong dumpsite receives a daily average of 50 tons of waste from Nairobi and the local communities (UN-Habitat, 2017).

There is no appropriate solid waste management set up with the waste dumped without handling or treatment which presents serious health and natural dangers. The environment around the dumpsite is vigorously dirtied. This contamination incorporates surface and groundwater, air, soil and products contamination and visual scourge.

Ngong residents in the proximity of the dumpsite have complained of respiratory illnesses and skin infections. It has provoked the Kajiado County government to recognize appropriate waste management and disposal as one of their advancement needs. The Kenyan government moved toward the Italian Government to give a definite answer to the long-lasting solution of solid waste management and to make a pilot venture that could be reproduced in different towns in Kenya. The Italian Government is thinking about giving a delicate advance to the Kenyan government for the outline and development of a modern municipal waste recycle and treatment plant, because of sound practicality examine including the social and environmental impact assessment.

The county government of Kajiado has allocated the land for the construction of a new waste recovery plant away from the current dump site.

Waste Management situation in Kenya

Kenya aims to balance the broader economic and social challenges of development and environmental protection. For this reason, the country subscribes to the vision of a prosperous and equitable society living in harmony with our natural resources. It is also reinforced in the constitution under the fundamental right to a clean and healthy environment. Sound environmental management involves the utilization of waste decrease advancements in production, practical item plan, asset proficiency and waste prevention, re-using items where conceivable; recovering an incentive from items. Even though the end of waste entirely may not be attainable, deliberate use of modern waste management frameworks ought to be investigated and actualized.

The challenge of waste management influences each and foundation in the public eye. The allots set in this methodology cannot be attempted without an aggregate way to deal with waste challenges and the inclusion of a broad scope of partners in their usage. This National Solid Waste Management Procedure (NSWMS) looks to set up a typical stage for activity between partners to deliberately enhance waste management in Kenya. It is for this reason that the National Environment Management Authority (NEMA) with other stakeholders assessed waste management practices in five municipalities namely; Kisumu, Eldoret, Thika, Mombasa and Nakuru to form a basis on which this strategy was developed. The policy lays the framework for improved waste management in the country.

The essential controlling guideline on the National Waste Management Strategy is ZERO WASTE Standard whereby waste is an asset that can be tackled to make riches, work and decrease contamination of environment (NEMA, 2015). Because of the poor situation in regard to the current waste management facilities inside the 47 Counties, NEMA created least necessity focuses for administration of the present waste management facilities to continually advance consistency with the waste management regulations inside the counties. This activity will lead the nation to the favored state has moved from the present circumstance which is needing. These minimum requirement points are on waste collection, transportation, disposal and licensing were developed through a participatory process by five counties being Mombasa, Kisumu, Eldoret, Nakuru and Thika to help County Governments move towards full compliance of embracing sanitary landfills and other environmentally friendly waste management practices.

Solid waste management remains a significant challenge in all the 47 counties in the country. Over the years most local authorities did not prioritize the establishment of proper waste management systems, and hence the County governments have inherited this state of affairs. It has led to the current poor waste management situation across the country. Although Vision 2030 has prioritized on the five cities and towns for implementation of sustainable solid waste management systems, this Strategy shall be applied countrywide to address poor solid waste management, NEMA developed some minimum requirements as a baseline for implementation by the Counties. These included designations, securing and manning of the disposal sites, promotion of efficient collection and transportation of waste. The requirements were expected to ensure the continuous development of efficient solid waste management. This Strategy will, therefore, build on these on-going waste management efforts towards the attainment of full compliance and ensure a clean and healthy environment. It is proposed that this Strategy will cover fifteen years within the Vision 2030 framework and be reviewed every five years under the medium-term plans. With the full implementation of the Strategy, it is expected that the Country will have embraced environmentally sound waste management technologies and best practices.

Kenya has a growing human population and an increase in urbanization. The urban centers have attracted a large community of informal settlements dwellers and the middle class. This urbanization and increased affluence have led to increased waste generation and complexity of the waste streams. This trend is compounded by the growing industrialization of the Kenyan economy. Notwithstanding the presence of laws and arrangements controlling waste management, feeble usage and poor practices have prompted towns and urban areas being overpowered by their waste, thus influencing general health and the environment. Over the years waste management has been the mandate of the local Authorities. However, most local authorities did not prioritize the establishment of proper waste management systems and hence allocated little resources for its management. Further, the boards needed specialized and institutional abilities to oversee waste. It has prompted the present poor condition of waste management which incorporates unpredictable dumping, uncollected waste and absence of waste isolation the nation over.

Most towns and urban areas have wasteful waste collection and disposal systems. For example, an investigation improved the situation Nairobi demonstrates that around 30-40% of the waste created isn't gathered and under half of the populace is served ((JICA), 2010). In Nakuru, it's estimated that 45% of the waste generated is collected and disposed at Giotto Dumpsite, 18% is recovered, and the rest accumulates in the environmental.

Name of town	Estimated Waste generated (tons/day)	% Waste collected	% waste Recovery	Uncollected waste
Nairobi	2400	80%	45%	20%
Nakuru	250	45 %	18%	37%
Kisumu	400	20%	Unknown	Unknown
Thika	140	60%	30%	40%
Mombasa	2200	65%	40%	35%
Eldoret	600	55%	15%	45%

TABLE 1 SUMMARY OF WASTES GENERATION, COLLECTION AND RECOVERY STATUS IN MAJOR TOWNS **(NEMA, 2015)**

Waste transportation is rudimentary mainly using open trucks, hand carts, donkey carts among others. These poor transportation modes have led to littering, making waste an eye-sore, particularly plastics in the environment. However, some counties have adopted appropriate transportation trucks as stipulated by the Waste Management Regulations. Besides, County Governments have privatized waste transportation through Private Public Partnership arrangements. Disposal of waste in the country remains a significant challenge as most of the counties lack proper and adequate disposal sites. The few towns that have designated sites practice open dumping of mixed waste as they require appropriate technologies and disposal facilities. To address this situation, NEMA directed all county governments to identify areas of waste disposal and undertake necessary actions to manage the sites including fencing, manning and weighing of the waste.

There are various waste streams generated in Kenya, that can be categorized as domestic, municipal, industrial and hazardous wastes. Other emerging waste streams, such as e-waste, waste tires are as a result of growing industrialization and growth of ICT. The composition of general waste varies considerably between households, businesses, and industries. (NEMA, 2015)

The classification of the waste according to the Kenyan publication is:

1- Domestic waste:

Domestic waste is also referred to as garbage, refuse or trash. It consists mainly of biodegradable waste which is food and kitchen waste, green waste paper and nonbiodegradable such as plastics, glass bottles, cans, metals and wrapping materials. The composition of the domestic waste streams is a function of income, consumption patterns and recycling opportunities. Nationally domestic waste is not adequately managed and is disposed of at disposal sites with minimal sorting/segregation.

2- Waste Tires:

Waste tires are an emerging waste stream that has reached their end of life due to wear or damage and cannot be recycled or reused. There are no established formal systems for collection and recycling of tires except for retreading. The bulk of the tires are informally collected and often illegally burnt in the open to recover steel for recycling. It emits harmful gases causing air pollution and soil contamination arising from the residues. Currently, only two facilities in the country are using waste tires as fuel and for producing industrial diesel oil (IDO). To address the management of waste tires, NEMA has developed relevant regulations which are awaiting gazettement.

3- Construction and demolition waste:

The construction and demolition waste is generated as a result of new construction works, remodeling or demolition. Construction waste comprises debris, steel, timber, iron sheets, tiles and ceramics among others. Although construction and demolition waste is not classified as hazardous, it is a mixed waste source that requires separation into parts for recycling. These wastes currently end up in the disposal sites or are used for backfilling in road networks. Asbestos Waste Demolition wastes may include asbestos which is hazardous and can present a significant health risk when improperly disposed or reused. NEMA has developed guidelines on safe management and disposal of Asbestos.

4- Industrial waste:

Industrial waste is the waste created by mechanical action which incorporates any material that is rendered futile amid an assembling procedure. Industries produce both hazardous and nonhazardous waste. These wastes include chemical solvents, paints, sandpaper, paper products, industrial by-products, metals, municipal solid waste and radioactive waste. Currently, most of the hazardous industrial waste is not pretreated before reuse, recycling or disposal. It poses health risks to the handlers and causing damage to the environment. Disposal of hazardous industrial waste illegally occurs at the municipal dumpsites. However, some industries have embraced best practices in disposing of industrial waste by seeking guidance from NEMA on appropriate disposal methods.

5- Biomedical Waste

Biomedical waste also referred to as medical waste refers to waste generated in health facilities, research institutions or during immunization of human beings and animals. It is classified as; Infectious waste, sharps, pharmaceutical wastes, chemical waste and pathological waste. Biomedical wastes pose risks to human health due to its pathogenic characteristics and hence require prior treatment before disposal. Currently, segregation is fully embraced in most hospitals and clinics based on the guidelines issued by the Ministry of Health. Although the biomedical waste is expected to be disposed of through incineration, some find its way to the municipal dumpsites while some are handled through necessary facilities such as kilns. While big hospitals have embraced proper biomedical waste management, the primary challenge remains the small clinics which practice illegal disposal of these wastes. So far, NEMA has licensed 15 incinerators countrywide both in government institutions and private which have complied with the provisions of the Third Schedule of the Waste Management Regulations of 2006. Although the licensed incinerators are few, they are not operating at optimal capacity, and hence other medical facilities are encouraged to share.

6- E-waste:

E-waste is an emerging waste stream arising from Electrical and Electronic Equipment (EEEs) becoming obsolete at the end of life. Kenya has experienced a rapid increase in e-waste due to the adoption of Information and Communication Technology (ICT) across all sectors and an influx of low-quality EEEs. E-waste comprises heavy metal components and materials used in the manufacture of electronic goods. Some of these include mercury, brominated flame retardants, and cadmium which are considered hazardous if not well handled during dismantling or recycling can become harmful to human health and the environment. As a country, limited infrastructure has been put in place to deal with e-waste. NEMA has developed E-waste Regulations which will assist the nation in regulating e-waste by registering producers, licensing of recyclers and preventing entry of sub-standard EEEs. Also, the Regulation has extended responsibility to producers to bear the cost of recycling of the products commonly known as extended producer responsibility. Currently, there are two licensed facilities in the Country which are undertaking e-waste management.

Batteries: Batteries can either be alkaline (dry cells) or acid based which support domestic and industrial applications. The acid found (rechargeable and silver oxide) batteries contain heavy metals such as mercury and cadmium which are classified as hazardous substances. This hazardous material if not properly handled and disposed of presents is a risk on the human health and the environment. Currently, there are no recycling or disposal facilities for alkaline, rechargeable and silver oxide batteries. The batteries are disposed in the open dumpsites alongside domestic waste. On the other hand, lead-acid batteries which are also considered hazardous waste are recyclable, and by February 2015 NEMA had licensed two facilities for their recycling.

7- Fluorescent Lamps:

Fluorescent lamps are used for illumination and contain a small amount of mercury. The mercury is a neurotoxin and can be harmful even in small quantities. Fluorescent lamps can be successfully recycled, and the mercury recovered. However, if poorly handled at any stage this releases the mercury which is hazardous. Increasingly people are adopting florescent lamps as energy saving devices across the country which is likely to compound the challenge of their disposal. So far NEMA has licensed one facility for recycling fluorescent lamps.

8- Pesticide Waste:

Pesticides are chemicals used to control pests. Pesticide waste consists of expired and contaminated pesticides as well as the used containers. Because of their harmfulness, potential to contaminate and danger to human wellbeing, pesticide waste is to a great degree dangerous and must be transported, treated and discarded appropriately. These pesticides can contain persistent organic pollutants (POPs), which can gather in the evolved way of life if not all around oversaw. Larger scale generators of pesticides waste incinerate or export the waste to developed countries for treatment or disposal. However small-scale generators dispose of in their farms.

9- Used Oil and Sludge:

Used Oil and Sludge arises from the use of petroleum products. It contains potentially hazardous compounds such as poly-aromatic hydrocarbons that have carcinogenic and mutagenic properties. Used oil and sludge have a slow rate of decomposition, and hence any spillage can accumulate in the environment causing soil and water pollution. This waste is currently recycled to produce lubricants and industrial oil used in furnaces and boilers. Though illegal, used oil is also applied mainly in the treatment of timber and dust suppression. NEMA has developed guidelines for the management of used oil and sludge and has licensed a few used oil and sludge handlers.

10- Sewage Sludge:

Sewage sludge is a sedimented material that accumulates over time in the sewage treatment plants and ponds. The across the board transfer of mechanical gushing by means of sewage treatment works results in tainting of sewage slop with perilous synthetic concoctions, along these lines presenting specific difficulties for its demolition. Sewage ooze that is sullied by substantial metals from mechanical profluent can extremely debase rural land to which it is connected. However, a high proportion of the contaminated sewage sludge continues to be disposed of in dumpsites. In this regard, there is a need to pre-treat contaminated sewage sludge before disposal. Uncontaminated sewage sludge has a variety of commercial uses and can be recycled.

Waste Management challenges in Kenya

Waste management in Kenya has remained a significant challenge due to diverse factors. This range from problems associated with waste management systems, limited knowledge, attitude and practices, political will, technical and financial resources.

Kenya is a developing lower middle-income country, with a rising urban population, an improving economic situation and changing lifestyles. Hence, it faces the same MSW challenge as other lower-middle-income countries.

The increase in Kenya's urban population has reduced the capability of the county governments to manage the solid waste generated, with less than 40 percent being collected and disposed of at designated open dumpsites. The challenges that this waste poses to county governments and communities are varied. Much of the waste is poorly managed: waste is not collected, disposal sites are inadequate, or waste is contaminated with hazardous materials. It has significant impacts on human health, especially for those living near disposal sites. Such impacts range from clogged drainage and sewers, waterborne diseases like typhoid, cholera, and diarrhea, increased upper respiratory disorders from open burning of the garbage to malaria. The wasteful utilization of rare assets reflected in materials disposed of and relinquished as waste speaks to a free monetary and ecological cost borne by society in general. Despite efforts to encourage reuse and recycling, the amount of solid waste dumped remains high and is increasing.

The NAMA targets this missed opportunity by promoting an alternative to the existing waste value chain. Instead of waste being collected for disposal only, the NAMA facilitates the diversion of at least 90 percent of collected waste away from disposal sites and towards various recycling practices. The NAMA creates multiple links currently missing in the value chain: recycling points, where waste will be sorted for subsequent recycling; and composting facilities, for the organic waste treatment. The NAMA will also research and operationalize new recycling technologies as well as strengthen existing recycling industries. The NAMA is fully aligned with the policy goals of the Kenyan government (Kenya Vision 2030, National Climate Change Action

Plan (NCCAP), Environmental Management and Coordination Act (EMCA)), which promote the provision of sanitation services and recycling.

Under the NAMA, up to 600 tons of waste will be recycled every day, (which accounts for 25 percent of Nairobi's total waste). It will save more than 800,000 tons in CO2e emissions (over the 15 years' lifetime of the NAMA) and add 1,600 jobs to the economy (environewsnigeria, 2016).

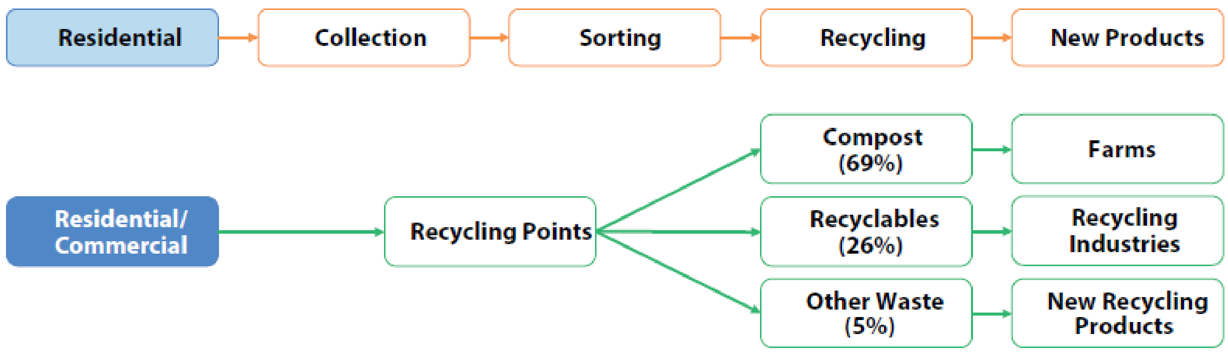

FIGURE 3 WASTE MODEL IN KENYA (NEMA, 2015)

Waste collection services will become affordable to more than half a million low-income residents, because waste collection companies will divert their waste from dumpsites to recycling points, thereby reducing their operating costs.

