



**DEPARTMENT OF BIOLOGICAL AND
ENVIRONMENTAL SCIENCES**

**Title: "NAVIGATING THE FUTURE: A COMPREHENSIVE
LITERATURE REVIEW ON SOLID WASTE MANAGEMENT
IN AFRICA, WITH A COMPARATIVE ANALYSIS OF
NIGERIA, KENYA, AND RWANDA"**

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DEDICATION

I dedicate this work to **God Almighty**, for his grace, wisdom, and endless love for me throughout this journey.

To my beloved husband, **Acha Ivo Tebid**, for your love, support and patience. This accomplishment is as much yours as it is mine.

To my **family (Nwanege Hansel Acha, Nwanege Marshall Chi) and friends**, for their support, encouragement, love, and for believing in me.

ABSTRACT

Solid waste management (SWM) is a very crucial issue in Africa, aggravated by rise in population, rapid urbanization, change in consumer behavior and limited infrastructure. Though some African countries are experiencing progress with innovative waste management plans, they are continually confronted with challenges like limited data, inadequate funding, poor public involvement. This study aims to explore and analyze innovative waste management strategies in Rwanda, Kenya and Nigeria. Using a comparative analysis review, it explores the policies, innovations, challenges and opportunities within these countries and suggests a way forward for sustainable waste management in these countries and throughout the nations of Africa. This research has made use of research reports, journals and articles from Web of Science, ResearchGate, Google Scholar, and other reputable sources. The results demonstrate Rwanda's remarkable efforts, influenced by powerful governmental and community involvement, including a nation wide ban on plastic bags and the implementation of smart waste management systems. It also shows how Kenya is making use of artificial intelligence and progress in e-waste management which places emphasis on solutions that are technology-driven. Nigeria on the other hand is delving into circular economy business models for effective management of waste and economic growth. This study demonstrates best practices, difficulties and opportunities for enhancing SWM in Africa, giving key insights for policy makers and stakeholders.

Keywords:Innovative waste management , solid waste management,waste management in Africa, waste management in Rwanda, waste management in Kenya, waste management in Nigeria.

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ABBREVIATIONS

East African Organization (**EACO**)
Southern African Development Community (**SADC**)
Regional Strategic Development Plan (**RISDP**)
The Economic Community of West African States (**ECOWAS**)
The United States Environmental Protection Agency (**US EPA**)
Organization for Economic Cooperation and Development (**OECD**)
Material recovery facilities (**MRFs**)
Waste-to-energy (**WtE**)
Landfill gas (**LFG**)
Municipal solid waste (**MSW**)
Extended producer responsibility (**EPR**)
National Environmental Management Authority(**NEMA**)
National Waste Management Strategy (**NWMS**)
Electrical and Electronic Equipment (**EEE**)
Environmental Impact Assessment (**EIA**)
Rwanda Environmental Management Authority (**REMA**)
Environmental Management and Coordination Act (**EMCA**)
Waste and Circular Economy (**WCE**)
Ministry of Environment (**MoE**)
Ministry of Trade and Industry (**MINICOM**)
Centre for Innovation and Technology Transfer (**CITT**)
Kigali Institute of Science and Technology (**KIST**)
Republic of Rwanda (**ROR**)
National Domestic Biogas Program (**NDBP**)
Netherlands Development Organization (**NDO**)
Netherlands Directorate-General of Development Cooperation (**DGIS**)
Ministry of ICT and Innovation (**MINICT**)
Rwanda Information Society Authority (**RISA**)
the Norwegian Development Agency (**NORAD**)
Technical Vocational schools (**TVET**)
Canadian International Development Agency (**CIDA**)
Nigeria Circular Economy Working Group (**NCEWG**)
Nigeria’s circular economy programme (**NCEP**)
Nigeria’s circular economy road map (**NCERM**)
Extended producer responsibility (**EPR**)
National Environmental Standards and Regulations Enforcement Agency (**NESREA**)
Nigeria Circular Economy Working Group (**NCEWG**)
Nigeria’s circular economy programme (**NCEP**)
Nigeria’s circular economy road map (**NCERM**)
United Nations Development Program (**UNDP**)
Sustainable Waste Innovation for a Future in Transition (**SWIFT**)
Small and medium-sized enterprises (**SMEs**)

CHAPTER ONE - INTRODUCTION

1.1 Background

Africa is currently dealing with a huge social and economic transformation that has come as a result of rapid urbanisation, population growth and changes in purchasing habits of consumers. These changes brings about an exponential increase in waste generated in African countries (Fig 1). This puts more pressure on the existing waste management services and infrastructures in African countries thereby making the challenge faced with poor waste management systems even worse (Godfrey,et al 2019). The lack of quality available data about waste generated in Africa makes it difficult for different countries to develop innovative programs to improve the utilization of waste. Thus having a good understanding on what the current waste management situation is and developing innovative and strategic opportunities to improve the situation is therefore an important aspect to drive sustainable development in African countries(Romeela et al 2015).

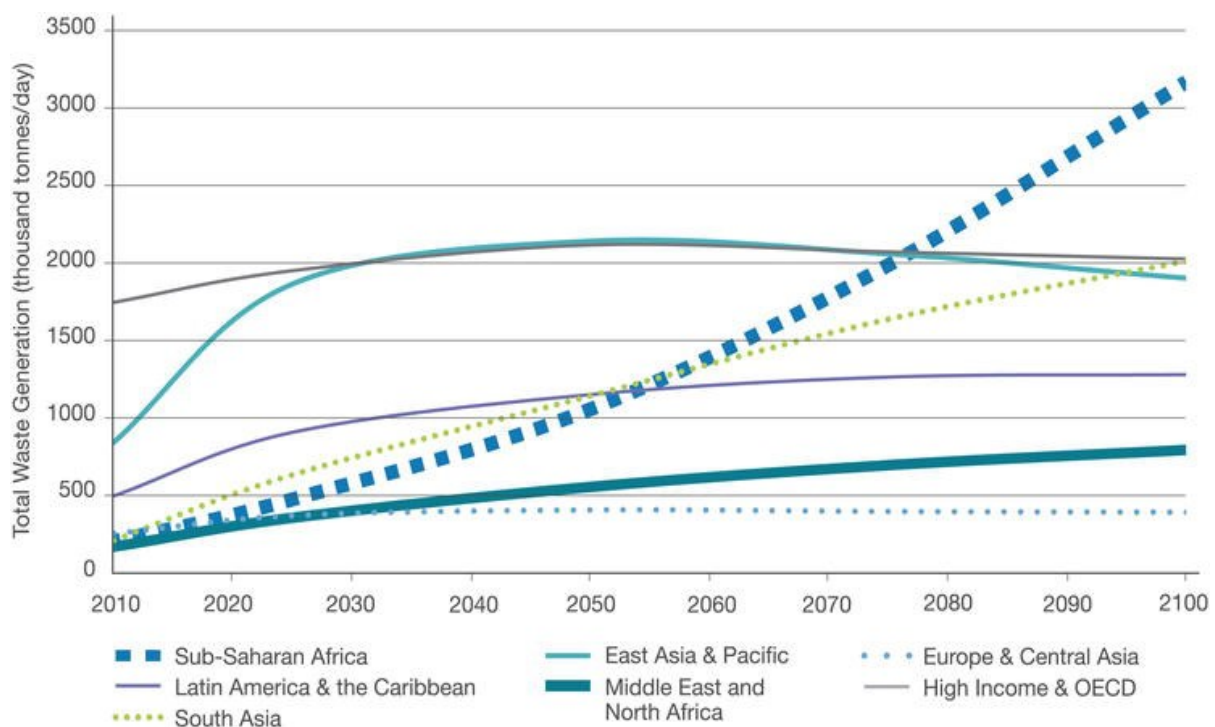


Figure 1 Projected increase in waste generation in Africa from 2010-2100.