Kenya Vision 2030. Kenya's Vision 2030 is the national long-term development blueprint for Kenya that is implemented through a series of five-year development plans—the current being the Second Medium Term Plan (SMTP) 2013-2017. Vision 2030 intends to change Kenya into a recently industrializing "middle-income nation giving a high caliber of life to every one of its natives by 2030". Vision 2030 is a living document that was first published in 2007 and is currently updated periodically in a web-hosted version. (Government of Kenya (GoK),, 2013b)

Kenya's Vision 2030 is roused by the rule of practical advancement and by the requirement for value in access to the advantages of a perfect domain. So, the focus will be on four strategic initiatives:

Conservation: the country will intensify conservation of vital natural resources sustainably without compromising economic growth. Kenya intends to have achieved 10 percent forest cover by 2030. Besides, research activities into the viable usage of natural resources will be undertaken.

Pollution and waste management: Despite the high rates of development visualized in Vision 2030, Kenya will dynamically apply measures to make preparations for the unfriendly impacts of expanded contamination and waste.

ASALs and high-risk disaster zones: enhancing disaster preparedness in all disaster-prone areas and improving the capacity for adaptation to global climatic change.

Environmental planning and governance: building the institutional capacity in environmental planning and improving the impact of environmental governance to improve the overall management of the environment.

But instead of the vast effort that done by the NAMA, they are still facing many problems. These problems are summarized as follows:

Lack of awareness and knowledge: There are limited awareness and understanding of the importance of a clean and healthy environment. It has led to poor practices by the public towards waste management which has led to environmental pollution. As such there is poor handling of waste at the household level including lack of segregation, reuse, reduce and recycling. Also, negative attitude towards waste management and failure to take individual responsibility has contributed to poor practices such as littering, illegal dumping, and open burning.

Political influence and lack of good will: Political good is key to the ultimate success of proper waste management in the country. Unfortunately, the waste management agenda has not been prioritized, leading to poor investments and funding.

Disposal sites: Availability, siting, and management. The county governments are expected to designate waste disposal sites/facilities within their areas of jurisdiction. However, the availability of public land for a disposal site remains a challenge. In situations where the property is available, the neighboring communities are opposed to it being in their backyard. It is as a result of poor management of the existing sites. It has culminated in dumpsites being sited on environmentally sensitive areas such as river banks, forests, and wetlands.

Funding: Lack of prioritization for waste management in the counties has led to inadequate budgetary allocation. As a result, control of the entire waste management cycle (collection, transportation, and disposal) is hampered. Low funding has also affected investment in waste management facilities and equipment.

High poverty levels: High poverty level, especially in informal and low-income settlements, has compromised the ability to pay for waste management services. It has led to a lack of collection leading to illegal waste dumping in undesignated areas sites, streams, rivers, and highways. The situation is further compounded by lack of access and waste management infrastructure.

Lack of segregation: There is a lack of waste segregation at source leading to mixed wastes which are collectively disposed of in the dumpsites. Where sorting is done, the problem is compounded by the lack of compartmentalized vehicles for transportation of the sorted waste leading to the remixing. It hampers material recovery, reuse, and recycling. The sorting has mostly been relegated to the lowly in society such as the waste pickers and street urchins.

Limited technical competencies: Like a Country, Kenya is faced with limited technical skills in waste management. It has led to poor management of waste management facilities and equipment and their failure to attain optimal operating capacities.

Slow adoption of modern technological options: Although there are many waste management technologies in the country, there has been a low adoption of the same by the relevant practitioners. This as a result of diverse factors including inadequate financial resources to purchase the equipment, lack of incentives including tax waivers, resistance to change, lack awareness, unavailability of land and weak enforcement.

Waste Management situation in Ngong city

Ngong is a town close to the Ngong Slopes along the Great Rift Valley inside Kajiado County, situated in the southwest of Nairobi, in southern Kenya. The number of inhabitants in Ngong is 157,188. Ngong was the focal town of Ngong division while Kajiado Province was a locale. Following information, which is useful to a good understanding of the SWM situation in Ngong city, comes mainly from the investigation done by Politecnico di Milano in February 2018

(PoliMI-Ngong, 2018). Kajiado County Government represents the intermediate level of public institutions, consisting in a county executive and a county assembly. The CG is recently born, as defined in the new Constitution of Kenya (2010). Within the MSWM system, the CG is the authority responsible for its management through the Department of Water, Irrigation, Environment and Natural Resources. According to (PoliMI-Ngong, 2018), the CG has the following tasks:

- Interactions with PSPs and Nuru.
- Planning of the SWM.
- Street cleaning and collection from street containers for leasehold areas.
- Surveillance of the Ngong dumpsite and regulation of the access by trucks.

The collection of waste in Ngong is performed by Private Service Providers (PSPs) and the County. The CG is responsible for street cleaning and street collection, street containers are moved to the dumpsite through a skip loader and emptied there. PSPs performed a sort of door-to-door collection at the household level. The coverage of the collection is ensured apparently by the private land tenure system, whether leasehold or freehold. In freehold areas, the coverage is guaranteed by PSPs, while the County Government is charged with the collection of leasehold areas (and residents should pay a tariff) (PoliMI-Ngong, 2018).

Waste is finally disposed to the dumpsite of Ngong. The closure of this dump site and its substitution with a new facility is the purpose of this project, as the dumpsite is located next to the center of Ngong. The slum of Mathare is rising at the limit of the dumpsite.

Concerning the amount of waste, at the beginning of the study, no information was available about the volume of the dumpsite, which has been subsequently measured. The daily amount of waste entering the dumpsite was estimated between 120 t/d to 160 t/d depending on the interviewed subject (PoliMI-Ngong, 2018).

Many public and private organizations that are involved in the SWM in Ngong city, and each different organization has their activities in participating (PoliMI-Ngong, 2018):

Nuru Youth Group: Nuru Youth Group is the Community based organization (CBO) responsible for the management of Ngong dumpsite. The role of Nuru is unofficially recognized by the

County Government and PSPs (Private Service Provider). Nuru Youth Group started its activity in 2004 when some persons began to buy plastics from the dumpsite.

The principal roles within Nuru are the following (PoliMI-Ngong, 2018):

1. Selectors (pickers): most of the members are selectors, mainly specialized on different materials (e.g., polyethylene);
2. Traders: 3 buyers inside Nuru, two outsiders; the bargain is done by persons (buyers) and not by the office
3. Cleaners: no specialized people.
4. Breeders/farmers: Animals within the dumpsite (cows, pigs) are not owned by Nuru group but private, some of the workers built the stalls inside the dumpsite to breed their animals.
5. Non-members select organic or carry materials within nets to clean up.

Private Service Providers (PSPs) are organized in associations and should be considered an essential stakeholder as they provide the service of waste collection to most of the households in Ngong. They can also collect information on waste streams and contact a massive number of customers, having a pivotal role in participation and awareness activities.

<u>Em Bulbul associations:</u> Em Bulbul is a township of Ngong in which exists a network of associations involved in waste management and concerned with environmental protection. These associations seemed to play an essential role in transforming Em Bulbul from a slum to a township when the market of Em Bulbul itself was a dump site. Moreover, they represent a valuable stakeholder due to their direct involvement in the substantial waste collection and their strong concerns about the environment, public hygiene, cleanliness of the town.

<u>KEREA (Kerarapon Resident Association):</u> Kerarapon is a township of Ngong composed by 800 households and about 5000-6000 people. It is the association gathering residents of Kerarapon, and it is genuinely concerned about the establishment of the new facility.

Ngong Dumpsite, (started between 1990 and 1995) in Ngong has never been illegal, and the County Government owns the land. There is a school that was located there after the establishment of the dumpsite, and the slum has raised in the area destined to liquid waste treatment (lagoon), occupying it. NEMA has refused to license it because it does not encounter ten minimum requirements from the regulation, even if the County Government is operating the dumpsite in agreement with NEMA.

Nuru Youth Group is working inside the dumpsite, performing management of waste and recyclables separation. A division between shifts exists: men and women work at the dumpsite mainly on different days. PSPs used to separate recyclables before disposing waste at the dumpsite. Consequently, no valuable items entered the dumpsite. Without useful items, waste pickers (which collect recyclables but manage the waste as well) would not be attracted by the dumpsite. Concerning materials reaching the dumpsite, the stream is not constant. Part of the materials is selected before entering the dumpsite.

Some issues have been mentioned as:

- Access road: The access road is unpaved, and it is approximately long 300 m. Problems rise when it rains and become necessary to control the entrance to the landfill to avoid the bogging down of trucks.
- Water bodies: Oloolua river passes directly through the dumpsite. In proximity to the dumpsite, there was a spring, and it is not clear if it still exists. The sewage system in the upper part of the town has broken down, so it may influence the situation in the landfill.
- Dangerous areas: Several areas of the dumpsite have been identified as dangerous by local workers. In most cases, the maximum slope coincides with the presence of smoke, apparently due to self-combustion.
- Access: Kids accessing freely to the dumpsite are considered an issue.

Characterization of the MSW

It was possible to calculate the waste composition in Ngong town, by applying average values elaborated by JICA to the total amount of produced waste. Results are presented in the following table. The waste composition was calculated for each generation source (Residential areas, Commercial establishment, Public facilities, Markets, Roads). We will refer to average values, calculated on the total of waste produced in Nairobi City.

Amount of waste entering the dumpsite of Ngong

The daily generation of MSW for the city of Ngong has been estimated in 103.32 t/d (PoliMI-Ngong, 2018). Nonetheless, the waste is coming as well from other towns or neighbourhood of the city of Nairobi.

The data gathered so far indicates that the sources of solid waste in the Ngong's dumpsite are Nairobi areas (Langata) (21 %), Kiserian (7.5 %), Ngong (28 %), Rongai (43.5 %).

Moreover, it was also reported that the dumpsite receives occasionally waste from as far as the Wilson Airport. Based on the preliminary assessment on waste generation and composition, the overall waste stream to be managed at the new facility is estimated in the range 100 to 160 tons per day (peak days). It can be rephrased into a low quantity of 130 tons/day, leading to an annual amount from 50,000 to 60,000 tons of mixed waste. Most of this quantity (approximately 70%) is an organic waste. It should also be taken into account that the annual growth rate (AGR) of waste discharged in the dumpsite has been estimated at 6%, which comes as a product of 5.5% AGR of the population by 0.5% AGR of waste per capita. It means that if – even for only one year - waste is disposed of to the existing dumpsite, proper landfill restoration will be more expensive since an additional amount of waste will have to be transferred to the TWTF." (PoliMI-Ngong, 2018)

	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday
Lorries	121	132	109	80	18	76	59
Pick-Ups	10	15	12	3	3	3	12
Skip Loaders	18	18	0	0	0	18	6
Mini- Lorries	7	0	18	8	0	21	14
Tippers	0	0	0	24	0	24	0
Handcarts	1	1.5	1	1	1.5	1.5	3
total	157	166.5	140	116	22.5	143.5	94

Table 2 Amount of waste entering the dumpsite of Ngong (PoliMI-Ngong, 2018)

Residential waste generation rate		0.49	*(kg/d/per capita)*
Total population		151393	*(inhabitants)*
Total amount of produced waste		103.32	*(t/d)*
Waste Composition		Weighted Ratio (average values) (%)	Daily production (t/d)
Food Waste		68.99	71.28
Paper	*Recyclable Paper*	4.18	4.32
	Recyclable Cardboard	0.82	0.85
	Mixed Paper	1.12	1.16
	Diapers	3.31	3.42
	Subtotal-Paper	9.43	9.74
Plastics	*Plastic Sheet*	3.54	3.66
	Recyclable Plastics	3.32	3.43
	Plastics PET Bottles	1.86	1.92
	Other Plastics	0.7	0.72
	Subtotal-Plastics	9.42	9.73
Rubber & Leather		0.27	0.28
Textiles		0.72	0.74
Yard Waste		0.7	0.72
Lumber & Logs		0.36	0.37
Other Org. Waste		1.74	1.8
Glass	*Returnable Bottles*	1.22	1.26
	Other Live Bottles	0.53	0.55
	Glass bins	0	0
	Broken Glass	1.4	1.45
	Glass-Subtotal	3.15	3.25
Metals	*Tin Cans (steel cans)*	1.06	1.1
	Aluminum cans	0.85	0.88
	Metals Copper	0	0
	Other Metals	0.36	0.37
	Metals-Subtotal	2.28	2.36
Dirt, Ash, Stone, Sand		2.51	2.59
Unclassified Residual Waste		0.34	0.35

Domestic Hazardous Waste	0.09	0.09
Batteries - Dry Cells	0.03	0.03
Other Domestic Hazardous Waste	0.06	0.06
Total	100	103.32

TABLE 3 PHYSICAL PROPERTIES OF THE SOLID WASTE

Chemical Characteristics of the MSW

The chemical composition of solid waste is essential in evaluating the alternative processing and options such as incineration, composting and energy recovery. Typically, solid waste is a Combination of semi-moist, organic and inorganic materials. To assess the possible use of solid waste as fuel, the essential chemical properties to be calculated are moisture, ash and Volatile Solids. For the difficulties to have all the exact data for the studied case of the studies, Literature data has been taken as a first assumption in the following table.

	Moisture (%)	Ash (%)	Volatile solids (%)
Food Waste	70%	9%	21%
Paper	13.00%	6%	81%
Plastics	6%	9%	85%
Fines	30%	35%	35%
Glass	3%	95%	3%
Ferrous metals	5.00%	93%	3%
Non-ferrous metals	5.00%	93%	3%
Unclassified Residual Waste	30%	35%	35%
Domestic Hazardous Waste	30%	35%	35%
Batteries, Dry Cells	5%	93%	3%
Other Domestic Hazardous Waste	30%	35%	35%

TABLE 4 THREE-CONTENT ANALYSIS OF SOLID WASTE (GROSSO, 2017)

Technological options for MSW management

Throughout the years waste management has been the command of the nearby Experts. Be that as it may, most nearby experts did not organize the foundation of appropriate waste management frameworks and consequently dispensed little assets for its management.

The primary interest in the studied case of study regarding the kind of waste and the management and treatment options are mainly for the unseparated waste, organic waste, and recyclables waste.

- Unseparated waste: Some undeveloped towns and cities have inefficient waste collection and disposal systems. For instance, a study done for Kenya-Nairobi indicates that about 30-40% of the waste generated is not collected and less than 50% of the population is served (NEMA, 2015). In Nakuru, it's estimated that 45% of the waste generated is collected and disposed at Giotto Dumpsite, 18% is recovered and the rest accumulate in the environmental.

  Disposal of waste in the country remains a significant challenge as most of the counties lack proper and adequate disposal sites. The few towns that have designated sites practice open dumping of mixed waste as they lack appropriate technologies and disposal facilities. To address this situation NEMA directed all county governments to designate areas of waste disposal and undertake necessary actions to manage the sites including fencing, manning and weighing of the waste.
- Organic Waste: It is the waste that is subjected to decay with time and evolve highly offensive odor and gases which are highly detrimental to health. It breeds flies, mosquitos, etc. produces diseases like typhoid, diarrhea, etc. (Gagiya, 2016) In compliance with the existing data regarding the waste composition in Ngong; the organic waste mainly is food waste. The FAO report could perceive a reasonable example in food waste at the worldwide level. While middle and higher income locales demonstrated more noteworthy sustenance misfortune and waste amid the downstream stage or at the utilization level, developing nations will probably lose or food waste at the upstream stage because of the absence of legal collect systems and foundation. The following food is wasted along the chain; the higher is its environmental effect since then we likewise

need to think about the energy and natural resources exhausted in preparing, transporting, putting away and cooking it. If incorporated into a rundown of nations positioned by their greenhouse emissions, food waste would come in the third spot, directly after the USA and China (Dana, 2015). Food waste that ends up in landfills produces a significant amount of methane, a more powerful greenhouse gas than even CO_2. For the uninitiated, overabundance measures of ozone-harming substances, for example, methane, CO_2, and chlorofluorocarbons retain infrared radiation and warmth up the earth's atmosphere, causing global warming and climate change. With agriculture representing 70 percent of the water utilized all through the world, food waste likewise speaks to a remarkable misuse of freshwater and groundwater assets. It is said that a volume of water about three times the volume of Lake Geneva is utilized to deliver food that isn't eaten. By tossing out one kilogram of hamburger, it is squandering 50,000 liters of water that were used to provide that meat. Similarly, almost 1000 liters of water is wasted when pouring one glass of drain down the deplete. On the off chance that taking a gander at arriving utilization, around 1.4 billion hectares of land, which is about 33% the world's aggregate rural land zone, is utilized to develop food that is wasted. A great many gallons of oil are likewise wasted each year to deliver sustenance that isn't eaten. Moreover, this does not by any means consider the adverse effects on biodiversity because of exercises like monocropping and changing over wild terrains into agricultural regions.

- **Recyclable waste:** Recyclable materials fuse various sorts of glass, paper, and cardboard, metal, plastic, tires, materials, and equipment. The composting or other reuse of biodegradable waste, for example, food or garden waste is likewise viewed recycling. Materials as reused are either passed on to an aggregation center or got from the curbside, by then organized, cleaned, and reprocessed into new materials destined for collecting.

Waste Pre-treatment Technologies

Bio-drying

Bio-drying treatment (a short-time process of aerobic bioconversion) is applied to MSW as is, to MSW residual of selective collection, or to contaminated organic fractions (under-sieve from mechanical selection, etc.). The point is the abuse of the exothermic responses for the dissipation of the most noteworthy piece of the moistness in the loss with the least transformation of organic carbon.

Bio-drying is an aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. The significant difference of bio-drying from composting is that the principal objective is not to maximize the degradation process of organic material, but only to degrade the waste enough to generate biological heat to dry the waste (Veeken A., 2005).

The bio-drying process is distinct from composting in that the output of the composting process is stabilized organic matter, but the output of bio-drying is only partially stabilized. Also, the bio-drying process is of short duration one, and hence the emission factors are also short lasting. The process of bio-drying utilizes the auto-thermal heat generation due to microbial action on the waste material instead of thermal treatments in the conventional drying process. Hence this is an energy saving process when compared to drying since it effectively utilizes the biological heat energy.

The bio-drying process increases the energy content of solid waste by maximizing removal of moisture present in the waste matrix and preserving most of the gross calorific value of the organic chemical compounds through minimal biodegradation. The bio dried substrate is more suitable for mechanical processing since it reduces the adhesiveness of the substrate (Vasiljevic-Shikaleska A., 2014).

The incineration of bio-dried material can be carried out efficiently depending on the quality of the input materials of the MSW and heat recovery can be another energy producing option from this technology. Bio-drying renders the material more appropriate for here and now stockpiling and transport both by mostly bio-settling it and by lessening its moisture content

(MC) beneath the vital limit for bio-degradation to happen. Partial sanitization of the output is also accomplished for the bulk of the bio-dried product, but sanitization to high standards is not necessary because the bio-dried materials are intended after this to be used in other process either thermally recovered or as in this case a bioreactor.

The strategy based on temperature feedback control will be more promising for bio-drying technology, and the issue of homogeneity of the output of the bio-drying process is a subject need to be improved and hence to be investigated in future (Sharholy, 2008). In biological stabilization processes, the temperature parameter is more qualitative than quantitative. The bio-drying process is critical for control of physical and mechanical properties.

Bio-drying shows the following advantages:

- Several operating plants in real scale demonstrate that the technology is reliable.
- No auxiliary fuel is needed for drying thanks to the biochemical oxidation of a small part of volatile solids; that makes it an interesting decentralized pre-treatment of MSW.
- The volume of the reactor is potentially available for temporary waste storing.
- A reduction of mass to be transported in case of decentralized treatment plants can decrease the number of tracks on the territory.
- The treated waste is suitable for inert, metals and glass separation at high efficiency as demonstrated in real scale plants.
- The increase of Lower Heating Value (LHV) of the treated waste is exciting both for Refuse Derived Fuel production and for modifying the characteristics of the waste, when not suitable for direct combustion.

The above considerations allow proposing some criteria for bio-drying design:

- As the mass loss depends on the amount of putrescible materials present in the input waste, bio-drying can be correctly designed only if the future scenario of a particular collection is bright, data generated during the overviewed research allows choosing the mass loss value and the optimum lasting of the process.
- The Volatile solids (VS) consumption is minimized thanks to the avoidance of water addition; by this way the presence of carbon in the output can be maximized, giving

good results in term of specific LHV increase. The result is a concentration of the initial energy in a lower mass of waste (there is no energy generation), the mass loss can be related to the organic fraction (OF) content.

- The importance of the specific air flow-rate is related to the necessity of data availability for design criteria. The choice of the blower for the aeration of the waste also depends on the overall amount of air when the duration of the process is known, flow-rate variations depend on the management of the temperature process, the set of runs performed during the multi-year research gives essential information to this concern.
- The temperature of the process is regulated through the air-flow control, the temperature in the core of the waste can go over 55°C for three days if the OF is enough and the air flow is optimized.
- The optimum solution for minimization of the odor and polychloride-benzofurans (PCDD/F) impacts resulted in the one with RTO (Regenerative Thermal Oxidation) option applied for air treatment. Biofilter costs less, but the impact of a plant adopting this option could not comply with the quality targets of modern regulations, the design strategy of placing a biofilter on the roof of the plant could guarantee a lower impact mainly in the surroundings of the plant.

Waste Treatment Technologies

In numerous urban areas in developing nations, the most genuine environmental and health problems relate to insufficient solid waste management (SWM). Urbanization or expansion in the population, individually, prompts expanded waste generation in urban territories. The management given by municipal institutions and privately-owned businesses are not keeping pace with the measure of generated waste. A few issues are because of the disposal of organic waste into still regularly utilized open dumps. The waste, for the most part, organic waste, dumped in open spots makes substantial environmental contamination of soil, groundwater and surface waters (Veeken A., 2005). As mentioned before, the focus of the treatment technologies is only for the organic fraction of the MSW, because it is the main fraction of the case of study we are discussing and here the main treatment technologies related to this issue.

Anaerobic Digestion (AD)

Anaerobic digestion is a microbial conversion method that occurs in an aqueous environment, meaning that biomass sources containing high water levels (at least 60-70% in mass) can be processed without any pre-treatment (Ward AJ, 2008). It is a robust process, and its application for the treatment of organic waste has been emerging spectacularly with an annual growth rate of 25% during recent years.

In many low- and middle-income countries, the AD has been applied using manure or fecal sludge as the primary feedstock material. Especially in India, China and Nepal millions of biogas plants have been installed, but mainly in rural areas. In respect to the applicability of feedstock material, it is essential to know that only the organic dry matter content of the feedstock material contributes to biogas production.

Anaerobic digestion of organic waste provides many benefits. It includes the generation of renewable energy, a reduction of greenhouse gases, a reduced dependency on fossil fuels, job creation, and closing of the nutrient cycle. It transforms organic waste material into valuable resources, while at the same time reducing solid waste volumes and thus waste disposal costs. Biogas as a renewable energy source not only improves the energy balance of a country but also contributes to the preservation of the natural resources by reducing deforestation, and to environmental protection by reducing pollution from waste and use of fossil fuels (Al Seadi T. et al., 2008).

The anaerobic process is not as efficient as the aerobic process in breaking down waste products. Without free oxygen, bacteria cannot derive as much energy from the breakdown of food molecules as bacteria using oxygen. For instance, in a well-aerated compost pile, there is a rapid breakdown of the organic materials. With the energy released by microbial processes, the temperature inside a compost pile often reaches 70 °C during its most active period. Similar material placed in a biogas reactor (i.e., in an environment without oxygen) produces no appreciable heat, decomposes rather slowly, and most of the energy remains locked up in the form of methane. This difference between aerobic and anaerobic metabolism with regards to efficient use of energy is also evident by the stability of the process. Anaerobic digestion generation can more easily be disturbed than the process inside a compost pile. Changes in surrounding conditions, feedstock, or levels of toxic inhibiting substances can easily disrupt or stop the anaerobic process (House D., 2010) whereas it would hardly affect the composting process.

The organic dry matter is also called "Volatile Solids" (VS), which is the parameter commonly used to characterize the organic waste for anaerobic digestion. In general, the organic dry matter content of suitable bio-waste substrates ranges from 70 % to more than 95 % of the TS (Yvonne Vögeli, 2014). Substrates with less than 60 % organic dry matter content are rarely considered as valuable substrates for anaerobic digestion.

The most common indicator of digester performance is the biological methane potential (BMP), which describes the maximum possible volume of methane gas that can be produced per unit mass of solid or volatile solid matter (Buffiere P., 2006).

The characteristics of the waste materials used for the AD are highly dependent on the collection system, and one of the fundamental issues is whether inorganic materials contaminate the collected waste. If waste is being segregated at source and collected separately, the quality of this feedstock is increased, and the need for sorting at the AD plant reduced. Bacteria favor stable living conditions to be productive in the transformation of biomass into biogas. Fluctuation in feedstock does not enable bacteria to get embraced. It means no specialization of a few bacteria cultures is taking place leading to a process performed at the optimal level.

Dewatering of biogas is recommended for all applications, whereas desulfurization is mainly done before use in an engine. Hydrogen sulfide is a very aggressive gas responsible for accelerated corrosion. Biogas utilized for power creation in a block heat and power plant has, in this manner, to be dealt with by desulfurization. Due to the remove of the hydrogen sulfide, the gas stockpiling is ideally secured against corrosion (Müller, 2007).

AD has become economically more interesting in the last years than it was in the past. Some of the benefits shall be mentioned:

1) Replacement of fossil fuel: The production of biogas out of biodegradable solid waste can be used for cooking and light applications (low-tech) or to produce electricity and

heat (high-tech block power and heat plant). In this way, the utilization of locally accessible energy resources can be, at any rate on the long-run, all the more financially contrasted with imported fuel.

2) Production of nutrient-rich fertilizer: Organic waste is a valuable resource of nutrients. The degraded organic material can be applied as a fertilizer for agricultural purposes. The AD even enhances the compost quality by eliminating germs and making the supplements more plant open. On the off chance that there is a business opportunity for such sort of compost incomes can be produced.
3) Employment generation: Operation and management of anaerobic digesters require human resources. Especially low-tech plants that are not entirely automated must be fed, emptied and supervised. Depending on the activities required skilled and unskilled, but trained labor is needed.
4) Extension of landfill lifespan: The reuse of organic material leads to an MSW reduction. Space can be spared, and the landfill life expectancy can be broadened.

In developing countries, the AD is predominantly applied in rural areas (slurry-based dung digesters), where biogas has several benefits: (Müller, 2007)

- Biogas is a renewable energy source that can also be produced on a household level.
- Biogas reduces deforestation in many rural areas by replacing firewood (at least partly).
- Biogas improves living conditions for rural poor, mainly for women responsible for cooking and firewood collection. Biogas generates less air pollution by the combustion instead of wood or animal dung. By the usage of biogas less firewood needs to be collected; hence time is saved.
- Digested material is a nutrient-rich fertilizer and willingly applied by farmers.

In the context of MSW management, the implementation and operation of a digester plant on institutional or municipal level become more complicated compared to a household level dung digester. To make an appropriate feedstock quality segregation or separation of MSW is essential. The arrangement of intrigue is not just the digester plant itself yet, besides, the entire MSW management including gathering, transport, and transfer or reuse of residues.

Most feedstocks require pretreatment before digestion. Feedstock pretreatment includes sorting (if not already done at source), reduction in particle size and addition of water before the mixture is fed into the AD system. Pretreatment can enhance degradation of volatile solids and thus increase biogas yield (Tiehm et al., 2001). Some of the reasons why pretreatment of incoming waste is needed and how it can be achieved are described in the following paragraphs (Deublein D., 2011). Non - biodegradable material such as metals, plastic, and glass can cause disturbances in the liquid flow, may clog pipes and can remain as noxious matter in the residue. Conventional procedures for removal of this material are manual separation or magnetic separation for metals. High amounts of fibrous material (e.g., straw) or clumps of material need to be avoided as this hinders the degradation process in the digester. Straw can cause considerable scum layer formation which is difficult to control during digestion. Breaking apart the clumps in a rotating drum and shredding is recommended. Reducing the particle size of the feedstock is essential to avoid blockage of the inlet pipe, and to increase ease of degradation. As a general rule, substrate particle size with a diameter of max. 5 cm is recommended although the ideal size also depends on the diameter of the inlet pipe. Shredding of the feedstock into small particles increases the total surface area of the material thus increasing the area that can be degraded by microorganisms (Schnürer A., 2010).

Suitable feedstock loading of digesters is crucial to avoid problems with digestion. Dilution of bio-waste with water helps control the total TS fed to the digester. Feeding too much TS can lead to clogging of pipes. Too little TS (i.e., too much dilution with water) will decrease potential gas yield or, where the digester needs heating (e.g., in cold climates) it will increase energy requirements for the heater.

Composting

Composting has dependably existed on each field and woods floor, and instinctively it bodes well to compost the organic fraction of the municipal solid waste stream. Composting is a foundation of economic improvement, yet usually dismissed inside coordinated municipal solid waste management programs. More than 50 percent of a typical developing country city's municipal solid waste stream could be promptly composted. Composting is an essential procedure where enhancement endeavors are utilized to build the rate of decay (along these lines decreasing expenses), limit annoyance potential, and create a clean and promptly attractive completed item. Composting builds the recuperation rate of recyclable materials—family source separation of recyclable paper, metal and glass is as of now basic in many developing countries.

All organic matter will in the long run decay. Be that as it may, a few materials are more appropriate for composting than others. The raw materials which are most suitable for composting include: vegetable and natural product waste; cultivate waste, for example, coconut husks and sugar stick waste; crop residues, for example, banana skins, corn stalks and husks; yard waste, for example, leaves, grass and trimmings; sawdust; bark; household kitchen waste; human excreta and animal manure. All these organic materials are promptly found in municipal solid waste created in developing nations. Animal waste, for example, carcasses and fish scraps, can be utilized too yet they will probably pull in unwanted vermin and produce smells. Other organic matter, for example, wood, bones, green coconut shells, paper, and cowhide break down gradually and frustrate the treating the composting procedure (Lardinois, 1994).

The high organic content in the MSW stream of developing countries is perfect for composting. In any case, the municipal waste stream likewise contains expanding amounts of glass, plastics, metals and dangerous materials which can taint the completed compost. Isolating contaminants from the crude material at the compost site is wasteful since it requires extra exertion, space, and time, and it is likely that a significant part of the pollution has effectively influenced the organic fraction. Source separating the waste before the collection is usually an environmentally and technically better way to improve the quality of the final compost.

Organic waste (OW) comprises the main fraction of 55% of total municipal solid waste in developing countries (Troschinetz, 2009). Until a few years ago, the final destination of OW was either disposal in landfills or incineration. Although this situation persists in many countries, other nations have considered more sustainable methods for waste management and have developed new legislation regarding the final disposal of solid wastes which involves material valorization of OW. Material valorization is usually conducted by biological processes such as composting and anaerobic digestion. Both processes are based on biological degradation of the organic matter and occur under aerobic and anaerobic conditions, respectively. Compost, an organic amendment, is the final product of the composting process. Biogas, which contains a mixture of gases consisting mainly of methane (CH_4) and carbon dioxide (CO_2), and a non-stabilized digestate, are the final products of the anaerobic digestion process. Both processes are an efficient and environmentally friendly alternative for managing FW and are used extensively worldwide. Diverting municipal solid waste organic material from landfills to composting or anaerobic digestion has many environmental benefits. Among them, reduction in landfill emissions of greenhouse gases (GHGs) and improvement of soil properties through compost application have been highlighted (Bernstad, 2016).

Briefly, the production of high-quality compost requires that the process must be appropriately controlled and managed. OW is a highly heterogeneous material with high moisture content, high organic to ash ratio, and an amorphous physical structure.

Also, OW can contain a high level of latent materials, for example, glass or plastic relying upon the collection system. These specific qualities will influence a few parts of the procedure. The pH, carbon to nitrogen ratio (C/N), moisture content, aeration rate, particle size, and porosity must be adequately set considering the characteristics of the OW.

The source-separation of the organic fraction of municipal solid waste (OFMSW) is a crucial process because it reduces the non-organic content in bio-waste, and thus, the impurities such as heavy metals and pesticides in the compost (Haruta, 2003). Understanding the factors affecting the presence of non-organic impurities in bio-waste is required to avoid adverse effects such as higher treatment costs, reduced plant capacity, and lower compost quality (Puig-Ventosa, 2003).

The composting process is conducted in a series of different microorganisms aiming to degrade organic matter. Therefore, the monitoring of these microorganisms in succession is vital for effective management of the composting process, the rate of biodegradation, and compost quality is given that the appearance of some microorganisms reflects the maturity of the compost (Jurado, 2014).

BENEFITS OF COMPOSTING

- Increases in general waste preoccupation from final disposal, particularly since as much as 80% of the waste stream in low-and middle- income nations is compostable (Hoornweg D., 2000).
- Produces a valuable soil amendment—integral to sustainable agriculture.
- Advances environmentally sound practices, for example, the decrease of methane generation in landfills.
- Enhances the effectiveness of fertilizer application.
- Can reduce waste transportation requirements.
- Addresses noteworthy health impacts coming about because of organic waste, for example, decreasing Dengue Fever.
- Gives an astounding chance to enhance a city's general waste collection program.
- Can coordinate existing casual divisions associated with the collection, separation, and recycling of wastes.