Source: UNEP (2018)

The aim of this project is to contribute to explore the future of managing waste in Africa by analyzing innovations and opportunities for sustainable waste management in African countries, the challenges that comes with it and providing insightful knowledge and recommendations to advance waste management in African countries in a sustainable way. Kenya, Rwanda and Nigeria will be used as case studies because they represent different social and economic and environmental background that will give important insights into the diversity of waste management in Africa.

This project will make use of already available data, literature and knowledge of waste management project in the case study nations. It will comprise of a comparative analysis of the current waste management situation, the different options of waste management, present practice of waste

management. This will be done by looking at the successes, shortcomings, opportunities and innovations. And finally drawing from the trends, make recommendations for advancement of waste management in African countries.

This study is very important and timely to address economic issues that comes with increased urbanization, population growth and changes in lifestyle so as to realise a cost effective and efficient management of waste.

1.2 Problem statement

The management of waste in Africa is a serious and urgent matter with different issues and opportunities across nations. The present situation of waste management in nations across Africa like Kenya, Rwanda and Nigeria shows a wide variety of economic, environmental and governance challenges. Insufficient waste management actions have caused social issues, environmental degradation, and economic issues leading to a negative impact on the sustainable development in African nations (Romeela et al 2015). The absence of good innovative waste management infrastructures and strategies is a huge barrier to enable Africa in moving to a circular economy and has huge stumbling blocks to reaching the SDG goals. (Ezeah 2010). This research is thus motivated by the drive to fill the knowledge gap by analyzing and comparing current actions and drawing from that to recommend future sustainable actions for the management of waste.

1.3 Aims and Objectives

1.3.1 Aim

The aim of this project is to analyse innovations and opportunities for sustainable waste management in African countries, the challenges that comes with it and provide insightful recommendations for sustainable waste management . This will be done by carrying out a comparative analysis between Kenya, Rwanda and Nigeria. These nations are used as case studies because they represent different social, economic and environmental background that will give important insights into the diversity of waste management in Africa.

1.3.2 Objectives

- Carryout an extensive literature review study of solid waste management in African countries, to gain understanding of the already existing practices and shortcomings.
- Carry out a comparative analysis of waste management actions, policies, and initiatives in Rwanda, Kenya, and Nigeria by identifying the successes, innovations and shortcomings in waste management in these nations.
- Identify opportunities and trends for managing waste in these case study nations in a sustainable way by looking at current research and developments.
- Provide policy recommendations and actionable strategies based on the findings from the literature review and case study analysis to contribute meaningfully to the discourse on sustainable waste management in African countries.

1.4 Key policies guiding waste management in Africa

Waste management in Africa is a huge problem and serious and urgent attention needs to be given to it (Bello et al. 2016). National policies and strategies related to waste have been drafted to deal with this problem. Also, policies and legislation that is specific to each country have been developed. These policies are elaborated upon below (Bello et al. 2016).

1.4.1 Continental policies

The “Africa we want” 2063 plan that was drafted in 2013 is a 50 years plan to transform Africa’s social and economic framework. The plan is to build a prosperous Africa on the grounds of growth and sustainable development, listing 10 goals to direct the transformation (AUC 2015a). In the plan for the years 2014-2023, particular goals have been listed to be achieved in the first 15 years which includes guides to waste management transformation (AUC 2015b). Especially on the first goal which aspires to give everyone good quality of life, living standard and wellbeing and area 4 of that goal which gives priority to up-to-date, cost effective and liveable surroundings and good quality services. The goal also aspires for African cities to recycle at least half of waste generated by 2023 (UNEP 2018)

Health and Environment Declaration in Libreville (Gabon) in 2008 signed by nations in Africa. They committed to not allow environmental deterioration from affecting human health (WHO 2008). African nations committed to implement the Bamako convention 1991 which talks of banning the importation of waste into Africa and regulate the transportation of hazardous waste across Africa (AU 1991). They also committed to the implementation of the Bali declaration 2008 on “managing waste for the purpose of human health and wellbeing” (UNEP 2008). The declaration identifies the challenges that comes with implementing strategies to guard people from dangers that arise from degraded environment, uncleanliness, and inadequate management of waste etc. As a result of this 11 commitments were listed for the purpose of reducing the risk of environmental degradation and it’s effects on the health of the people (UNEP 2018).

1.4.2 Regional policies

2011 development plan of East Africa list out a wide range of December 2012 to 2015 strategic goals which includes particular achievable targets. It identifies that there is no good legislation, not much money and low service when it comes to municipal waste management and very little attention allocated to the management of solid waste which is a huge problem faced by many other nations. Although no specific strategy for waste management has been recommended, Objective 6 of Priority Area 4 in the development plan (focused on conserving the environment, sustainably managing resources, and mitigating the effects of climate change in East African nations) addresses key concerns such as plastic collection and management, as well as the creation of guidelines for electronic waste management. The plan outlines specific waste management targets, which include:

- By 2014, there should be a regional policy that address plastics and plastic waste management.
- By 2014, there should be an electronic waste management guideline (EAC 2011)

While there is no proof that a comprehensive regional policy to manage plastics has been developed, both Rwanda (2008) and Kenya (2017) have successfully implemented total bans on the use of plastic bags (NEMA, 2017). Other countries in the region have introduced partial bans. Additionally, in 2013, the East African Communications Organisation (EACO) developed a model framework for e-waste management to address the growing issue of electronic waste (EACO, 2013).

In 2001 the Southern African Development Community (**SADC**) came up with a Regional Strategic Development Plan (**RISDP**) which is a guideline that helps to direct the integration plan of the SADC from 2005-2020 (SADC 2001).

The RISDP has as objective to cause more integration in the SADC poverty will be eradicated and non economic and economic goals will be achieved. Major reasons for inadequate management of

wastes in the SADC countries were identified which includes; (i) High rate of generating waste, (ii) Inadequate ability to deal with the increase volumes of waste generated, (iii) high waste management cost, (iv) absence of good technologies and methods of disposing waste, (v) not enough material and man power available, and (vi) poor implementation measures. All these has brought about the rampant disposal of domestic and industrial waste in open sites in many SADC nations (SADC 2001). In order to handle these issues, concerned nations have made commitments to enhance good management of the environment by controlling pollution, managing waste and conducting environmental education which includes (i) education on waste and pollution that arises as a result of industrialization and urbanization, (ii) coming up with projects that will help curb pollution and manage industrial and domestic waste (SADC 2001). Though it is unclear if these countries have implemented these guidelines.

The Economic Community of West African States (ECOWAS) came up with a regional plan on electronic wastes in 2012, plan on managing chemicals and hazardous wastes in 2015 and a plan to manage plastics in 2016. The objectives of the plan on electronic waste was to add strength to the already available guidelines to help nations join forces to control the used electronic materials that are being imported and (ii) to encourage diverse government institutions and the government tiers in ECOWAS nations and organizations to work together (Osibanjo 2012).

1.4.3 International conventions

- Minamata Mercury Convention in 2013 (UNEP 2013a)
- Bamako convention to ban waste from being imported into Africa and to ban transport and management of hazardous waste across African nations which was developed in 1991
- The convention on persistent organic pollutant done in Stockholm in 2001 (UNEP 2011)
- Convention on stopping the disposal of waste and other substances and the marine pollution that was done in 1974 (UNEP 2009) which was aimed at stopping the release of waste into the sea which could harm humans, marine life and other resources, and distort other sea functions.
- The United Nation guideline on Climate Change done in 1992 which was updated in 2022

All these conventions are put in place to help nations manage waste in a sustainable way and record data about their efforts to implement the guidelines. All these plans and policies indicates that Africa has a commitment to improve the management of solid waste at all levels. Though there are no good results to these commitments due to the lack of implementation. (UNEP 2018)

2 CHAPTER TWO - LITERATURE REVIEW

2.1 What is Solid waste

Currently, there is still a lot of debate on what solid waste really is (Read, 2001). The weight of most of the definition is geared towards important elements like the material origin, its elements and ability to be harmful to the environment. The United States Environmental Protection Agency defines waste as substances that are considered as rubbish, effluent or unwanted as a result of a process or materials that are broken, spoiled or out of use US EPA,(2016). While Igoni et al., (2007) defines it as substances that are considered of no use to the consumer and needs to be despatched. The common grounds for both definitions is that it is the producer or owner who defines what waste is. Because of this research the EU framework Directive definition of waste will be used. According to the EU Framework solid waste can be defined as items which are despatched of or intended to and which follows these characteristics

- Trash from production and consumption
- Expired products
- Contaminated items
- Items whose function is not satisfactory (Europa, 2006).

2.2 Global views on waste management

For governments to be able to develop good and functional waste management systems, information about the types and volumes of waste that is generated is very vital (Kaza, Yao, et al 2018).

Presently, world municipal waste (MSW) generation is at 2.01 billion tonnes per year, meaning per capita waste generation per day is 0.74 kg. Out of all these wastes generated 323 million tonnes (16%) is being recycled and 46% is being released in an unsustainable manner (UNEP 2018).

As at 2018, Bermuda, Canada and USA recorded the highest amount of waste generated per capital which is 2.21kg daily (figure 2) (Kaza, Yao, Bhada-Tata et al 2018) while the lowest waste generation was recorded in the low and middle income countries like Cameroon and Chad. Sub-Saharan African nations has been recorded to generate 62 million tonnes per year with an average per capital daily generation rates at 0.65kg. This increased waste generation is due to population growth, economic growth and urbanization. (Hoornweg and Bhada-Tata, 2012)

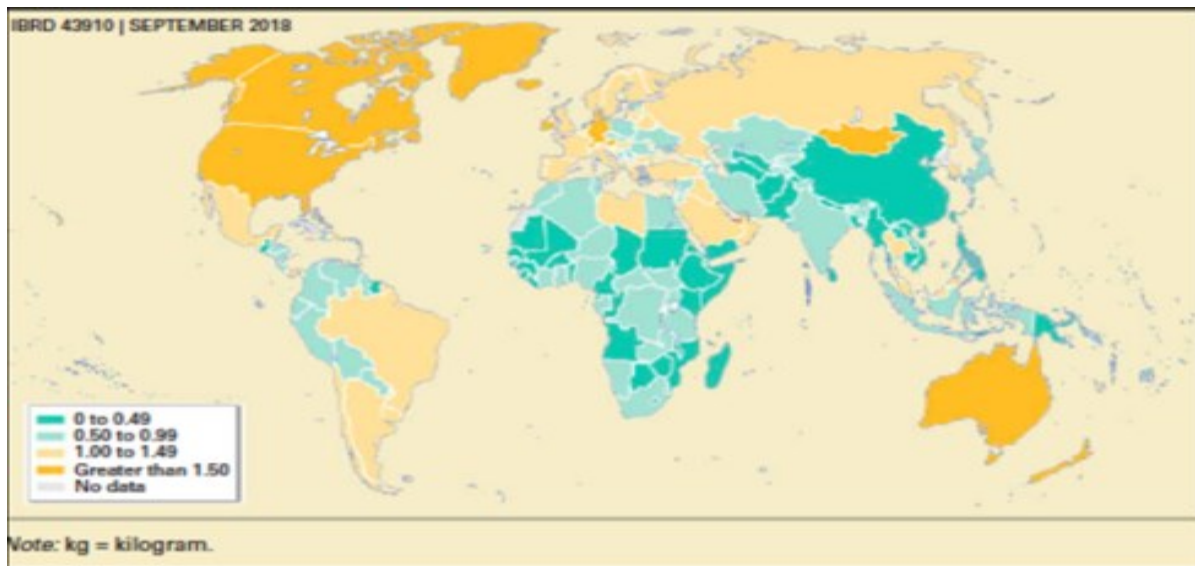


Figure 2 Amount of waste generated (per capita)

Source: Kaza, et al., (2018)

Global waste generation is expected to reach 3.4 billion by the year 2050 (Kaza, et al., 2018, p.24) with high income countries generating at a slower rate (figure 3), while in low or middle income countries, it is forecasted to double or even tripple over the next 300 years (Hoornweg and Bhada-Tata,2012)

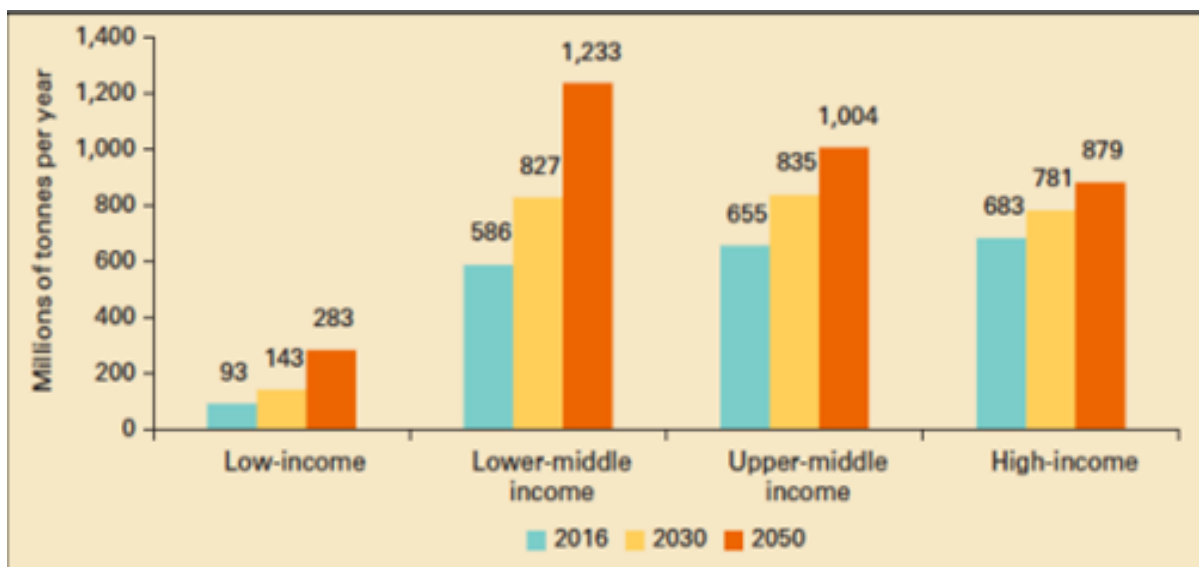


Figure 3 Projected waste generated based on levels of income.

Source: Kaza, et al., (2018)

Though USA produces the highest waste, it is able to recycle 35% of it's waste which is relatively low when comparad to the quantity of waste they generate. Germany has the most efficient system of managing waste, recycling up to 70% of it's municipal solid waste (Nichols & Smith, 2019). Generally high income countries focus more of their attention on material recovery (Hoornweg and Bhada-Tata, 2012)

Meanwhile, there is lack of efficient recycling system in developing countries with low income countries depending on open dumping due to lack of good landfills. Almost 93% of the waste generated in Africa is despatched of on open spaces, roads, in waterways etc which has negative effects on the environment (figure 4) (Hoorweg and Bhada-Tata, 2012)

Though developing countries have a far lower waste management system, developed countries still ship their waste to developing countries mainly because of lower cost of operation, lack of environmental regulations and cheap labour (Kaza, S., et al. 2018)