CONSTRAINTS ON COMPOSTING

- Inadequate attention to the biological process requirements
- Over-emphasis placed on mechanized processes rather than labor-intensive operations
- The absence of vision and advertising anticipates the last compost item
- Poor feedstock which yields poor quality finished compost, for example, heavy metal contamination
- Poor accounting practices which neglect that the economics of composting relies on externalities, such as reduced soil erosion, water contamination, climate change, and avoided disposal costs

Pyrolysis

According to (Agbontalor E.A., 2007), there are numerous change courses of transforming biomass into a sustainable type of energy, one of which outstanding ones is pyrolysis. Pyrolysis has a place with a thermo-chemical process. Thermal treatment of the solid waste reduces the mass by 70–80% and volume by 80–90% (Lombardi, 2015). The time required for thermally treating the waste takes only minutes or hours and forms a stable odor free product, free of pathogens.

Regarding GHG, the thermal treatment is better than biological or landfills. Landfills emit methane (four times more effective greenhouse gas as compared to CO2) during the anaerobic digestion of waste, while thermal treatment releases only CO2 and other gases such as CO, methane having high calorific value is extracted for energy recovery (Sharholy, 2008). As stated by (Sharholy, 2008) all waste to energy thermochemical techniques have been tried and tested in developed countries with positive results.

The available technologies for the thermochemical treatment of waste are pyrolysis, gasification, plasma gasification and incineration. The historical backdrop of pyrolysis dated the back in the 1990s in the United States of America when the issues identified with dioxin inspired incinerator makers to create pyrolysis process for taking care of municipal solid wastes with moisture contents of 30 to 70% (Czernik, 2004) In developing countries, most pyrolysis forms are done in heaps, earth hill, and pit ovens with the sole point of delivering charcoal of low quality (Bamigboye, 2003).

Pyrolysis speaks to a procedure of thermal degradation of the loss in the aggregate nonappearance of oxygen at a temperature scope of 300 °C to 850 °C. The thermal degradation is associated with two sets of decomposition namely primary decomposition of the solid fuel and secondary reactions of volatile condensable organic product (tar) into low molecular weight gases and char. The reaction products are a gaseous product, a pyrolytic liquid, and char, with ash as an undesirable residue. The other unwanted products formed are flue gases which need treatment, making the pyrolysis process more expensive. Also, high amounts of inorganic constituents such as potassium in the raw material cause fouling or bed agglomeration (Di Blasi, 2008). Pyrolysis process can be worked at various heating rates. The fast pyrolysis is portrayed by high heating rate alongside high heat transfer in the reactor, a short residence time of the products in the vapor phase (below 2s), and rapid cooling of vapors to form liquid product (Bridgewater, 2002). Slow pyrolysis or conventional pyrolysis is characterized by slow heating rate and high residence time of vapor products. The slow pyrolysis is thus characterized by comparable yields of gaseous, liquid and vapor products (Di Blasi, 2008).

Pyrolysis process offers the accompanying favorable circumstances among others:

I. Since pyrolysis happens in the oxygen-free environment, there is lower air outflows, and this is advantageous to both human and environment (Eunomia Research and Consulting, 2008).
II. The pyrolysis plants can be modular. They are included little units, which can be added to or taken as waste streams or volumes change (e.g., with expanded reusing) and are along these lines more versatile and can work at a little scale than mass consume incinerators (Eunomia Research and Consulting, 2008).
III. Pyrolysis plants are snappier to develop and set (Oladeji, 2012b).
IV. Pyrolysis processes produce more useful products than standard incineration. It is because; gases, oils and solid char obtained from the process can be used as bio-fuels or purified as a feedstock (Oladeji, 2015).

The three most significant products of pyrolysis of biomass residues are described as follows:

1. Char Product:

   Char is a solid product of pyrolysis. It is usually characterized by bulk density, a proximate analysis which includes moisture, volatile, ash contents and fixed carbon contents. Promote portrayal incorporates basic investigation (carbon, hydrogen, oxygen, and nitrogen), energy value (low and high heating qualities) and permeable properties (Nugranad, 1997) Every one of these attributes are normally decided through different American Principles for Testing Materials (ASTM).

2. Liquid Product:

   The liquid product is typically the bio-oil got from the procedure of pyrolysis. It is usually broken down for its physicochemical properties (Biomass Technology Group, 2003). The oils have eating estimations of 40-half of that of hydrocarbon fuel (Yaman, 2004). Notwithstanding, it must be noticed that a few issues may happen in combustion systems when these liquids are scorched crude without updating. This since they have high water substance, and this is impending for a start. Additionally, organic acids in oils are profoundly destructive to conventional construction materials. Now and again, solid might be in the liquids, and this may square injectors or erode turbine sharp edges. Be that as it may, the organic acid in the bio-oil can be isolated through partial refining (Bamigboye, 2003). Besides, over time, the reactivity of some components in the oil may lead to the formation of larger molecule resulting in high viscosity and slower combustion (Oasman, 1999).

3. Gas Products:

Gas products are also known as pyro gases or syngas. With a thermal conductivity locator. A portion of the gases that can be distinguished is CO2, H2, O2, N2, CO and CH4 relying upon the composition of different biomass feedstocks (Oladeji, 2012b).

Every one of these items has got its particular application. For instance, the char products could be utilized for conventional and mechanical house applications as in residential cooking and as fuel in open hearth heater for blacksmithing and goldsmithing activity (Fapetu, 2000a). The bio-oil can be used in internal combustion engine (Bridgewater, 2000); (Biomass Technology Group, 2003), while the pyrolytic gas could be used as household cooking gas and as fuel for gas lamps (Bamigboye, 2003); (Bridgewater, 2002). The pyro gas can be gathered and utilized as a supplemental fuel for heating the pyrolysis reactor. Besides, various applications are accessible for gases from biomass pyrolysis. Discoveries demonstrate that pyrolysis gas compared with traditional gasification gas is more favorable, as it is higher in thermal quality and subsequently can be connected in a gas turbine or other ignition motors for power generation (Chen, 2003). Aside from the utilization featured as fuels the results of pyrolysis can be utilized specifically fields. For example, the pyrolytic char for the most part has a permeable structure and a surface territory that is proper to use as active carbon (Yaman, 2004). The fluids acquired from pyrolysis contain numerous substance chemical compounds that can be utilized as feedstock for union of fine synthetics, cements, composts and so on (Meir, 1999). In old Egypt, the substance items acquired from pyrolysis had been utilized for the conservation of dead bodies (Czernik, 2004).

Gasification

Most mixed municipal solid waste advancements endeavor to treat substantial amounts of heterogeneous mixed Waste streams. This can be engaging governments which would prefer not to source separate waste and look for a solitary, mechanical arrangement. Be that as it may, the approach of searching for an innovation settle for mixed waste treatment presents special difficulties and isn't as effective as more far reaching source separation methodologies.

Thermochemical treatment processes are an essential component of a sustainable integrated municipal solid waste (MSW) management system, as confirmed by several analyses and studies (Brunner, 2004); (Psomopoulos, 2009) and, above all, by waste management systems that are operating successfully worldwide. They are characterized by higher temperatures and conversion rates than most other, biochemical and physicochemical, processes, so allowing an efficient treatment of different types of solid waste, in particular of unsorted residual waste (i.e., the waste left downstream of separate collection, which cannot be conveniently recycled from an environmental and economic point of view).

Gasification of solid combustible matter is not a new idea nor a new technology, industrial applications for the production of town gas from coke date back to the beginning of the XIX century, while a number of large-scale plants for the production of electricity from coal or heavy oil residues have been built in the US and Europe in the last 30 years (Gumz, 1950); (Simbeck, 1993). A large number of detailed studies and projections have been developed either on technological aspects and the market potential of Integrated Gasification Combined Cycle (IGCC) plants (Bechtel, 2003).

In 2007, more than 100 plants fed with coal or petroleum residues were in operation, for a total capacity of more than 48,000MWth of syngas heating value. Ultimately on its feasibility.

Gasification, or ‘‘indirect combustion'', in particular, is the conversion of solid waste to fuel- or synthesis-gases through gas forming reactions: it can be defined as partial oxidation of the waste in the presence of an oxidant amount lower than that required for the stoichiometric combustion. Some portion of the fuel is combusted to give the heat expected to gasify the rest (auto-thermal gasification), as on account of air gasification, or thermal vitality is given by an outside supply (allo-thermal gasification), as on account of plasma torch usage. The outcome is definitely not a hot flue gas as in the traditional direct combustion of wastes yet a hot fuel gas (''maker gas'' or ''syngas''), containing a lot of not wholly oxidized items that have a calorific esteem, which can be used in a different procedure hardware, even at various occasions or locales. The organic content of the waste is changed over predominantly to carbon monoxide, hydrogen and lower measures of methane, although the syngas is generally contaminated by undesired products such as particulate, tar, alkali metals, chloride, and sulfide. Decreasing landfill volume and high expenses related with traditional incineration technologies firmly increment the enthusiasm on the utilization of the gasification procedure to MSW: the proof that gas is more available to deal with (and to consume) than a solid waste makes it a contender to end up the thermal treatment of the not so distant future, for both the unsorted residue dry part fraction downstream of separate collection and that delivered from mechanical treatment of MSW.

The solid waste gasification is a complicated process that includes some physical and chemical interactions that occur at temperatures generally higher than 600 °C, the exact temperature depending on the reactor type and the waste characteristics, in particular, the ash softening and melting temperatures. Oxidation medium generally classifies the different types of waste gasification processes: the process can be carried out by partial oxidation with air, oxygen-enriched air or pure oxygen; by steam gasification; by plasma gasification. The partial oxidation with air generates a producer gas diluted by the atmospheric nitrogen (up to about 60%) that has a calorific value ranging between 4 and 7 MJ/m^3 N. This esteem was viewed too low as used in a gas turbine (since it is astoundingly lower than that of natural that is near 38 MJ/m^3 N) but in the last years the market makes available new generation gas turbines that can efficiently burn low heating value syngas (provided that it is partially cooled and adequately cleaned to protect turbine blades) (Mastellone, 2010b). Some processes are operated with oxygen-enriched air, i.e., a mixture of nitrogen and oxygen having an oxygen content more massive than 21% and up to 50%. The objective is to get a higher heating value gas as a result of the diminished nitrogen content, that makes conceivable to complete auto-thermal processes at a higher temperature, without high utilization of oxygen (Mastellone M.L., 2010a).

The incomplete oxidation with unadulterated oxygen creates a syngas free (or almost free) of atmospheric nitrogen and after that with a higher calorific esteem, extending somewhere in the range of 10 and 15 MJ/m^3 N. The extra speculation and working expenses for oxygen generation in an air separation units (ASU) are lovely and seem advocated just for large-scale units (more monstrous than 100 kt/y). From the obtained higher syngas heating value, reduced volumetric flow rate, low tar content and, in particular, vitreous ash production (that allows more comfortable disposal options). The steam gasification generates a high hydrogen concentration, medium heating value (15–20 MJ/m^3 N), nitrogen-free syngas. In this case, steam is the only gasifying agent, the process does not include exothermic reactions, and then it needs an external source of energy for the endothermic gasification reactions. In case of (thermal) plasma gasification, the heat source of the gasifier is at least one plasma bend burns that make an electric curve and deliver a high-temperature plasma gas (up to 15,000 °C), which thus permits control of temperature freely from changes in the feed quality and supply of a gasification operator (air, oxygen or steam). It allows variations in the feeding rate, moisture content and elemental composition of the waste material: plasma gasifiers can, therefore, accept feedstocks of variable particle size, containing coarse lumps and fine powders, with minimal feed preparation.

The performances of a waste-to-energy gasification-based process are necessarily affected by the specific properties of the municipal solid waste. The most important properties for gasification are elemental composition, lower heating value (LHV), ash content (and composition), moisture content, volatile matter content, other contaminants (like N, S, Cl, alkalis, heavy metals, etc.), bulk density and size (Zevenhoven-Onderwater, 2001).

Some of these properties are so crucial that most of the current gasification technologies generally utilize pre-processed waste or refuse-derived fuel (RDF) rather than the waste as it is. The pre-treatment is mainly oriented to adequately limit the highly heterogeneous nature of the waste and reduce its size as well as its ash and moisture content. Moreover, the composition of waste (in particular its heating value) and that of its ash (that in some cases could provide a catalytic action) could suggest to investigate the possibility to utilize a co-gasification process, i.e. to feed into the gasifier a mixture of different fuels since the possible synergy between their products and intermediates could lead to maximizing the process performance, to reduce the carbon losses (in both particulate and tar fractions) and to increase the energy content of syngas.

Given the characteristics of the MSW feedstock and the issues at stake in conventional combustion plants. Waste gasification must cope with further problems specific to the waste feedstock: considerable variability of composition, high concentrations of contaminants, unfavorable chemical properties (high moisture, low LHV, high ash content), unfavorable physical properties (irregular particle size, low density). This situation has induced most of the proponents of waste gasification to pursue the more manageable ‘‘two-step oxidation'' scheme. In fact, for a feedstock with composition and physical properties varying over such a wide range like MSW, generating a syngas that can reliably meet the stringent specifications of an internally-fired cycle or even more a synthesis process is a formidable challenge. Moreover, even if technical challenges could be overcome, at the small scale typical of waste treatment plants net energy conversion efficiencies are likely to be lower than those of combustion plants, while investment and operating costs tend to be higher.

Gasification process offers the following advantages among others: (Arena, 2012)

1. Gasification delivers a middle item, which is appropriate for use in an extensive variety of utilization, for example, energy generation or liquid fuels and synthetic concoctions fabricating forms. In actuality, regular WtE units specifically combust waste feedstock.
2. There is a potential for higher effectiveness change when the fuel gas is scorched in gas reciprocating engines or gas turbines or, better, coordinated gasifier combined cycles, contrasted and conventional Rankine steam cycle power systems.
3. Operating temperatures typically lower than those of direct combustion reduce the potential for alkali volatilization, fouling, slagging, heavy metal volatilization and (for fluidized bed reactors) bed agglomeration.

4. Application for power generation at a smaller scale (typically lower than 120 kt/y), for which the conventional direct combustion system could be not convenient since gas cleaning (that is primary concern and expense) could be less relevant.
5. Gasification plants are often modular (and this allows the possibility to modify the capacity of solid waste treatment) and are also quicker to build.

Hydrothermal Liquefaction

Water present in biomass poses an adverse effect on pyrolysis, as it requires a high heat of vaporization. It limits the options for biomass as feedstock and overall process economy. In general, pyrolytic liquefaction usually liquefies biomass suitably having <40% of moisture contents. Water contents in tropical grasses can be as high as 80–85% or similarly ~90% for aquatic species (Akhtar J., 2011). Biomass usually requires preprocessing to suit for pyrolysis applications. In order to cater to moisture content problem, few studies have suggested atmospheric drying followed by mechanical dehydration.

Nevertheless, other means of drying has also been applied. Solar drying may be, but it requires longer times for biomass to lower the moisture contents. Other dehydration methods are costly and make pyrolysis processes uneconomical. One solution to handling high moisture contents in biomass can be hydrothermal liquefaction of biomass. This method can liquefy biomass with any level of moisture contents.

Furthermore, the use of catalyst enabling the reactions is not frequent in pyrolysis, while the solvents employed for HTL act as catalysts, rendering higher quality products as compared to those obtained from pyrolysis. Finally, the HTL product has lower oxygen and moisture content and higher heating value in comparison to the pyrolysis product which reduces both the fixed and operative costs of handling equipment and storage (Bensaid S, 2012), rendering the HTL technology more competitive for biomass conversion to fuel products. Nevertheless, it should be noted that the high-pressure operation raises the investment costs of HTL units.

HTL has undergone in recent years a sudden increase in the number of publications as a promising technology for biomass conversion. However, the knowledge generated is somewhat fragmentary. Comparing the research findings appeared to be quite challenging due to the wide variation in the different feedstock types, initial states, reaction conditions and/or catalysts utilized. Having established that there are very significant differences between available biomass liquefaction feedstocks, thermo-chemical liquefaction seems to be a popular technology to convert waste biomasses into liquid fuels efficiently. The properties of biomass liquefaction products depend from the type of biomass feedstock and the different operating conditions. In general, biomass-derived bio-crudes produced by liquefaction have high heating value, low oxygen content and low moisture content. However, they have high viscosity, corrosive activity, and relative low stability. Although stability problems can be solved by using solvents or co-solvents, however, further upgrade of HTL products is needed via upgrading processes such as hydrodeoxygenation in order to convert HTL products to transportation fuels.