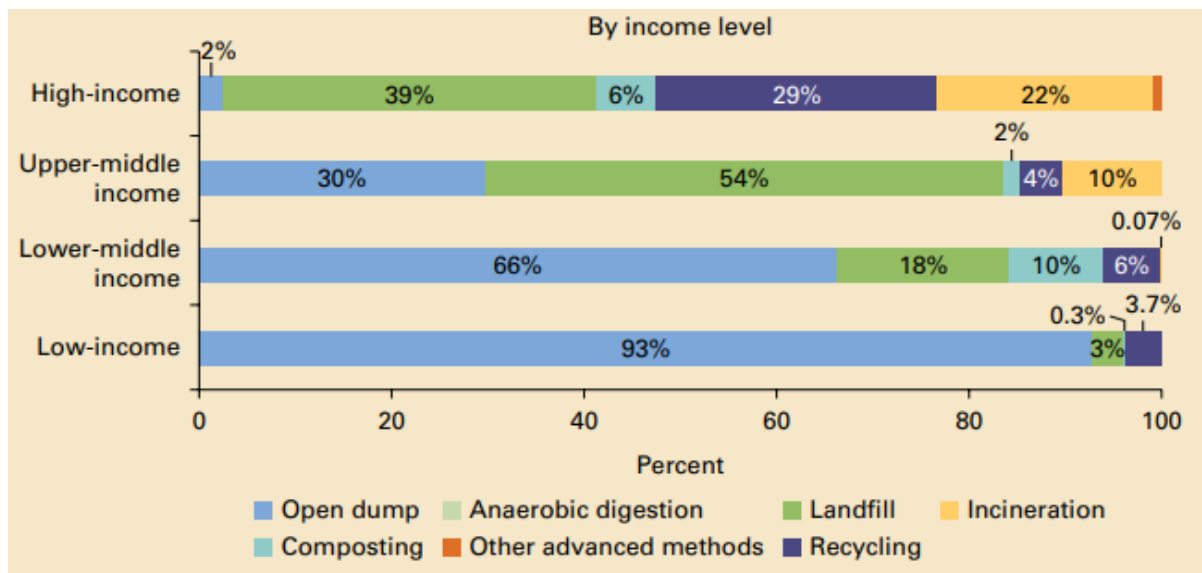


Figure 4 Disposal Methods Based on Levels of Income.

Source: Kaza, S., et al., (2018)

2.3 Present Situation of Waste Management in Africa

2.3.1 Management of solid waste

2.3.1.1 Waste generation

In 2012, Africa generated 125.0 million tonnes of MSW yearly. Out of which 18 million tonnes was generated by Sub-Saharan Africa (Scarlat et al. 2015). Sub-Saharan African nations possess a relatively lower per capita waste generation than North African nations (Figure 5A). In 2012, Africa generated an average of 0.78 kg of waste per capita per day, which is lower than the global average of 1.24 kg per day (Scarlat et al., 2015). Though there are some differences in the quantity of waste generated (Figure 5A), ranging from 0.09 kg daily in Ghana to 2.98 kg daily in Seychelles. Small – island states usually records high percapital rates of waste generation due to tourism and good accounting of their waste generated (Hoorweg and Bhada-Tata, 2012). There are also noticeable discrepancies in MSW generation through African nations (Figure 6A). South Africa (23.21 million tonnes), Egypt (18.35 million tonnes), and Nigeria (17.45 million tonnes) are among the top waste-generating countries in Africa, based on yearly estimates (Scarlat et al., 2015).

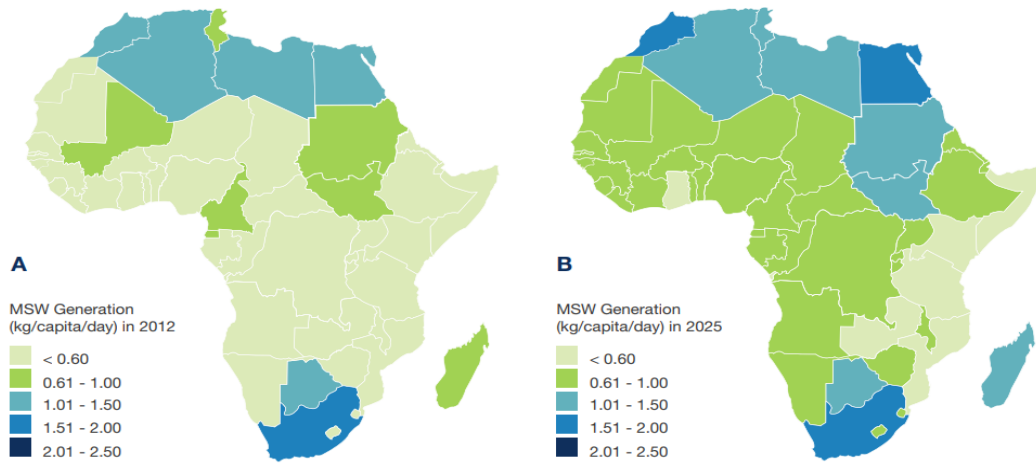


Figure 5 Spatial pattern of daily waste production per person in African nations in 2012 (A) and projected for 2025 (B)²
 Source: UNEP (2018)

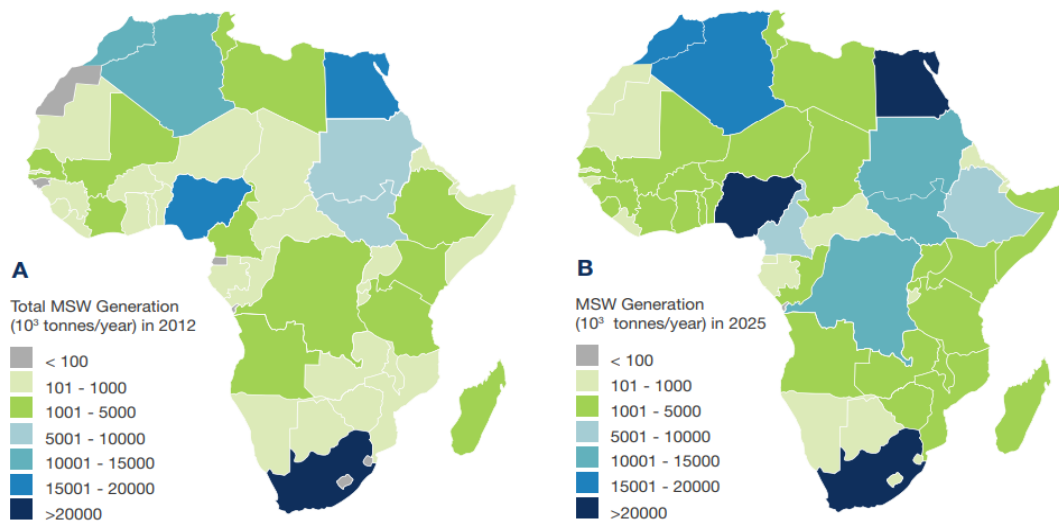


Figure 6 Total generation of MSW (10^3 tonnes/year) of African nations in 2012 (A) and projected for 2025 (B)³.
 Source: Daniel Hoornweg et al 2012)

The rate of MSW generation significantly vary amongst African cities ranging from 0.32 kg/capital/day in Addis Ababa, Ethiopia to 0.95 kg /capital/day in Lagos, Nigeria (Figure 7). This variations amongst citites is usually caused by lifestyle, culture and income level. (Kawai and Tasaki 2016).

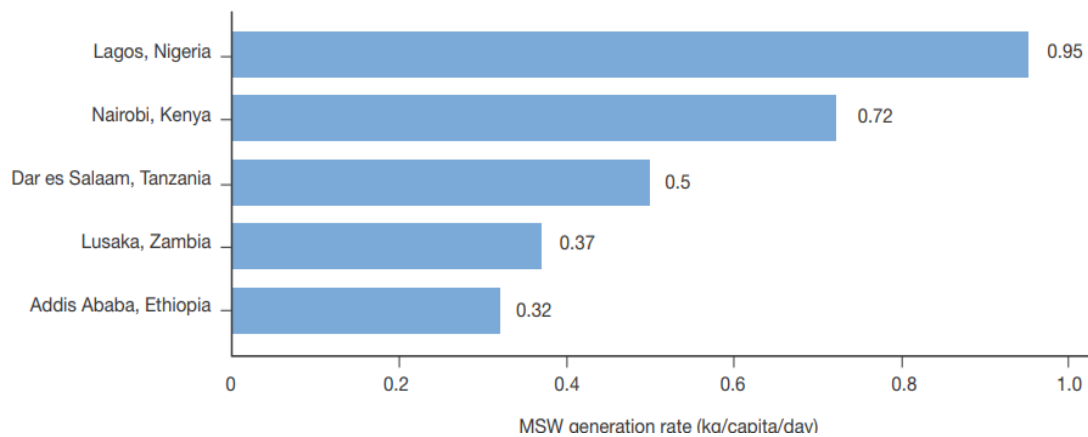


Figure 7: Amount of generated MSW in various cities in Africa

Source: Kawai and Tasaki (2016)

2.3.1.2 Waste composition

Waste composition has direct influence on its collection and disposal methods. MSW composition is usually shown in terms of the portion of metal, glass, paper, plastic, organic and other material (Table 1) (Hoornweg and Bhada-Tata, 2012).

Table 1 Sources and Types of waste.

Type	Source
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping, telephone books, paper beverage cups, shredded paper
Organic	Process residues, food scraps, wood, yard (leaves, grass, brush), waste
Glass	Coloured glass, broken glassware, bottles, light bulbs
Plastic	Packaging, bottles, containers, bags, lids, cups
Metal	Foil, cans, tins, non-hazardous aerosol cans, railings, bicycles, appliances (white goods)
Others	Textiles, rubber, leather, multi-laminates, appliances, e-waste, ash, other inert materials

Source: Hoornweg and Bhada-Tata, (2012).

World bank records shows that Sub-Saharan Africa generates 57% of Organic waste out of the total MSW that is generated (Figure 8) (Hoornweg and Bhada-Tata, 2012). Sub-Saharan Africa also generates 13% of plastics which is relatively higher than the global average. Waste composition is different for different cities according to their lifestyle, and level of income. Information from 11 cities in Africa records 60% of organic waste out of the total MSW though it varies amongst cities. Low and middle income nations generate mostly organic waste while high income nations generate diversified waste most of which are papers and plastics (10% of the MSW) (Table 2) (Hoornweg and Bhada-Tata, 2012). The fact that most of the waste generated in Africa is organic presents a significant environmental risk when it is released into landfills. However, it also indicates a substantial potential for effective waste management if appropriate waste treatment technologies are implemented (Hoornweg and Bhada-Tata, 2012).

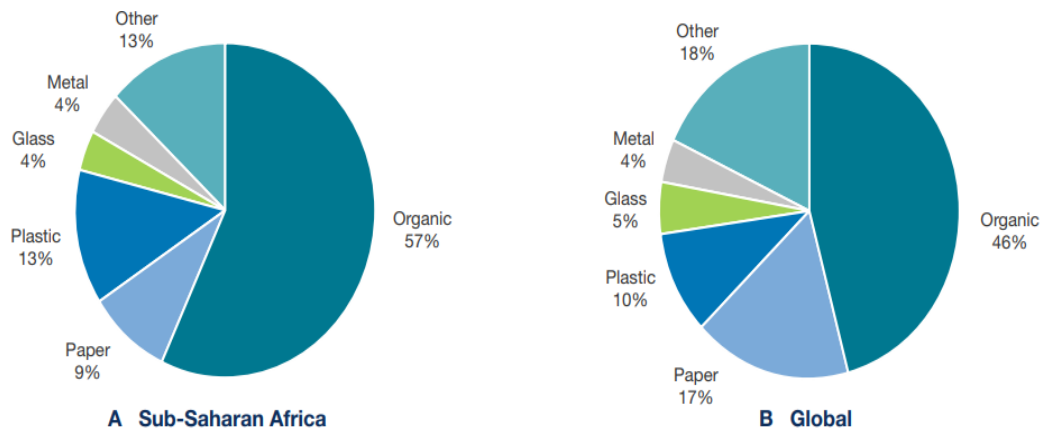


Figure 7 Composition of MSW in sub-Saharan Africa and the world at large.
Source: Hoornweg and Bhada-Tata (2012)

Table 2: Composition of MSW in some cities in Africa

City	Composition (percentage)						Reference
	Organic	Paper/ card- board	Plastic	Glass	Metal	Others	
Kampala, Uganda	77.2	8.3	9.5	1.3	0.3	3.4	Bello <i>et al.</i> (2016)
Dar es Salaam, Tanzania	71.0	9.0	9.0	4.0	3.0	4.0	Bello <i>et al.</i> (2016)
Ibadan, Nigeria	69.6	7.67	4.47	2.00	1.65	14.6	Adeyi & Adeyemi (in press)
Accra, Ghana	65.0	6.0	3.5	3.0	2.5	20.0	Oteng-Ababio <i>et al.</i> (2013)
Moshi, Tanzania	65.0	9.0	9.0	3.0	2.0	12.0	Bello <i>et al.</i> (2016)
Sousse, Tunisia	65.0	9.0	9.0	3.0	2.0	11.0	UN-Habitat (2010)
Nairobi, Kenya	65.0	6.0	12.0	2.0	1.0	15.0	UN-Habitat (2010)
Lagos, Nigeria	62.6	10.7	4.2	2.5	2.2	19.7	Adeyi & Adeyemi (in press)
Abuja, Nigeria	56.3	11.4	10.2	3.9	5.2	N/A	Imam <i>et al.</i> (2008)
Cairo, Egypt	55.0	18.0	8.0	3.0	4.0	12.0	UN-Habitat (2010)
Tshwane, South Africa	53.8	11.5	9.5	6.7	1.8	16.7	Komen <i>et al.</i> (2016)
Windhoek, Namibia	48.0	15.0	11.0	14.0	4.0	8.0	Hartz & Smith (2008)
Average	62.8	10.1	8.3	4.0	2.5	12.4	

Abbreviation: N/A, not available

2.3.1.3 Waste infrastructure and services

Infrastructure and waste services in most of the African nations is provided by the state, not the municipality because they are not financially and technologically capable to despatch good services since providing waste management services to the public is very expensive (McAllister 2015). Usually, the private sector is more able to give those services even more than the municipality can but the residents have to pay for it (Imam *et al.* 2008)

Many of the municipalities have had to join forces with the private sector in order to provide low cost yet good services leading to a better collection of solid waste (Bello *et al.* 2016). Therefore, the municipality is gradually shifting it's role from service to management of waste service (Le Courtois 2012). Most often, there are other actors that participate in the collection of waste and transfer

services. They include the informal sector, NGOs, associations, women etc. Table 3 illustrates the models used to deliver basic waste services in three cities in Africa.

The management of solid waste can take up a big chunk out of a city’s budget in low and middle income nations. Most cities sometimes spend between 20-50% of their yearly municipal budget on the management of waste (Dukhan et al. 2012, Kubanza and Simatele 2015). 50-90 % of that budget usually goes only to the collection of waste (Hoornweg and Bhada-Tata 2012). If residents in the municipality are not able to pay for their waste services, this can greatly affect the quality of services that is offered. According to UN Habitat 2010 less than 50% of people in cities in Africa are able to pay for their waste services. For example in Cameroon only 10% of the residents can pay for their waste services, the town of Moshi in Tanzania have 35% of the residents who can pay, Nairobi-Kenya has 45%.

Men and women possess disparities in perspective when it comes to using and disposal of waste. They also have differences in their willingness and their ability to pay for the services they get. In Ekitistate, Nigeria, women have more willingness to pay than men would do. (Adebo and Ajewole 2012). Therefore, when drafting policies and guidelines to advance waste services, the differences in gender should be taken into consideration.