Hydrothermal liquefaction is a system for getting spotless biofuel from biomass within sight of a dissolvable at direct to high temperature (250 – 550 °C) and pressure (5 – 25 MPa). Hydrothermal decomposition of biomass prompts the development of different mixes relying on working parameters. The part of preparing conditions including final liquefaction temperature, residence times, the rate of biomass heating, size of biomass particles, type of solvent media and hydrogen donor solvents is essential for the bio-oil yield and quality of the product. HTL, also known as hydrous pyrolysis (Jazrawi C, 2014), is a very flexible technology as far as the type of feedstock is concerned, as a wide variety of bio-based and waste feedstocks have been tested including woody biomass, industrial wastes, food wastes, swine manure, algae, arborous crops, wastes from forest industry etc. During the HTL process, biomass is directly converted to bio-crude in the presence of a solvent and in some cases catalysts at temperatures lower than 400 °C. Most studies in the literature have been conducted in small-scale batch type-reactors with slow heating rates and long residence times. In order for this technology to become more economically feasible and chemically controllable research in continuous reactors is required.

Hydrothermal liquefaction is an environmentally friendly technology. Unlike the hazardous products of combustion, such as ammonia, NOx, etc., hydrothermal oxidation converts heteroatom's present in biomass is converted into harmless byproducts. Under hydrothermal water conditions, biomass and oxygen rapidly oxidize or mineralize to form CO_2 orH_2O.

Nitrogen heteroatom present in biomass mainly converts N_2 with some N_2O. Sulfur, chlorine, and phosphorous are mainly oxidized to their respective inorganic acids that are neutralized to salt by adding a suitable base (Peterson AA, 2008). However, the presence of acids during hydrothermal processing can harm the vessel lining and require some precautionary measures. Hydrothermal oxidation is a useful proven technology suitable for the full range of feedstock including wet biomass, sewage sludge, and high sulfur coals.

Since the feed-in HTL is complicated, so is its final product, typically a two-phase mixture of bio-crude and process water with suspended char particles. Small amounts of synthesis gas are produced as well. The aqueous phase contains a significant number of polar water-soluble organics (WSO), most commonly aliphatic and aromatic alcohols, acids, and ketones. The derivatives of cresols, phenols, pyrans, and furans are standard as well, and so are sugars (Effendi A, 2008). Compared to that, bio-crude from HTL contains non-polar short and long-chain aliphatic, cyclic, and aromatic units. Functional groups of limited polarity can occur as well. The aqueous phase and bio-crude have a common origin, i.e., the biomass and its derivatives dissolved in near- and supercritical water, from which the bio-crude is formed during the cooling step.

The elaborate makeup of the liquid HTL products makes them an analytical challenge. While many techniques can be used for the general description of the product properties (e.g., heating value, acid number, viscosity), a more detailed characterization is required for understanding the mechanisms behind HTL, optimizing the process for oil production, and designing an appropriate upgrading route for the bio-crude. Additionally, the knowledge about the composition of the water phase is crucial for selection of optimal waste treatment and disposal procedure. A detailed description of the composition can usually be obtained by a combination of chromatography and spectroscopy, e.g., gas chromatography-mass spectroscopy (GCeMS), which may be the most common analytical tool for the description of liquid HTL products (Cemek M, 2001).

Bio-reactor Landfill

A landfill is an engineered land method of solid waste disposal in a manner that protects the environment. Within the landfill biological, chemical, and physical processes occur that promote the degradation of wastes and result in the production of contaminated leachate and gas. Thus, the landfill design and construction must include elements that permit control of landfill leachate and gas. The inclusion of environmental barriers such as landfill liners and caps frequently exclude moisture that is essential to waste biodegradation. Subsequently, waste is contained or buried in the cutting-edge landfill and remains for all intents and purposes flawless for extended stretches of time, perhaps more than the life of the barriers. Be that as it may, waste stabilization can be improved and quickened to happen inside the life of the barriers if the landfill is composed and worked as a bioreactor. Bioreactors are landfills where controlled expansion of non-hazardous liquid wastes or water quickens the decay of waste and landfill gas generation. As indicated by the Environmental Protection Agency, there are roughly 2,500 allowed municipal solid waste landfills (MSWLFs) as of now in action in the United States. Roughly 10% of these facilities will include retrofitting bioreactors and start leachate recirculation on existing landfill infrastructures.

According to the Solid Waste Association of North America (SWANA), a bioreactor landfill is: "a controlled landfill or landfill cell where liquid and gas conditions are actively managed in order to accelerate or enhance bio stabilization of the waste. The bioreactor landfill fundamentally builds increases the extent of organic waste decomposition, conversion rates, and process adequacy over what might somehow, or another happen with the landfill ".

A bioreactor landfill is commonly thought of as sanitary landfill that utilizations improved microbiological procedures to change and balance out the promptly and reasonably decomposable organic waste constituents in a brief period (typically 5 to 10 years) in contrast with an ordinary landfill (ordinarily 30 to 50 years or more). A bioreactor landfill administrator endeavors to control, screen, and streamline the waste adjustment process as opposed to containing the losses as required under current directions. If operated in a controlled and safe manner, bioreactor landfills can provide a more sustainable and environmentally friendly waste management strategy compared to standard practices. The bioreactor landfill requires a particular framework plan and operational changes to improve and control the adjustment procedure. These include:

Liquid Addition: The expansion of moisture to landfilled waste makes a situation ideal for those organisms responsible for waste decomposition. The moisture accessible in the waste is typically not adequate to meet the microbial prerequisites, so outline and operational changes are expected to add liquids to the landfill waste. Recirculation of leachate is the most widely recognized liquid supply, yet other waste sources can likewise be utilized.

Air Addition: Another element proposed for some bioreactor landfills is the addition of air. The addition of air, and in this way, oxygen promote the aerobic stabilization of the landfilled waste. It is a similar procedure that decomposes waste in a conventional waste compost system. Aerobic waste decomposition is a quicker procedure in contrast with anaerobic waste decomposition. The high-impact system might be useful for receiving bioreactor innovation in cold regions.

Other Factors: While moisture addition, and to a lesser degree air expansion, are the essential advancements for upgrading waste stabilization in controlled bioreactor landfills, other landfill environmental conditions are some of the time proposed for control also. These incorporate temperature, pH, and supplement level. Optimum temperature is known as between 34 to 40°C for the mesophilic microorganisms and up to 70°C for thermophilic microorganisms (Gurijala, 1993). In cold regions, low temperatures can be a problem, so aerating landfilled waste is used to heat up in the starting phase of the anaerobic bioreactor. In operating anaerobic bioreactor, temperature control is a critical issue to prevent from catching fire. pH effects on the activity of methane-forming bacteria. The range of 6.8 to 7.4 is known as the optimum pH for the methane-forming bacteria (Reinhart, 1997).

There are four reasons by and large referred to as avocation for bioreactor innovation:

a) To build the potential for waste to energy conversion.
b) To store and additionally treat leachate.
c) To recoup airspace.
d) To guarantee sustainability.

This fourth legitimization for the bioreactor, maintainability, has the most critical potential for an economic benefit because of lessened expenses related to kept away from long-haul checking and upkeep and postponed siting of another landfill.

The bioreactor process enhances gas generation that can provide a revenue stream and decrease the contaminant load in the leachate. Both of these activities reduce the potential risks associated with the landfill while increasing its long-term stability. Operating a landfill as a bioreactor offers several potential benefits over a conventional landfill:

Waste Stabilization: The primary advantage of operating a bioreactor landfill is active waste stabilization, making bioreactor operation a more sustainable waste management option. It, in turn, relates to several other advantages.

Leachate Treatment, Capital, and Operating Costs: Utilizing leachate recirculation for moisture addition may offer impressive costs investment funds on leachate treatment. At destinations where leachate treatment isn't costly, this preferred standpoint may not be huge. At destinations with constrained leachate management choices, sparing could be generous.

Air Space Recovery: It has been demonstrated that a 15 to 30 percent gain in landfill space, because of an expansion in the thickness of waste mass, can be accomplished when a landfill ends up balanced out. In the event that the landfill administrator structures their succession to use this airspace gain, savings can be generous.

Landfill Gas Generation Rates: In bioreactor landfills, gas generation rates are much higher than in conventional landfills. Therefore, landfill gas can potentially be recovered and used economically.

Environmental Impacts: A bioreactor offers a significant decrease in environmental effects as the waste gets balanced out in a limited capacity to focus time when the landfill is as yet being observed and when the landfill foundation is in top condition.

Post Closure Care, Maintenance, and Risks: The landfill is settled in a limited capacity to focus time. Along these lines, the last cover settles, and repairs required lessen upkeep and checking costs in contrast with the customary dry tomb landfills. To date, the administrative experts have not lessened the long-term monitoring frequency and duration for bioreactors.

Bioreactor landfills offer a few potential advantages, however they can be a reason for concern if bioreactor activities, for example, leachate recirculation are not performed effectively. A couple of the more typical concerns and conceivable techniques for forestalling and alleviating these worries are portrayed as:

Leachate Seeps: At the point when the fluids are included at high pressure or a flow rate higher than the nearby infiltration rate or absorption capacity of the waste mass, there is a probability of leaks. Seeps may be observed along the slopes of the landfills where leachate front meets the daily cover due to preferential flow paths and channels.

Landfill Slope: Since liquids are added to the bioreactor; interior pore water pressure can increment and consequently diminish the sheer quality of the waste. Intemperate pore water pressures can cause slope failures.

Temperature Control: Aerobic waste degradation expands waste temperature fundamentally. The expanded temperature, if not controlled, can cause fires. Temperature rise can be controlled by ceasing air infusion by cutting the source of oxygen, recycling raw leachate and altogether wetting the specific area.

Gas and Odor Control: Gas production is improved at bioreactors. If the gas is not controlled, scents and other environmental issues with a gas can result.

Fire and Explosions: The essential concern while working anaerobic bioreactor is the potential for combustibility and dangerous gas blends including oxygen and methane. The combustibility extend for methane is somewhere in the range of 5% and 14%, yet this just alludes to the combustibility of methane with air (Timothy G. Townsend, 2008). Whenever nitrogen and other diluent gases are available, this range is diminished. The other worry with the high-impact bioreactor is unconstrained fire. In the anaerobic bioreactor, air is injected into the bioreactor to promote aerobic microorganisms to decompose the waste. The aerobic activity generates high temperature, at places due to high temperature and low moisture content spontaneous combustion may occur. So, temperature monitoring at different locations and depth of the aerobic landfill is critical.

Landfill Gas Extraction Issues:

Increased Atmospheric Emissions: For the most part, leachate recirculation and different types of liquid addition are worked on amid the operational long stretches of the landfill. Leachate creation is most celebrated amid this period, and it is the main time when certain kinds of liquid addition framework might be used (e.g., guide application to the working face utilizing tankers or splash framework). The working long periods of a landfill cell's life are additionally the time when gas accumulation proficiency might be at its most reduced. Hence, bioreactor landfill administrators must control and gather gas sooner than ordinary landfills, or else atmospheric emissions will be increased. Notwithstanding administrative issues and general environmental concerns, this causes operational issues in view of smell.

Increased Gas Collection Capacity: The limit of the gas collection and transport framework should be higher than a comparable size regular landfill (e.g., bigger pipe measurement). Since numerous bioreactor landfill administrators will hone liquids addition amid the operational existence of the landfill before closure, the approach for gas collection may should be not the same as common vertical well extraction frameworks at regular landfills. The extra measure of condensate ought to likewise be considered in the plan.

Liquids in Gas Collection Lines: The trouble with conventional gas collection devices at bioreactor landfills is that they tend to load up with liquids. Liquid and gas inside a landfill will take after the most straightforward course of action. On the off chance that a gas collection device catches some portion of an immersed zone, liquids from this zone can move into the device. This issue has been watched for both vertical wells and level trenches. The nearness of moisture significantly diminishes the capacity of the gas to travel through the waste. In the event that the waste encompassing a gas collection gadget is overwhelmed, regardless of whether a lot of gas are delivered, gas will move somewhere else to a way with less obstruction.

Waste Sorting

Sorting plants intended to accept mixed municipal waste, where all household waste is gathered in a single waste stream, are fit for removing metals and glass, and regularly debased plastics. The waste entering such a plant is as of now too blended at the purpose of gathering, precluding high-quality recycling. Waste sorting plants themselves can be pretty much complex, however for the most part, including a progression of sorting process bolstered by an assortment of subordinate offices intended to deal with the procedure and keep up yield quality. The point of sorting mixed municipal waste is to lessen the amount of waste going to landfill, as opposed to accomplishing high recovery rates for recycling. The nature of the materials evacuated is along these lines commonly lower than that from plants sorting mixed dry recyclables or source separated. The quality can be expanded by separately collecting bio-waste, expelling the primary contaminant from mixed municipal waste.

There are two different conceptual approaches to sorting waste: positive sorting and negative sorting. Positive sorting focuses on identifying and removing the desired fraction from the input waste stream (i.e., eddy current which targets specifically non-ferrous materials). Negative sorting focuses instead on identifying and removing a non-desired fraction (i.e., eliminating plastic bottles without the specific polymer properties required). Generally speaking, positive sorting results in a high-quality material product, but at the cost of efficiency, while negative sorting tends to be more efficient, although at the cost of quality of the obtained materials.

Manual sorting

Manual sorting systems utilize prepared investigators to outwardly recognize and sort mixed Municipal Solid Waste into assigned classes disregarding a means of transport. Manual sorting systems are for the most part one of two kinds - positive or negative sort frameworks. In a positive sort framework, its attention on distinguishing and expelling the coveted portion from the input waste stream (i.e., Plastics, Glass). At the point when Arranged materials are expelled in a positive, manual sort, they are either explicitly fed into a granulator or onto a second transport framework that feeds into a granulator. The upside of a framework where line monitors feed the second transport is that the second transport can be intended to consolidate a computerized sorting.

Semi-Manual sorting

The Semi-Manual Sorting plant is a kind of waste sorting plant gives, contrasted with the past manual case, the incorporation of a few machines expected to diminish the quantity of staff utilized and additionally enhance the nature of the chose waste fractions.

Semi-mechanized sorting operations comprise of

a) Unloading of waste (mechanized)
b) Loading of waste on conveyor belts (mechanized)
c) Hand picking of visually identifiable waste off the belt for reuse (manual)
d) Collecting, stocking and reloading the remaining waste (mechanized)

The decision of the number of workers in a semi-manual line can be determined by determining the amount of waste that needs to be picked up. The estimated values of amount waste can be picked up for one worker per day is shown in the table below

Material	Average ton/person/day	Range ton/person/day
Paper	7.58	8.36 – 13.05
Metals	6.06	1.21 – 17.53
Glass	8.28	1.02 – 16.11
Plastics	1.60	0.60 – 3.21
Average	5.12	2.69 – 8.88

TABLE 5 PRODUCTIVITY OF MANUAL SORTERS BY PICKING OFF A CONVEYOR BELT IN A SEMI-MECHANIZED SYSTEM (MCDOUGALL F., 2001)

Such a pre-pre-sorting facility ought to have the accompanying segments:

a) Transport lines for picking-off-the-belt.
b) Screening gadgets for measure detachment.
c) Shredders/crushers for measure decrease. Magnetic Separators.
d) The pre-sorting facility ought to be planned with adequate storage room and reserve gear to deal with framework breakdowns.

This process has many advantages over other solid waste sorting processes, for example:

- It has a superior management of time of service over manual sorting since the constant feeding speeds the work rhythm and defined by the speed of the conveyors, that will be adjusted for a constant rate of classification.

- It also has an advantage over the automatic process, since it has many times lower installation costs, besides generating more jobs in urban areas, promoting growth in the local economy.

On the Plastics/ Aluminum Sorting line, plastic bottles are manually removed from the stream, i.e., positively sorted, and separated into three grades: Natural High-Density Polyethylene (HDPE), Polyethylene Ter Ephthalate (PET), and colored HDPE.

Each grade of plastic is manually sorted and then tossed into a storage bin. The storage bins feed a baler which bales each grade of plastic for ease of storage and shipment. Because of the different idea of bundles from different providers, manual sort frameworks ought to be furnished with variable speed transport lines. Along these lines, the speed of the belt can be coordinated to the nature of material ignoring the line. Higher quality approaching parcels can, for the most part, be arranged more rapidly than minor quality bundles. Belt speeds utilized by the middle of the road processors shift broadly in light of approaching feedstocks and framework outline and can extend somewhere in the range of 30 feet/minute up to 120 feet/minute. Nonetheless, the best practice in deciding belt speed is to coordinate belt speed with material quality and the capacity of line assessors to accomplish a practical sort.

Manual sorting systems are for the most part one of two kinds - positive or negative sort frameworks. In a positive sort framework, holders are expelled from a surge of plastic compartments being persisted a transport framework. In a negative sort system, containers are left on the conveyor system, and unwanted materials or contaminants are removed from the conveyor line.

Automatic sorting

The effective utilization of automated sorting lies in deciding how every material stream reacts when acquainted with specific advances or procedures. The key is locating the right technology at the right stage in the sorting process to cause a single material stream to behave differently from others. Some automated sorting technologies rely instead on identifying and subsequently physically removing a particular material type, a subtly different approach. Wholly mechanized sorting operations comprise of

1. Unloading of waste
2. Size reduction of waste through shredders and crushers
3. Size separation of waste using screening devices.
4. Density separation of waste
5. Magnetic separation of waste, Magnets either lift ferrous metal from the waste or hold ferrous metal to the conveyor while another waste is allowed to drop.
6. Compaction of waste through balers/crushers.
7. Reloading of waste

In the following table, the summary of the above-described main usable technologies:

Pretreatment technologies	Bio-drying	• Aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. • The output of partially stabilized. • Utilizes the auto-thermal heat generation due to microbial action on the waste material. • Increases the energy content of solid waste by maximizing removal of moisture and preserving most of the gross calorific value of the organic chemical compounds. • Critical for control of physical and mechanical properties. • Reliable technology. • The temperature is regulated through the air-flow control

Treatment technologies	Anaerobic Digestion	• Microbial conversion method that occurs in an aqueous environment. • Produce biogas that is used in: Generation of renewable energy, reduction of greenhouse gases, reduce dependency on fossil fuels. • Most feedstocks require pretreatment before digestion.
	Composting	• Perfect for the high organic content in the MSW stream of developing countries. • Many environmental benefits as reduction in landfill emissions of greenhouse gases (GHGs) and improvement of soil properties. • Simple and cheap technology. • Require pretreatment. • Economical useful if there is a compost market available.
	Pyrolysis	• A procedure of thermal degradation of the loss in the aggregate nonappearance of oxygen. • Happens in oxygen-free environment. • Gases, Liquids and solid char obtained from the process can be used as bio-fuels or purified as a feedstock.
	Gasification	• Partial oxidation of the waste in the presence of an oxidant amount lower than that required for the stoichiometric combustion. • The outcome is not a hot flue gas as in the traditional direct combustion of wastes yet a hot fuel gas (syngas). • Gasification plants are often modular and quicker to build. • Operating experience is quite limited and data on actual performances, reliability and costs are fragmentary and incomplete. • does not need waste source separation.

	Hydrothermal Liquefaction	• System for getting spotless biofuel from biomass within sight of a dissolvable at direct to high temperature and pressure. • Can liquefy biomass with any level of moisture contents. • HTL product has lower oxygen and moisture content and higher heating value in comparison to the pyrolysis product. • Most studies in the literature have been conducted in small-scale batch type-reactors.
	Bioreactor Landfill	• It is landfill cell where liquid and gas conditions are actively managed in order to accelerate or enhance bio stabilization of the waste. • Moisture addition, and to a lesser extent air addition, are the main technologies for enhancing waste stabilization. • Gas production is improved at bioreactors. • It requires careful management of the landfill bioreactor, to avoid risks of fire and explosion

TABLE 6 SUMMARY OF WASTE TREATMENT TECHNOLOGIES

Proposal of a new treatment facility

The proposal of a new treatment facility was decided according to the kind of waste that will be treated in the new plant in the name of the physical and chemical characteristics of the treated waste and by taking in consideration the most sustainable and economical solution according to the current situation in Ngong city after closing the dumpsite.

The suggested plant design is composed of two main phases. The first one is the bio-drying of the received waste in order to decrease the moisture as the most significant fraction of the treated waste is organic waste which contains a high percentage of water, which need to be treated well in order to make the waste more applicable. After the bio-drying process, the waste is going to be sorted with a semi-automatic sorting line to separate all the recyclables materials from the waste. Finally, the waste is going to be treated in an anaerobic bioreactor to get used to the biogas production by the anaerobic process of the waste.

The management of a landfill as an anaerobic bioreactor is an approach to increase waste degradation and stabilization, methane production and management, and to reduce the lifetime of the landfill bioactivity. In the landfill bioreactor, the refuse stabilization is mainly optimized by moisture control through leachate recirculation. Increasing the moisture content and water flux through the refuse creates a favorable environment for organic matter biodegradation. Therefore, pretreating the waste before landfilling, and monitoring and controlling the waste moisture content, are the two primary options to optimize anaerobic MSW biodegradation and biogas production. It was found that a sustainable landfill should be able to manage the substances of the landfill in an eco-friendly, organized and acceptable manner. In the presence of proper management, the processes are cost effective and have no ill-effect on the ecosystem. A few factors, for example, natural consistency for groundwater defilements, landfill gas discharges, leachate attributes, liner steadiness, physical endurance and different components to fulfill life-cycle uprightness and financial practicality should be considered in the future for a subsequent analysis of the sustainability of the Bioreactor Landfill.

The beneficial features achieved at the closure stage of bioreactor landfills are:

- A limited quantity of leachate generated, which is amenable to on-site treatment with limited need for off-site transfer, treatment and/or disposal.
- Declined landfill gas (LFG) generation.
- Minimize long-term environmental risk.

Leachate can be injected into the bioreactor to stimulate the natural biodegradation process. Notwithstanding, bioreactors regularly require extra liquids, for example, storm water, wastewater, and wastewater treatment plant sludges to supplement leachate and to upgrade the microbiological procedure. Therefore, it differs from the landfill that recirculates leachate for liquid management because landfills that recirculate leachate may not necessarily operate as optimized bioreactors.

Upkeep of ideal moisture content close field limit is required for the bioreactor innovation. The moisture content joined with the organic activity of normally happening microorganism decays waste. Leachate recirculation into landfills is an advancement that usages overhauled microbiological systems to change and settle the expeditiously and sensibly decomposable natural waste constituents inside a shorter period, i.e., 5 to 10 years, of bioreactor process execution.

Four reasons that are broadly cited to adopt bioreactor technology:

1. To increase the potential for waste to energy conversion.
2. To store and/or treat leachate.
3. To recover airspace.
4. To ensure sustainability.

In order to achieve sustainability goal, contents of the landfill are managed so that outputs are released to the environment in a controlled way, residues left do not pose an unacceptable environmental risk, the need for post-closure care and resource depletion problem is not passed onto the next generation.

The potential operational benefits of recirculating leachate bioreactors are:

- Temporary storage of leachate and partial in-situ treatment of leachate and enhanced leachate quality.

- The volume of leachate is reduced by maximizing evaporative losses during recirculation.
- Improvement of LFG production rate and total yield.
- Enhanced decomposition increases the rate of MSW settlement.
- Again, in landfill space due to an increase in the density of the waste mass.
- Reduction in time and cost of post-closure monitoring.
- Decomposition and biological stabilization in years vs. decades in a traditional landfill
- Lower waste toxicity and versatility because of both oxygen consumption and anaerobic conditions
- A massive increment in LFG generation that can be utilized for energy on location or sold when caught
- Reduce environmental effects by containing the leachate and controlling the LFG outflows.

Bioreactor landfills generally are engineered system that requires higher initial capital costs, additional monitoring and control during their operating life. It involves lesser monitoring during the post-closure period compared to conventional "dry tomb" landfills. Issues that are required to be addressed during both the design and operation of a bioreactor landfill include:

- Increased gas emissions
- Increased odors
- Physical instability of the waste mass because of expanded moisture and density
- Instability of linear systems
- Surface seeps
- Landfill fires

Leachate recirculation also has few disadvantages. They include a reduction in the shear strength of MSW, therefore, potentially reducing the factor of safety for slope stability of the landfill; potential leachate breakouts from the sides of the landfill; an increase in the liquid pressure head on the liner, potentially increasing the risk for groundwater contamination. These aspects should be taken care of on a site-specific basis before implementing a leachate recirculation system.

Technical parameters

Bio-drying

Ideal bio drying can be accomplished through successful reactor outline and molding of the information material joined with reasonable process observing and control. Control can be practiced by changing the level of operational factors (reasonable to specifically control), educated by process state factors (appropriate to screen and assess). Run of the mill outline and operational decisions include:

1. Molding the input materials of the waste matrix through mechanical pre-preparing, e.g., comminution as well as mixing, influencing the physical properties of the matrix, for example, the resistance to airflow.

2. Sort of control of waste matrix, e.g., heaps (or ''bio-cells") or heaping in burrow windrow frameworks, influencing drying components including protecting impact and level of compaction;

3. Utilization of blending/disturbance/revolution of the waste matrix in dynamic reactors to homogenize it, i.e., accomplish normal conditions: e.g., by pivoting drum reactors (Bartha B., 2007); in any case, the more significant part of the current business outlines are static.

4. Aeration system design: altered air circulation frameworks have been tried, aiming to diminish the inclinations experienced in predominant unidirectional plans (Frei K.M., 2004b).

Aeration system design composes: Mechanically bolstered air circulation of waste is essential for bio drying. It gives a mass and vitality stream media, empowering:

- Water content evacuation.
- Heat exchange redistribution, evacuating intemperate heat and, altering the grid temperature.
- O2 conveyance to take care of the stoichiometric demand for aerobic decomposition.

5. Management of the aeration rate of the waste matrix, by control of the inlet air flow rate, to expel water vapor and off-gasses and control state process parameters, for example, substrate temperature and oxygen accessibility.

6. Outside systems for controlling the psychrometric properties of the inlet air (e.g., temperature, due point, relative moistness), by cooling and dehumidifying of the procedure air to improve its ability to hold water vapor, joined with halfway process air distribution.

7. Residence time inside the reactor, influencing the level of the consummation of biochemical and physical procedures.

Bioreactor

When considering the implementation of bioreactor technology at site, the following points should be taken into consideration:

Site Configuration: One of the imperative angles while considering actualizing bioreactor innovation is the site design. If the cells are planned with extensive areas, however, are permitted to accomplish a constrained height, bioreactor innovation may not be valuable from the imminent of accomplishing extra air space. With constrained cell height just restricted settlement can be accomplished. Be that as it may, from the waste stabilization considerations, a slight stature landfill may permit uniform dissemination of liquids through the profundity of the landfill, in this manner permitting quicker stabilization. Landfills administrators considering the execution of bioreactor innovation for the landfills situated in cold regions may not accomplish fast stabilization of waste. The waste decomposition is done by the bugs (microorganisms), and these can be viable in a given domain, and the temperature is one of the prime contemplations for their activity. Ideal temperature goes for anaerobic (mesophilic) life forms are accounted for between 34 to 40 °C. For the bioreactors located in cold regions, to increase the temperature, air circulation through the waste may be practiced. Air injection will onset aerobic activity, and the aerobic microorganisms can increase waste temperature and kick off the waste degradation process. Once the temperature rises, methanogenic microorganisms can take over and degrade the waste.

Leachate Collection System Design: Federal regulations prescribe a one-foot maximum allowable leachate head on the bottom liner. So, in the case of bioreactors, leachate collection system must be designed to accommodate the higher volumes of liquids that will be moving through the landfill. It may require increasing the pipe size at some locations and additional pumping capacity. The long-term porousness of granular seepage material ought to be assessed since the base of the landfill must function amid the lifetime of bioreactor activities as there are expanded odds of its fouling due to leachate reusing. It might be valuable to depend on pressurized deplete fields, instead of depending on gravity seepage to keep up wanted stream rates. Utilization of high-density polyethylene (HDPE) pipes will be favored because of their quality and toughness. While changing over a current landfill to retrofit as a bioreactor, existing leachate collection configuration ought to be assessed to learn its ampleness to oblige the high volumes of leachate.

Gas Collection System Configuration: For the most part, gas recovery and collection frameworks are introduced a couple of years after a landfill cell is finished. However, for bioreactor landfills, the gas collection system should be introduced either amid the waste filling in the cell or instantly after cell finish. Also, the gas collection system will be intended for dealing with higher pinnacle volumes, however, need to do as such for a shorter time. The plan contemplations will likewise incorporate the pressure development condition on geomembrane cap when the gas collection system is closed down for any breakdowns. Another critical perspective in outlining and working gas collection system will be to avert liquids interruption into the gas collection wells.

Cover Soil Usage: The effective distribution of recycled leachate or water in the waste mass is best accomplished in a homogeneous waste medium. The nearness of nonstop low porousness soil layers can block the moisture stream. It can make slope stability worries and additionally dry pockets of waste. Notwithstanding security issues, zones of low penetrability can cause confined ponding of fluids and leachate breakouts. Utilization of waste materials with porousness near that of MSW, for example, mulch, are possibly helpful choices Utilization of elective covers that don't make such barriers and can alleviate these impacts can be useful. Much of the time, elective covers have been observed to be very financially savvy when contrasted with soil. The conceivable substitute covers might be as blankets, sprays or some other interchange material. The blankets might be as canvases that can be laid after the day's landfilling procedure and can be expelled next morning. The sprays can be either slurries or foams. Slurries are solids mixed with water. Monetarily accessible slurries use daily paper, blended paper, wood fiber, cement kiln dust, or fly ash, alongside mixing agents and water. Foams are involved manufactured materials, for example, pitch or cleanser that are blended with water. The utilization of substitute everyday cover will be chosen because of cost-benefit economics.

Waste Stream Characteristics: A homogeneous waste mass can help distribute the liquid. Therefore, it might be useful, if the waste stream does not contain apparent measures of tires, yard waste, lumber, tree trunks and appendages, bulky waste, sludge, ash, household hazardous wastes, or shingles, etc. These wastes should be intercepted and directed for on-site or off-site processing and disposal by means other than landfilling. Waste segregation may include separation of construction and demolition (C&D) wastes from the MSW stream. Pre-processing of waste like shredding, recycling and segregation and so forth (with the purpose of expanding organic content and high uncovered surface territory) before putting in a landfill might be valuable to advance uniform moisture distribution and diminish differential settlements. Constrained shredding can be acquired by spreading deny in thin lifts and utilizing landfill gear to tear open plastic sacks and separate holders. Mechanical shredding can be proficient and powerful in reducing particle size; be that as it may, it is a work concentrated and staggering expense action, which may not be financially savvy. Waste will be set in the landfill with lessened compaction, to advance leachate recirculation. The lessened compaction can be accomplished by constraining the number of passes of the compactor over the waste. On the other hand, light compaction equipment can be utilized for leveling the waste. The waste will come at last settle because of moisture addition, the heaviness of overlying layers, and waste degradation, hence airspace lost because of original position with low compaction might be recouped with time.

Amount of waste entering the plant

The plant is designed to treat the municipal solid waste in Ngong city which are supposed to reach about 104390 ton/year in 20 years. The proposed idea was for the closure of the Ngong Town illegal dumpsite and to design and construct a modern integrate municipal waste to energy plant.

Design Process

The proposed design of the new WtE plant consists of 4 main phases, Control and Acceptance phase, Bio-Drying phase, Semi-Manual Sorting phase, The Bio-Reactor Landfill phase and then the extracted biogas will be upgraded to be used in further utilizations

Control and Acceptance

The MSW that will arrive at the treatment plant has to be controlled before doing any treatment process on it due to the presence of hazardous waste that can't be allowed to enter the plant. All the waste that are specified as hazardous waste according to (NEMA, 2006) shall be treated separately away from the MSW. The process of controlling and accepting the waste is done manually by workers in a space outside the plant with area of 356 m^2 which is mainly calculated depending on the amount of waste which is coming to the plant per day, then it is moved to be stored in a bunker by using a bulldozer, which also has an area of 356 m^2. After the chosen waste are sent to the bunker, then it starts to be transported by another bulldozer to the bag opener machine which is used mainly to open the waste bags before sending them to the biological treatment of the waste which is the bio-drying process. Taking in consideration also a proper area between each phase to allow a smooth movement for the bulldozer to move the waste between those phases which is assumed to be 6 m between the controlling and accepting phase, the bunker and bag opener. The total area of the control and acceptance is calculated by the following formula:

$$Area = 356\ (Area\ of\ bunker) + 356\ (Area\ of\ accepting\ space) + 25(Area\ of\ bag\ opener) \\ + 3\ (\ space\ between\ the\ control\ \&\ acceptance\ and\ the\ bio-drying) \\ * 64\ (total\ Lenth\ of\ the\ whole\ area\ ) = 1110\ m^2$$

Bio-drying process

Bio-drying is the procedure by which biodegradable waste is quickly heated through initial phases of composting to expel moisture from a waste stream and henceforth lessen its overall weight. In bio-drying processes, the drying rates are augmented by biological heat in addition to forced aeration. The significant portion of biological heat, naturally available through the aerobic degradation of organic matter, is utilized to evaporate surface and bound water associated with the mixed sludge. This heat generation assists in reducing the moisture content of the biomass without the need for extra fossil fuels, and with minimal electricity consumption.