Table 3 Model of delivering basic waste service in some African cities

Country	Sweeping	Collection and transfer	Recycling	Treatment	Disposal
Maputo (Mozambique)	Municipality	Private sector and municipality	Private sector	N/A	Municipality
Ouagadougou, (Burkina Faso)	Private sector under municipal control	Private sector and municipality	Private sector and municipality	Municipality	Municipality
Qena (Egypt)	Municipality	Private sector and municipality	Private sector and municipality	N/A	Municipality

Source: GIZ (2014)

2.3.1.4 Waste collection

In 2012, 68 million tonnes (55%) of all MSW was collected out of all the generated waste in Africa (Scarlat et al. 2015), out of which 44 % came from Sub-Saharan Africa. In some African nations, the rate of collection varies between 18% to more than 80% (Figure 9). By 2025, it is forecasted that the rate of collection will rise to 69% (UN Habitat 2024 . Even though the waste collection rate is expected to increase, the uncollected waste will not decrease due to the anticipated rise in municipal solid waste (MSW) generation. As a result, Africa will likely continue facing challenges with MSW collection until 2025, posing ongoing risks to human health (Scarlat et al., 2015).

The Collection coverage (proportion of residents who receive waste collection services) in African nations varies significantly from 25-99% (Figure 10). (UNEP 2015). This variation can occur not only between countries but also between cities within the same country. For example, in Lagos,

Nigeria, and Sousse, Tunisia, collection coverage exceeds 90%, while in Jammima, Ethiopia, and Wa, Ghana, it is around 55%. Also in a nation like Ghana, we find notable differences in collection coverage between cities like Wa (28%) and Accra (80%). This could be as a result of the structural differences in the community.

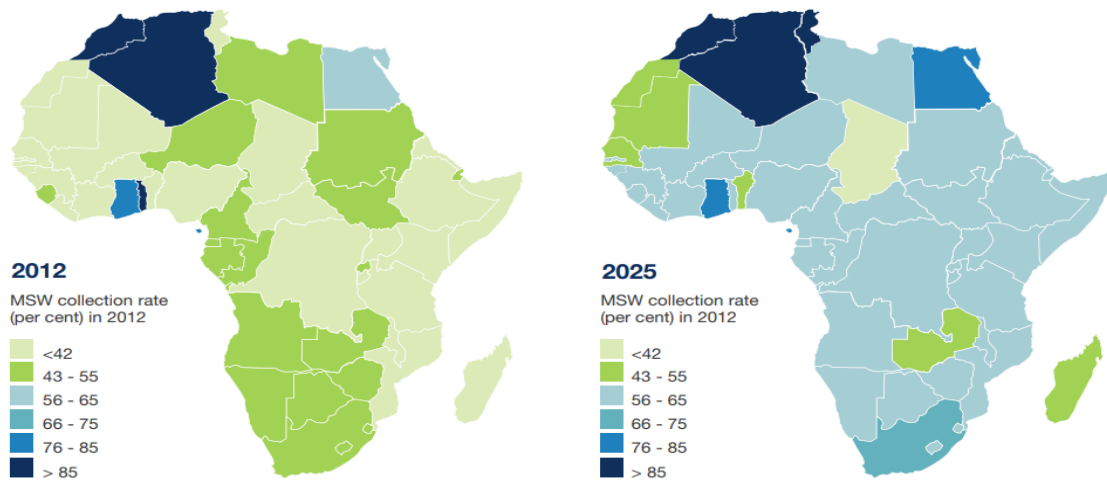


Figure 8 Rate of MSW collection(in percent) in 2012\2025
Source: Hoornweg and Bhada-Tata (2012) and Scarlat et al. (2015)

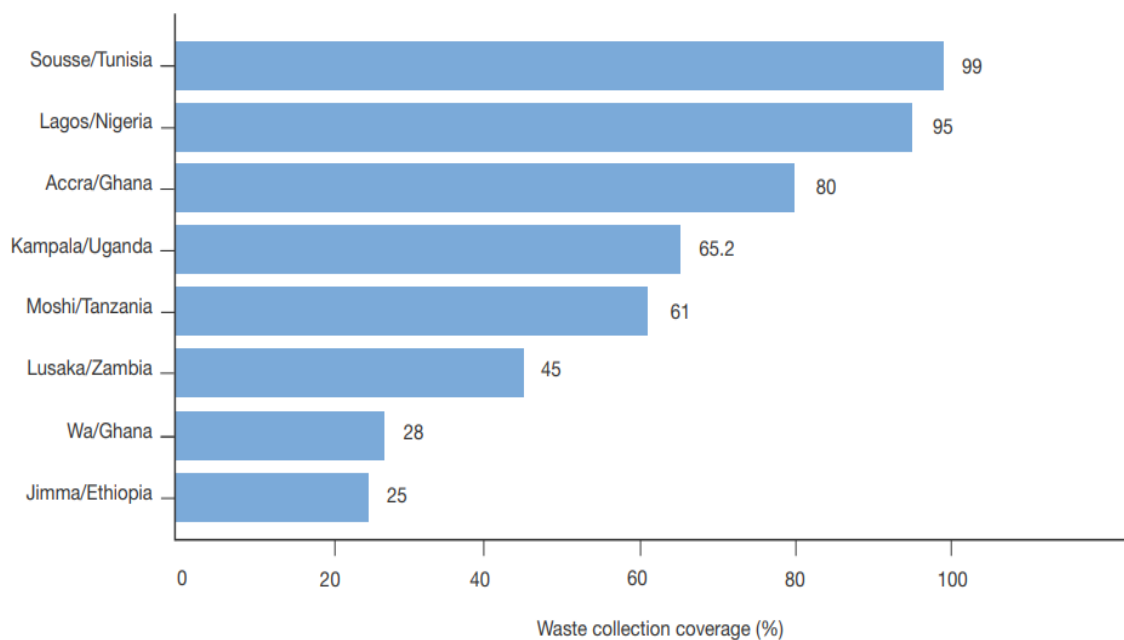


Figure 9: Collection coverage of MSW in some African cities.
Source: UN-Habitat (2010), Getahun et al. (2012), Madinah et al. (2014)

More so, collection services can also vary within the city as well where waste collection services is enjoyed only by residents who reside in the center of the cities and in the rich neighbourhoods (Medina 1999). Collection coverage in low and middle income countries could vary from 90% in cities to 10% in local areas (UN-Habitat 2010). This often leads to uncontrolled dumping and accumulation of waste that is not collected in open areas like the markets, near houses, water courses, street corridors, drainage paths etc (Simelane and Mohee 2012).

In most cities in Africa, the model for delivering waste services can vary between cities and between towns and cities due to the differences in the road infrastructures (Table 4) (GIZ 2014). In the cities and towns, basic collection is not require so much finances because it is done by little and medium scale service providers (Le Courtois 2012, UN-Habitat 2010, GIZ 2014). In the rural areas with poor road infrastructures, collection services are done by the communities with the use of manual materials like tricycles, wheel barrows etc (GIZ 2014). In urban areas, collection of waste is characterised by door to door services (Bello et al. 2016). In cities in Africa, transport vehicles used to transport waste include lorries, trucks, tippers etc. The number of times waste is collected vary between and within cities. Frequency of collection is higher in high income areas than in the low income areas (Mpofu 2013, Bello et al. 2016). Eventhough the collection of waste is usually done by the municipality of private sector, the informal sector also play a significant role is the collection of waste (Figure 11). For example, in Nairobi, Kenya, the city council collects 500 tonnes daily, the private sectors collects 500 tonnes daily and the informal sectors like the waste pickers and recyclers collects 350 tonnees daily (Mwesigye et al. 2009).