In bio-drying, the primary drying mechanism is convective evaporation, using heat from the aerobic biodegradation of waste components and facilitated by the mechanically supported air flow. The principal bio-drying losses are divided between:

- Volatile fraction of the organic carbon (equal to 50% of the carbon content of "organic" and "fines") (Bartha B., 2007)
- Water evaporation following the heat released by the biological oxidation of carbon, assuming 55% thermal losses. The moisture connect of the waste matrix is reduced through two main steps: (C.A. Velis, 2009) water molecules evaporate (i.e., change phase from liquid to gaseous) from the surface of waste fragments into the surrounding air. The evaporated water is transported through the lattice by the air flow and evacuated by the fumes gasses. A restricted measure of free water may leak through the waste grid and be gathered at the base of the bio-drying reactor as leachate.

The energy necessary for evaporation to occur (vaporization latent heat, or enthalpy of vaporization) and any additional if the hygroscopic limit is reached, is provided mainly by aerobic biodegradation. In contrast, conventional drying employs external sources of heat. The aerobic decomposition of organic matter by microorganisms is an exothermic biochemical transformation that can rapidly raise matrix temperatures to the thermophilic range.

$$EV_{H_2O} = \frac{Heat\ released\ from\ the\ oxidation\ of\ carbon \times useful\ heat\ for\ eva}{Latent\ heat\ of\ water\ evaporation}$$

$$EV_{H_2o} = \frac{3.7 \times 10^8 \left({}^{Kj}/_{day}\right) \times 45\%}{2400\ ({}^{Kj}/_{Kg_{H2o}})} = 69.2\ \frac{ton}{day}$$

After the bio-drying process the outflow of this process is the inflow of the Sorting process.

We can calculate the duration of the bio-drying process by assuming that its first order kinetics with k = 0.08 dy^{-1}, $\frac{C}{C_0}$= 0.5, by using the following formula,

$$t = \frac{-1}{k} \times ln\frac{C}{C_0} = 9\ days$$

As any other bio-drying process oxygen is needed for the formation of carbon dioxide but it is not efficient to use pure oxygen as it will consume more energy and costs more money.

By knowing that percentage of oxygen in air is 21% and assuming the effective air needed is twice the stoichiometric air, then the air supply needed can be calculated by multiplying the effective air with the amount of carbon in both the organic and the fines fraction in the treated waste as mentioned before.

$$total\ carbon\ losses = 11.31\ \frac{ton}{day}$$

$$Effective\ Air\ \left[\frac{m^3 n}{Kg_c}\right] \times Carbon\ Content_{organic,fines}\ [\frac{Kg_C}{Kg_{rw}}]$$

Air Supply = 1408 $\frac{m^3{}_{n,air}}{t_{rw}}$

Hourly flow of air =$\frac{Air\ Supply}{working\ hours \times working\ days}$= 6.52 $\frac{m^3{}_{air}}{h.t_{rw}}$

The bio-drying basin is working for 365 days yearly without stopping, so to determine the size of the heaps we assume that the number of heaps are 18 heaps and the number of processing days (9 days) and the daily volume input of waste is calculated by

$$\text{Daily volume input} = \frac{Daily\ flow\ rate\ of\ RW}{Specific\ weight\ of\ RW} = 892.14\left[{}^{m^3}/_{day}\right]$$

	Volume [m^3]	Height [m]	Width [m]	Length [m]	Area [m^2]
One heap	432	4	6	18	108

TABLE 7 HEAP SIZING

Finally, having the size of the lines, and the number of lines, assuming the spacing between each heap is 2 m, the total floor area of the bio-drying basin is

$$Total\ Area_{Basin} = 142\ (width\ of\ the\ basin) \times 18\ (length\ of\ heap) =\ 2556\ m^2$$

Finally, the design of the air blowers depends on the air flow rate which can be calculated by

$$\text{air flow rate} = \text{Hourly flow of air} \left[\frac{m^3{}_{air}}{h.t_{rw}}\right] \times \text{weight of heap [ton]}$$

$$\text{weight of heap} = \text{Volume } [m^3] \times Specific\ weight\ of\ RW\ \frac{ton}{m^3} =\ 142\ \text{ton}$$

air flow rate = 930 $m^3/_{hr}$ = 0.25$m^3/_{sec}$

Then, this air flow can be divided by the flow capacity of each one of the different types of air blowers, and obtain the number of air blowers, ensuring to provide the amount of air needed. More over in each one of the cases are added 3 more air blowers per heap as back up.

Number of AB per heap	Flow rate for AB $m_n{}^3/s$	Total AB per heap	Total AB for bio-drying basin
6	0.05	9	162

TABLE 8 AIR BLOWERS DESIGN

The waste is moved from the bag opener to the bio-drying basin and from the bio-drying basin to the next sorting process by a conveyor belt, the length of the conveyor belt is calculated by

$$L = 142\ (width\ of\ the\ whole\ basin) \times 2\ (both\ sides\ of\ basin) + 1\ (the\ distance\ between\ the\ main\ conveyor\ belt\ and\ the\ heap) \times 18\ (number\ of\ heaps) \times 2\ (both\ sides\ of\ the\ basin) = 320\ m$$

The characteristics of the bio-dried materials with respect to the water content, the carbon content and the non-carbon content, is shown in the table below.

	Food Waste	Paper	Plastics	Fines	Glass	Non-ferrous metals	Ferrous metals	Unclassified Residual Waste
Water content (t/d)	74.00	1.88	0.87	2.90	0.12	0.08	0.09	0.16
carbon content	9.46	10.25	14.94	1.85	0.09	0.03	0.03	0.01
Non-carbon content	40.20	13.21	10.38	8.92	8.70	2.85	3.25	0.67
Total	123.67	25.34	26.19	13.66	8.90	2.96	3.38	0.84

TABLE 9 CHARACTERISTICS OF THE BIO-DRIED MATERIAL

Waste Sorting Process

1. **Screen Drum** for the separation by size of the waste as it has two streams coming out from it. The first stream is for materials with a dimension more than 200 mm which goes to another mechanical process that weights 92.31 t/d. The other stream is for materials with a dimension less than 200 mm which goes directly to manual separation to separate the glass and after this goes to the final phase which is the bioreactor landfill, the amount of that stream is 112.64 t/d. The glass which is manually separated from this stream and sent to collecting chamber to send after this to the recyclables customers. The amount of glass that is sent to the collecting chamber is 5.61 t/day, and the area of the glass storage chamber is 36.2 m^2. The drum screen that should be used with a diameter of 250 mm with a screening surface of 47.4 m^2which has a production rate of 10 ton/hour that can work for around 12 hours per day.

Two proposals were designed in order to manage the most sustainable solution regarding the current situation of the area.

The First Proposal is: Semi Manual Sorting

This proposal was mentioned in order to find an optimal efficiency sorting method for the bio-dried waste. The mix of use automatic machines to separate part of the waste with higher efficiency and also to reduce the size of the materials in order to achieve higher efficiency in the bioreactor, and also the use of manual sorting by trained workers to offer some job opportunities to the people there and reduce the cost of the energy and machines.

The waste is transferred between the sorting machines through a conveyor belt, which takes the waste from one stage to another until it delivers the waste to the final disposal which is the bioreactor landfill. The conveyor belt in this phase is designed right after the bio-drying basing with a length of 78 m and a speed of 0.5 m/s.

The bio-dried waste is treated in the following way:

2. **Primary Shredder** This machine homogenizes the waste and reduces the water content, helping to get better efficiency, to tear the textile materials and to shred plastic and wood items and small size of output material (< 200 mm). The primary shredder receives the mainstream that comes from the drum screen, and due to the reduction of the water content, the out stream from the primary shredder is 89.76 t/d. The primary shredder has a dimension of the size grinding chamber of 960 x 1500 mm, with a production rate with an average of 10 ton/hour. It should work for around 10-12 hours per day depending on the amount of waste will be treated by day.
3. **MAGNETIC SEPARATOR** This machine helps to recover the 80% of the ferrous metals. After the Primary Shredder, the first aim of the Mechanical Refining Part, is the recovery of recyclable fractions, mostly metals; therefore, we use the magnet. The secondary stream from the magnetic separator is sent by conveyor belt to a chamber to be resold as a recyclable material. The amount of the ferrous metals that are recovered from the magnetic separator is4.8 t/d which will be stored in a storage chamber with an area of 3.6 m^2.
4. **Eddy Current Separator**, this machine can recover the 90% of the non-ferrous metals where Metal Waste reuse/recycling ≈ 100% of reusable metal scrap or waste. (Allison Kasozi, 2010), The non-ferrous metals are sent to a press chamber. Then the remaining stream is sent by using a conveyor belt to be sorted manually by workers to separate the paper and plastic from sending them to press chambers to be prepared to send them to recyclables customers. The amount of the non-ferrous metals that are recovered from the Eddy Current separator is 2.18 t⁄d, and it is stored in a chamber with an area of 11.1 m^2.

5. The stream that comes out from the Eddy current separator is **manually separated** by workers to separate the plastics and papers from the waste. The amount of material that is separated depends on the efficiency of the pickup workers so assuming the recovery efficiency for papers and plastics are 50%, so the amount of paper and plastic that will transfer to the storage chambers are 10.48 t/d and 11.51 t/d respectively, to be stored in different storage chambers with areas 50.3 m^2 and 63.6 m^2 respectively. Then the remaining waste to be sent to the bioreactor landfill.

The Second Proposal is: Manual Sorting

The manual sorting line is designed in order to study the difference between using only labors in sorting the bio-dried waste and using some machines in order to see the difference in the efficiency of sorting in terms of tons of recovered material and also in terms of economic efficiency like energy consumption, labor cost, job opportunities which will be discussed more in details in the following chapter.

The amount of recovered materials is shown in the table below

Material	Food Waste	**Paper**	Plastics	Fines	Glass	Ferrous	Non- ferrous metals	Unclassified Residual Waste	Total
Efficiency value	0.000	0.500	0.500	0.000	0.800	0.400	0.200	0.050	
Recovered materials t/d	0.000	10.771	11.786	0.000	2.137	0.355	0.541	0.021	25.61
OUTPUT to Bioreactor t/d	**37.10**	**10.77**	**11.79**	**3.42**	**0.53**	**0.53**	**2.16**	**0.40**	66.70

TABLE 10 THE AMOUNT OF RECOVERED MATERIALS

Finally, in the flow chart below, it is obvious the amount of waste that entering the plant with mentioning the exact amount of secondary stream from all the phases. The control phase, the hazardous waste will be rejected. The bio-drying phase, the amount of water and organic carbon that will be lost during the bio-drying process. The sorting phase, all the secondary streams that goes out either from the sorting machines like ferrous or non-ferrous metals or from the manual sorters like glass, plastic and paper.

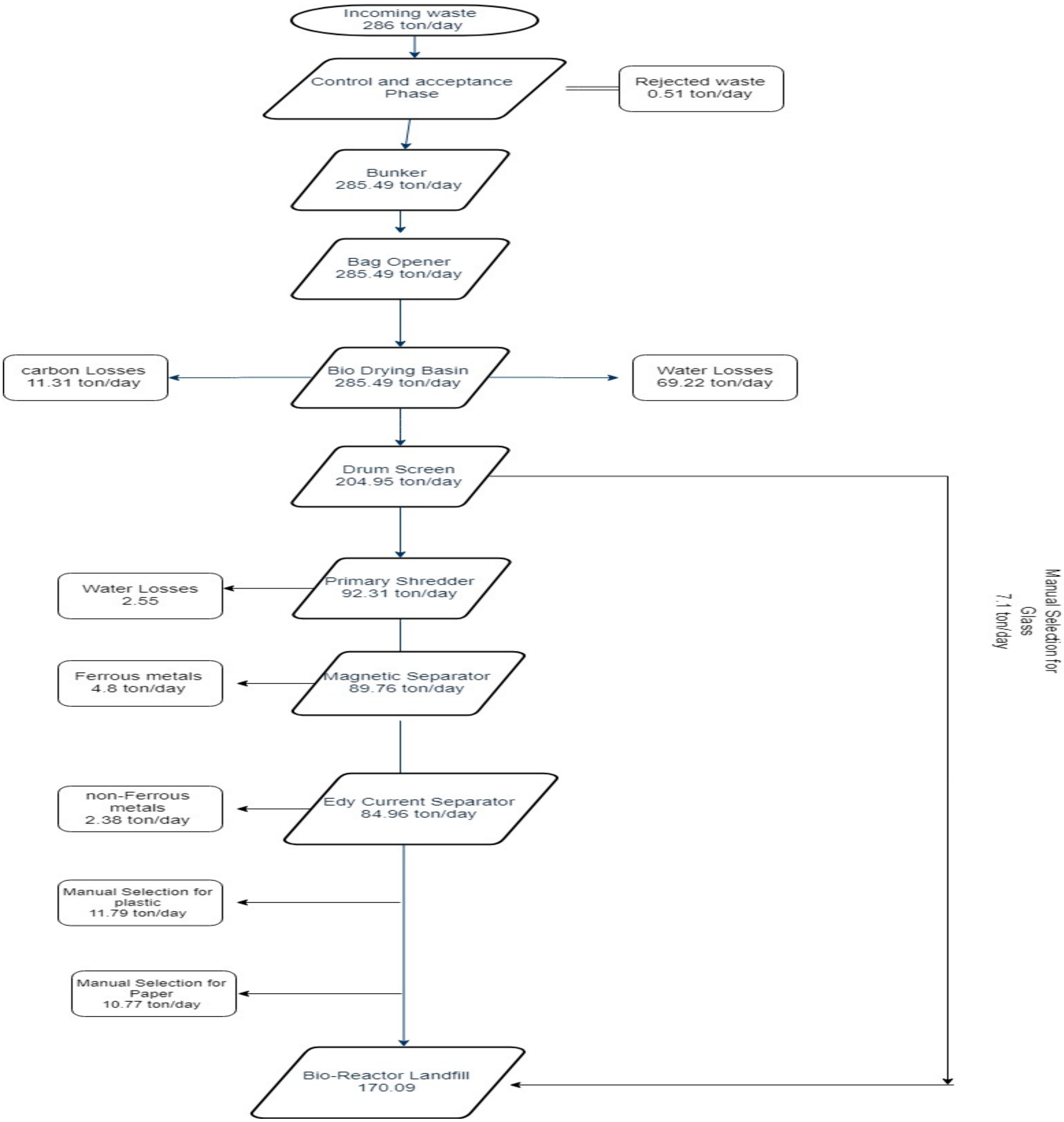

FIGURE 4 MATERIAL FLOW CHART OF SEMI MANUAL SORTING LINE

The Bioreactor landfill

After taking out all the recyclables materials from the two streams, the remaining waste will be sent to **Anaerobic Digester** to be treated and produce Biogas and leachate which can be further treated to produce compost to be used as a soil improver.

For the semi-manual sorting proposal:

Mass FLOW:	Food Waste	Paper	Plastics	Fines	Glass	Ferrous	Non- ferrous metals	Unclassified Residual Waste	**Total**
OUTPUT to A.D. (t/d)									
From Drum screen	86.57	3.80	0.79	10.25	0.62	1.66	0.54	0.42	
From Edy current	0.70	0.43	0.47	0.17	0.00	0.00	0.24	0.01	
From Sorting line	34.18	10.48	11.51	3.18	2.67	0.53	0.22	0.38	
Total	121.45	14.71	12.77	13.59	3.29	2.19	1.00	0.81	169.81
Recovered material (t/d)									
Total	0.00	10.48	13.35	0.00	5.61	0.77	2.37	0.02	32.60

TABLE 11 SECONDARY STREAMS FROM THE SEMI-MANUAL SORTING LINE

The bioreactor is designed to treat 126 t/d which is the average amount of waste that the bioreactor will receive in 20 years by taking into consideration a 6 % of the population increase per year.