Table 4 Methods of collecting MSW in two African cities

City	City area	Primary collection	Collection point	Secondary collection	Transfer station
Maputo, Mozambique	Inner city	1.1–2.5 cubic metre containers		Motorized communal collection	
	Residential inner city	Motorized door-to-door collection, one step			
	Suburban areas	Manual block collection	Large containers	Trucks	
	Rural areas	Self service	Unmanaged drop off point	Motorized communal collection	
Gena, Egypt	Urban areas	Manual block collection	Collection trucks	Trucks	
	Semi-urban areas	Motorized door-to-door collection, one step			

Source: Adapted from GIZ (2014)

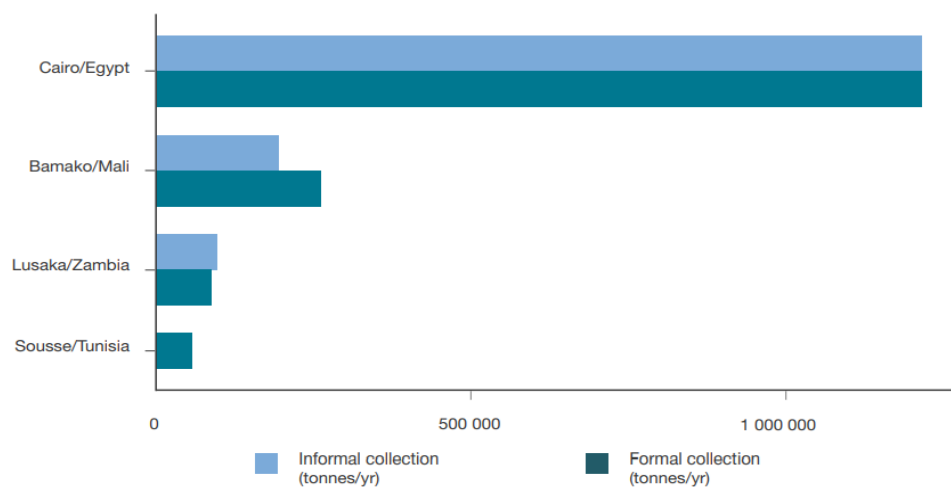


Figure 10 Amount of waste collected (formal and informal) in some cities in Africa.

Source: UN-Habitat (2010), Gunsilius et al. (2010)

Approximately 56% of people in the urban areas in Sub-Saharan Africa reside in slums (UN, 2017) where there is little or no availability of waste collection services partly because of poor roads and waste infrastructure (UN-Habitat 2010). The roads in these areas are unpaved, narrow, sloping and slippery and with these kind of roads, recent system of waste collection cannot be implemented. There is a need for innovative ways to ensure that these areas receive waste collection services.

Even though majority (60%) of the African people live in the rural sector (World Bank 2015), there is very small or no services provided to manage waste (UNEP 2015). It is not easy to collect waste in such areas because the houses are scattered all over the area. There is also the illegal dumping or open burning of wastes (Hangulu and Akintola 2017). This is becoming a huge problem especially as more and more plastics, diapers, and health care items are being consumed. There is very little information about the waste generated in rural areas (Jakobsen 2012), even the quantity of waste, where it comes from, composition and how it is managed. The general assumption is that rural areas don't generate much waste because they have smaller consumption, small usage of packaging, low income, and increase level at which items are reused (Hoorweg and Bhada-Tata 2012). Because waste from rural areas are usually more organic, it is usually reused and recycled (composting and anaerobic digestion) (Couth and Trois 2012, Jakobsen 2012).

There is significant potential for using biogas and composting techniques to manage organic waste and meet the demand for energy and fertilizer in African rural areas (Rupf et al., 2016).

2.3.1.5 Waste disposal

In Africa, waste is predominantly disposed of in either controlled or uncontrolled ways because these methods are more cost-effective compared to more advanced waste management practices (Figure 12) (UNEP 2015). This reliance on cheaper disposal options often leads to environmental degradation and public health risks. In low-income nations, only 35% of waste is disposed of in a controlled manner, whereas in middle-income nations, this figure rises to 68%. This discrepancy reflects the differences in infrastructure, resources, and regulatory enforcement between these income groups (UNEP 2018).

Currently, nations in Africa are gradually improving their infrastructure for end of life waste. They are improving from unmanaged to managed dumping, managed landfills, and sanitary engineered landfills. Though it has been proven that it is challenging to operate engineered landfills in line with the guidelines once it has been established. For example, Bishoftu city in Ethiopia constructed a sanitary landfill in 2013, but it became operational in 2016 because of lack of financial and human resources to operate the structure (Veses et al. 2016). One way to solve this problem is for the municipality to allow the private sector to operate the landfill while the municipality apply stringent operational requirements. Methods of disposal vary amongst African nations (Figure 13). African nations are also making some positive changes when it comes to disposal. They are changing uncontrollable disposal to controlled disposal and disposals in landfills.

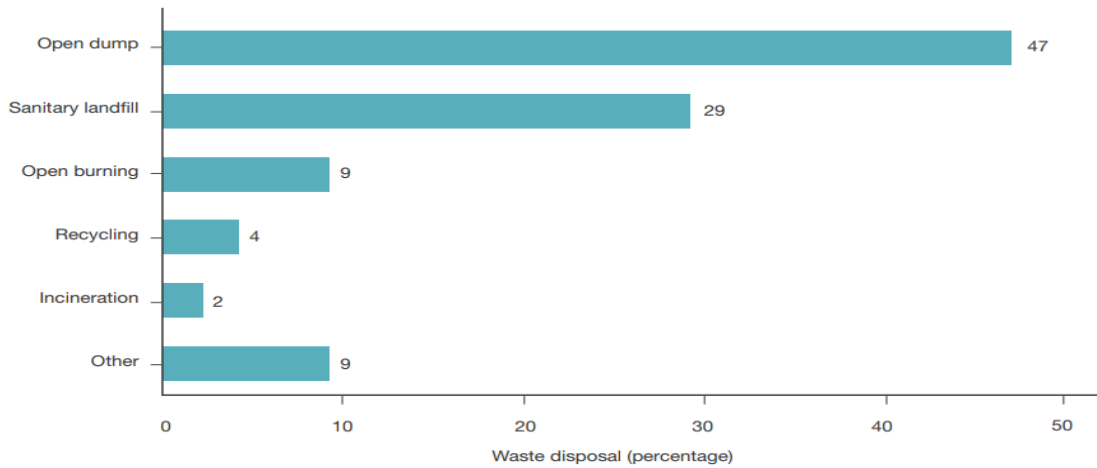


Figure 11 How end-of-life MSW is disposed in Africa.
 Source: Hoornweg and Bhada-Tata (2012), Periou (2012)

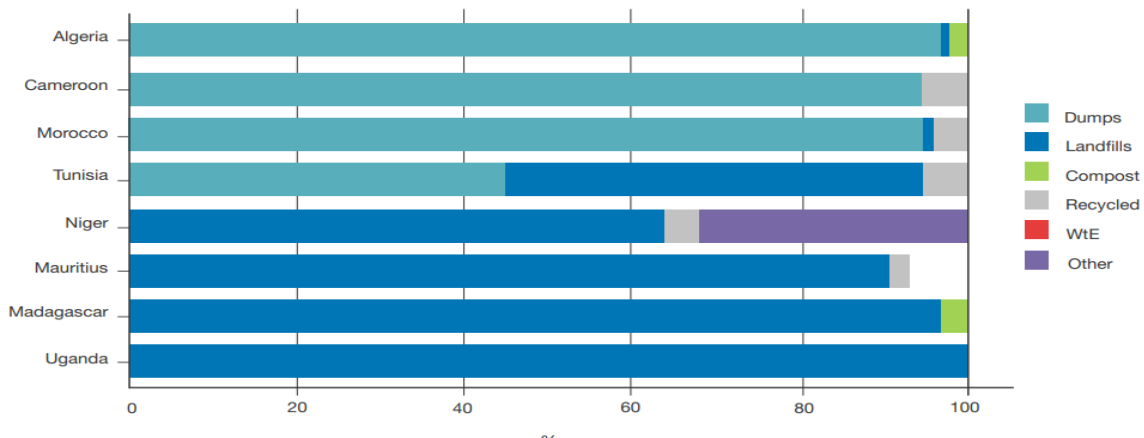


Figure 12 Methods of disposal of MSW in African nations.
 Source: Hoornweg and Bhada-Tata (2012)

2.3.1.6 Waste recycling

The rate at which Africa recycles its waste is just 4%, which is less than the average rate of recycling in many OECD nations (Organization for Economic Cooperation and Development) which was recorded at 30% in 2013 (OECD 2015a, 2015b). Sub-Saharan nations have only minimally organized recycling systems.