Average waste(t/d)	Daily Volume input (m^3/d)	Bioreactor volume(m^3)	Height(m)	Width (m)	Length (m)	Area (m^2)
126	157	1147956	20	200	287	57398

TABLE 12 THE BIOREACTOR LANDFILL FOR A DESIGN PERIOD OF 20 YEARS FOR SEMI MANUAL SORTING LINE

For the Manual Sorting line also, the same procedure has been followed the only difference is the amount of the received materials as shown in the following table

Mass FLOW:	Food Waste	Paper	Plastics	Fines	Glass	Ferrous	Non- ferrous metals	Unclassified Residual Waste	Total
OUTPUT to A.D. (t/d)									
From Drum screen	86.57	3.80	0.79	10.25	0.62	1.66	0.54	0.42	104.65
From Sorting line	37.10	10.77	11.79	3.42	0.53	0.53	2.16	0.40	66.70
Total	123.67	14.57	12.57	13.66	1.16	2.19	2.70	0.82	171.35
Recovered material (t/d)									
Total	0.00	10.77	13.62	0.00	7.75	0.77	0.68	0.02	33.61

TABLE 13 SECONDARY STREAMS FROM THE MANUAL SORTING LINE

The amount of sorted waste that the bioreactor will receive in the case of manual sorting line will be higher than that of semi manual sorting line. As we explained before, the same aspects had been followed also for the fact of taking in considerations the yearly waste increase. So, the amount of sorted waste that the bioreactor will receive in this case is calculated to be 127 t/d.

Average waste (t/d)	Daily Volume input (m^3/d)	Bioreactor volume(m^3)	Height (m)	Width (m)	Length (m)	Area (m^2)
127	159	1158516	20	200	290	57926

TABLE 14 THE BIOREACTOR LANDFILL FOR A DESIGN PERIOD OF 20 YEARS FOR MANUAL SORTING LINE

Landfill Gas Production

Landfill gas (LFG) is a by-product of anaerobic waste decomposition, LFG creation is quickened in anaerobic bioreactor landfills. Gas from anaerobic decomposition of waste is fundamentally made out of methane (CH4) 50-75% and carbon dioxide (CO2) 25-50 %. %. Run of the mill landfill gas has marginally more CH4 than CO2. Other follow parts, for example, water vapor, hydrogen sulfide and an assortment of natural synthetic substances, additionally discovered likewise found in LFG.

The increased gas production may prove beneficial to the landfill operator. The economics of gas conversion to energy at times becomes more feasible when there is greater gas production over a shorter period. If the increased gas production is managed correctly, it has positive implications for energy production and environmental impact. However, if not collected immediately, much of the advantage of energy recovery is lost and impacts the environment due to uncontrolled release of LFG to the atmosphere. Voluntary use of LFG may also be eligible for carbon credits for the landfill operator.

Different techniques may be used to collect LFG. Possible options include the use of horizontal collection systems or vertical wells. A blower system is used to induce a vacuum in the gas manifold and the wells or trenches and to extract gas from the landfill interior. The vacuum has to be maintained in such a way so as not to draw air into the landfill, as the air drawn into the landfill may slow down the methanogenic microbial activity and can also result in landfill fires.

Generation of biogas will start after 1-2 years since a minimum amount of waste is needed before enhancing its generation through leachate recirculation. The amount of biogas produced will be burned in a co-generator unit producing heat and power. Such thermal energy will be enough to power the bio-drying, and a considerable fraction of the electricity can be fed to the grid, ensuring the economic self-sustainability of the entire system.

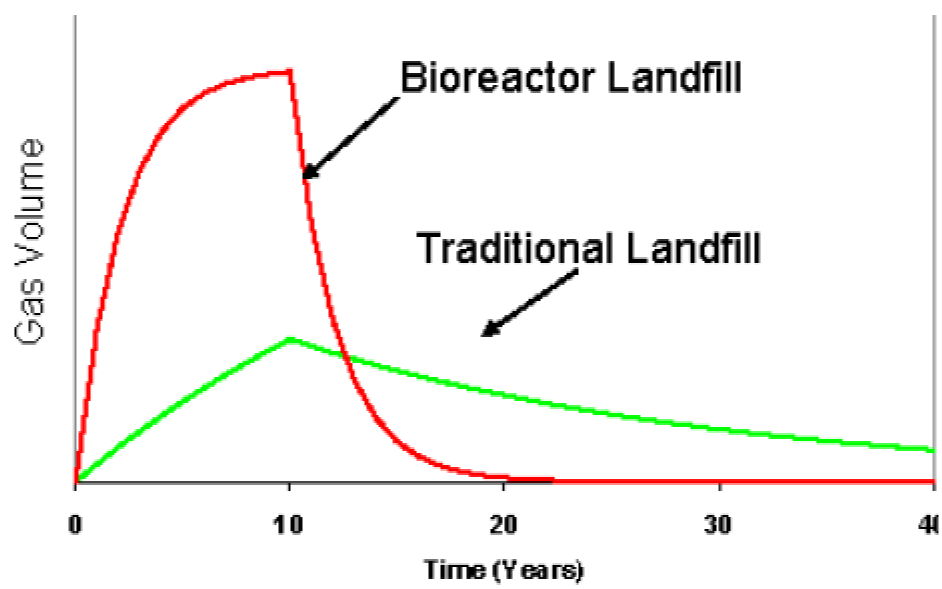

FIGURE 5 GAS GENERATION RATE IN TRADITIONAL AND BIOREACTOR LANDFILL (TIMOTHY G. TOWNSEND, 2008)

The biogas production from the anaerobic digestion process of high organics samples is primarily affected by its organic loadings, temperatures, retention time in the reactors, pH and the degree of contact between the incoming substrate (feed slurry) and a viable bacterial population. The BMP (biomethane potential) is estimated to be 0.3 ${m_n}^3 {Kg_{VS}}^{-1}$. For the biogas production, the values are in the range of 100-150 m^3t^{-1} (Grosso, 2017). By knowing that the amount of waste that goes to the bioreactor is around 46000 t/year, so the Biogas produced by the bioreactor is 4.6×10^6 – $6.9\times10^6 m^3/year$. For each cubic meter of biogas contains the equivalent of 6 kWh of heat energy, For the total amount of the produced biogas, the predicted energy production is in the range between 27600 – 41400 MWh/year.

Energy Consumption of the new proposal

Air blowers

The energy consumption of the air blowers is determined by the type and the amount of air blowers that are needed for the bio-drying process as discussed in the chapters before.

Total number of AB	AB absorbed Power (KW)	AB Energy consumption (KWh/ton)	Annual Electric Consumption (MWh/year)
162	4.5	35	3669

Table 15 AB annual energy consumption

Conveyor belts

The energy consumption of the conveyor belts depends on the length the conveyor belt, the energy consumption (KW/m) and by the number of working hours and working days.

Total Length (m)	C. B. Energy Consumption (kw/m)	Working hours	Working days	Annual Electric Consumption(mwh/year)
400	0.3	16	340	688

Table 16 conveyor belts energy consumption

Sorting machines

The energy consumption of the sorting machines is determined by the energy consumption of each kind of machine per the amount of waste it treat per the number of working days which is 340 days per year

Machine	Average Electric Consumption (kwh/ton)	Annual Electric consumption (Mwh/year)
Drum Screen	1	70
Primary Shredder	11	345
Magnetic Separator	1	30.5
Eddy Current Separator	1	29

TABLE 17 SORTING MACHINES ENERGY CONSUMPTION

Then by analyzing the electric consumption for all the plant, then the Electric consumption for the first sorting proposal is:

The total electric energy consumption of the whole plant is = $4832\frac{MWh}{year}$

And the electric energy consumption for the second sorting proposal is:

The total electric energy consumption of the whole plant is = $4357\frac{MWh}{year}$

Tentative planimetric arrangement of the equipment

The new proposed plant is designed with most of the possible future probabilities regarding waste production increase or labor demand increase. The plant will be consisting of an open area to reject the unwanted waste, bunker to store the incoming waste, a bag opener to tear the waste bags. After this, the waste will be moved by a conveyor belt through all the remaining phases.

The bio drying basin consists of 18 heaps which can be constructed at different times and not all to be constructed at the beginning. Moreover, the manual or the semi-manual sorting lines and at the end the bioreactor landfill.

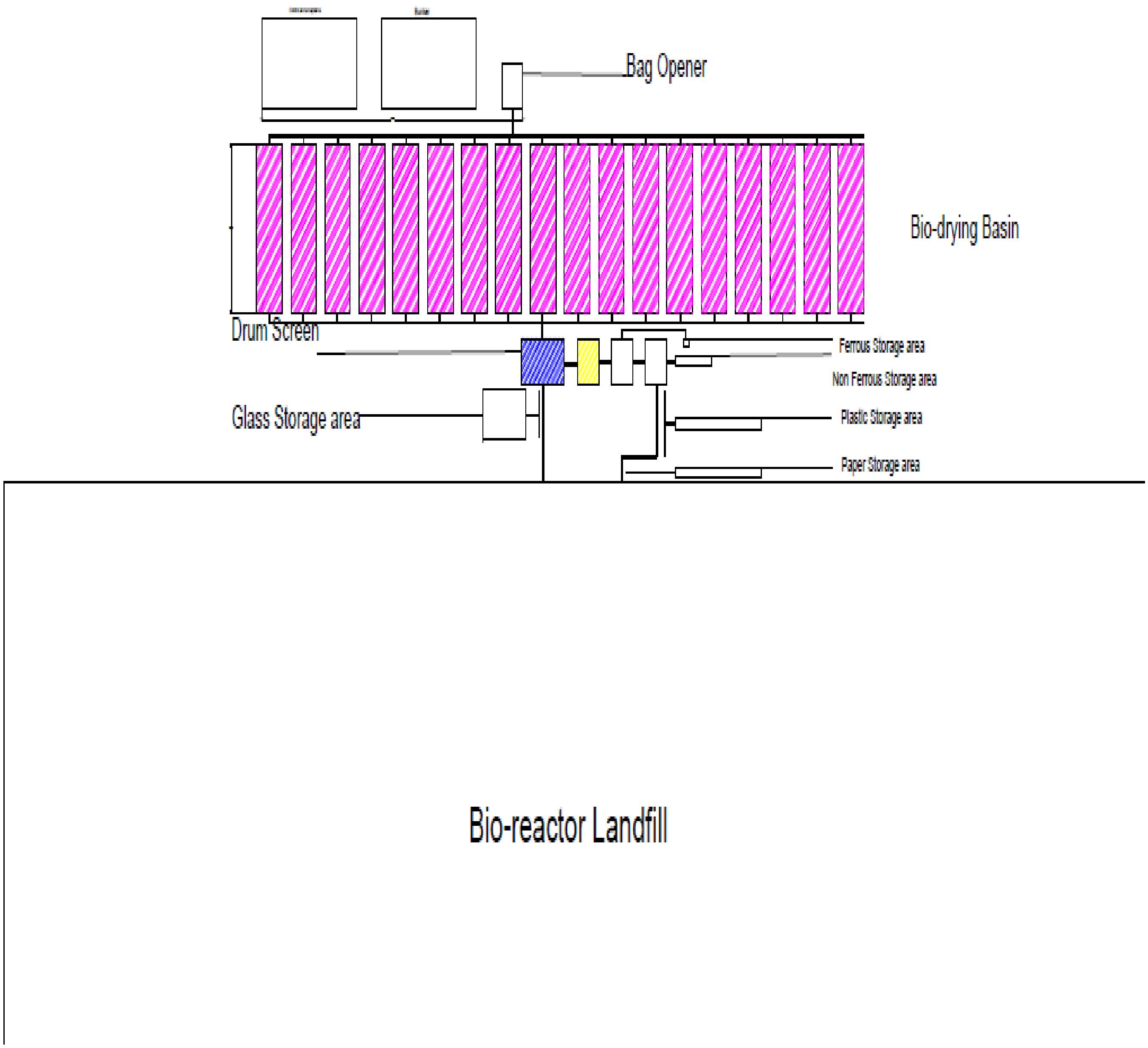

FIGURE 6 TENTATIVE PLANIMETRIC ARRANGEMENT OF THE PLANT

Labor situation from the dumpsite closure to the new plant

In the current circumstance, the management of waste in Ngong includes more than thirty Private Specialist co-ops, while around 200 people (of which 132 enrolled individuals from Nuru Y. G.) rely upon the determination and buy of recyclables in the dumpsite (PoliMI-Ngong, 2018). Any change in SWM may influence the work of individuals at present engaged with waste management. The alleged "waste pickers" are powerless against numerous adjustments in the waste management system which keep them from getting to recyclables, for example, the foundation of waste-to-energy plants or the response to substantial safety efforts which target them as lawbreakers. Specialists utilized in picking, sorting, cleaning, and business of waste at the dumpsite will be influenced by its conclusion since they hazard losing their wellspring of salary, and they can also be subjected to constrained relocation.

The following table shows the productivity of manual sorters by picking off a conveyor belt in a semi-manual sorting system (McDougall F., 2001)

Material	Average ton/person/day	Range ton/person/day
Paper	7.58	8.36 – 13.05
Metals	6.06	1.21 – 17.53
Glass	8.28	1.02 – 16.11
Plastics	1.60	0.60 – 3.21
Average	5.12	2.69 – 8.88

TABLE 18 THE PRODUCTIVITY OF MANUAL SORTERS

While the amount of the recovered materials as discussed in the previous chapters are

Material	Recovered weight ton/day
Paper	10.27
Glass	5.61
Plastics	13.12

TABLE 19 THE RECOVERED MATERIALS

From the previous tables, therefore, for the first proposal (the semi-manual sorting), the number of workers needed for the new treatment plant is estimated to be around 20 workers per day for the sorting process, and five heavy machinery operators (for the bulldozer and other heavy machineries) and two assistants. Also, there must be some supervisors in the plant to be sure that all the work is done in the right way, but this depends on the availability and the needs of the plant. On the other hand, for the second proposal (the manual sorting), the number of heavy machinery operators and the assistants is more or less the same while the number of workers is 25 workers per day due to the slight increase in the amount of recycled materials and the decrease in the amount of waste to be sent to the bioreactor.

Summary

To summarize the work done between the two proposals of the manual and the semi-manual sorting lines concerning recovered materials, labor, and energy consumption.

For the semi-manual sorting line option, it is clear that the number of workers is fewer than those needed for the manual sorting option due to the presence of more machines, as we saw before that 27 workers needed for the semi-manual sorting option, while 32 workers are needed for the manual sorting option. On the other hand, the amount of recovered materials is around 22 ton/day for the semi-manual, while they are in the range of 26 ton/day.

Moreover, the energy consumption difference between the two options is not very huge, as it is 4832 $\frac{MWh}{year}$ for the semi-manual sorting line comparing to 4357 $\frac{MWh}{year}$.

Conclusions

The generation of solid waste has increased all around the world over the last few decades and in particular in developing countries. They have some specific characteristics such as lack of adequate policies and legislation, lack of data, lack of financial resources, high content of organic matter in the wastes, among others, has made it harder to have an efficient and complete system of municipal solid waste management.

In this research, bio-drying with landfill bioreactor is presented as a possible solution for solid waste management in developing countries in a centralized as well as a decentralized approach according to the local conditions. The strengths of this technology are based on the ease of the process, its flexibility, the reasonable investment needs and the possibility to use the final product either biogas which can be used as energy source. Moreover, as the composition of the municipal solid waste has a high content of water and organic matter, the bio-drying stage allows to significantly decrease the mass of waste, while the bioreactor might benefit of the remaining organic matter to generate biogas for energy production.

Based on a literature review and the analysis of solid waste management situation in developing countries especially in Kenya, it was found that there is no specific operative guideline when addressing a bio-drying with landfill bioreactor in developing countries including not only the technical aspect but also the social and economic ones; furthermore, the planning system, which are critical steps in the overall process was done differently in each one of the studied cases and considered diverse aspects. In this order of ideas, it was not possible to adequately compare the cases between one another, creating the need of a unified evaluation system, which allows the comparison of their performances like the biogas production, which is the central aspect of the new facility.

Given these results, an operative guideline was designed in order to give advice about all the variables and considerations that should be taken into account when addressing a bio-drying with landfill bioreactor project. The central two main cores of the operational guideline are the planning system and the evaluation system, which were identified as significant stages.

The proposed planning system is integrated by the stakeholder analysis, environmental context analysis and the Bio-drying with landfill bioreactor plant analysis. The three of them try to integrate all the approaches that should be included and thought to design a bio-drying with landfill bioreactor facility. On the other hand, the evaluation systems aim to give an evaluation line to follow the performance of the bioreactor concerning biogas production. Moreover, given the possibility to modify the input data and adjust it to a new, different situation which can be applied in any developing country that this proposal can be useful for them. The evaluation system has the evaluation of the biogas production, which the estimated amount of biogas that could be produced if all the technical parameters have been followed according to the instructions, and also the situation of the labors that are needed to be implemented in the new facility.

However, the study presents some limitations which could be addressed in future researches, the most important one is the lack of application of the proposed operative guideline to a bio-drying with landfill bioreactor project, besides, it would be exciting to go further in the planning system, with specific charts and recommendations about how to complete the economic analysis. Moreover, it was difficult to find specific data about a bio-drying with landfill bioreactor in developing countries; this is one of the reasons why it is recommended to keep records and document at least the most important variables of these kinds of projects such as mass flows, costs, efficiency, population served, etc.

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