Some municipalities in countries like in South Africa has set up an on the site material recovery facilities (MRFs) (CSIR 2011 or WMO Africa), while some other municipalities don't yet have the logistics they need to segregate and separate the collection of wastes that can be recycled (CSIR 2011, Hoornweg and Bhada-Tata 2012).

Since recycled waste is primarily carried out in an informal way by households and the informal sector, the availability of information on recycling in Africa is lacking (Wilson et al. 2009, CSIR 2011, Godfrey et al. 2016). The waste pickers who constitute the informal sector reclaim the recyclables like plastics, ferrous metals, paper, glass and sell them to businesses that deal with

recyclables (Imam et. al. 2008, CSIR 2011, Hoornweg and Bhada-Tata 2012, GIZ 2014). E.g Yearly, the informal sector the city of Moshi in Tanzania recovers 11,162 tonnes of waste which is 18% of all the generated waste (UN-Habitat 2010). In Cairo, Egypt, South Africa and Moshi, Tanzania, there has been interestingly high rate of recycling which has been attained by the informal sector (UN-Habitat 2010, CSIR 2011).

The rate of collection of recycled items varies between African cities (Figure 14). Rate of collection is high (85%) in some cities like Bamako (Figure 14) and low (10%) in other cities like Lusaka, Addis Ababa and Sousse. It is high in Bamako because there is a good market for swine consuming and soil conditioning of recycled items (UN-Habitat 2010).

Sometimes, the non formal waste pickers function with strong assistance from the municipality as seen in countries like Tunisia and Morocco, Even though these services that are given by the informal waste sector is accorded little appreciation by the people and the municipality. For example, in Abuja, Nigeria, they were accused of illegal dumping (Imam et al. 2008), stealing public items like electric cables, aluminium railings, and iron bars to sell the metals from it (Godfrey et al. 2016) while in South Africa in 2014, the informal waste sector help the municipality save US\$20–50 million every year in landfill airspace. Therefore Africa has as a challenge to make use of the positive input that waste pickers brings through good participation, assistance and incorporation into the traditional waste economy (Wilson et al. 2006).

In Africa, there is limited knowledge that is made known when it comes to secondary material value chain. Some of the recycled items when sold abroad brings in revenue to the nations. E.g Senegal made US\$20 million and Tunisia made US\$30 million from exporting scrap metal, retrieved aluminium and plastics on 2007 (Chalmin and Gaillochet 2009) (Figure 15). Though countries like

China has established bans on recyclables. This will have a negative impact on nations that have a market for recyclables. Nations like South Africa have become resilient to shocks in the world recycling markets. 4.6% of their packaging and paper that needs to be recycled is gathered to be sold abroad (CSIR 2017). Lusaka, Zambia, Cairo, Egypt has saved US\$1.7 million and US\$16.9 million because they recycled waste that was meant to be disposed of in landfills.

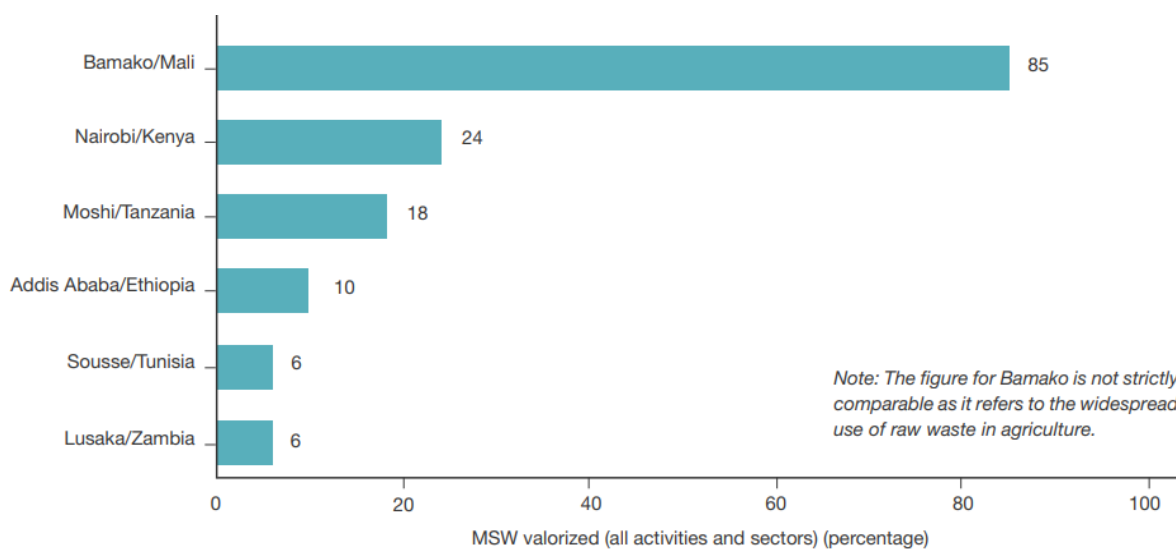


Figure 13 Rates of Recycling measured in percentage in some African cities.
Source: UN-Habitat (2010), Regassa et al. (2011)

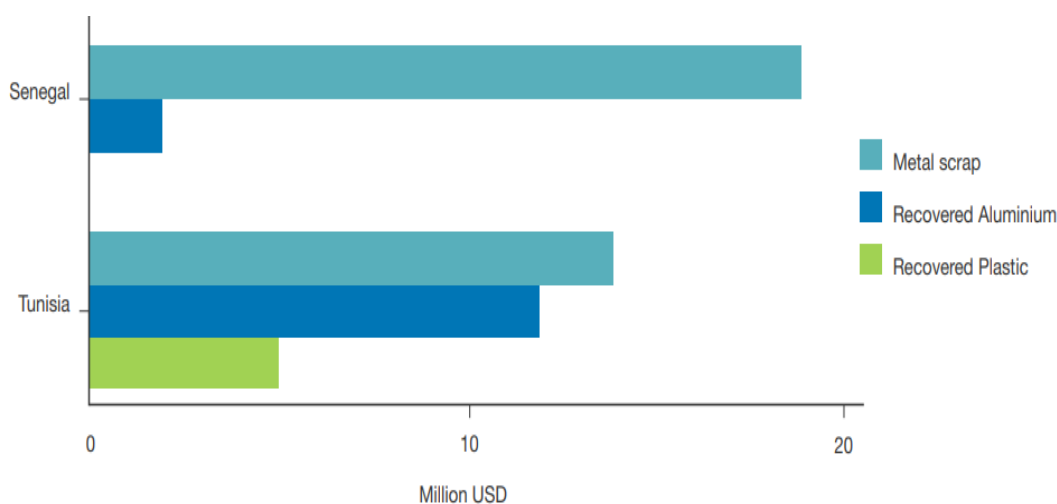


Figure 14 Money made from selling recycled materials overseas.
Source: Chalmin and Gaillochet (2009)

2.3.1.7 Treatment of waste and energy recovery

Other ways of treating waste like waste-to-energy (WtE) is also scarcely practiced in Africa with only just a little number of it that has been done successfully (Johannessen and Boyer 1999), like the project on eThekweni landfill gas (LFG) to power in Durban, South Africa. This project generated 7.5MW of power from 2 landfill areas (Kayizzi-Mugerwa et al. 2014).

In 2012, Africa had the potential to generate 1,125 PJ of energy from landfill gas (LFG) recovery and incineration (Scarlat et al. 2015). The fact that the continent has such potential is very important to the future of energy supply in Africa given the fact that in 2010, energy supply was at 29,308 PJ. (Scarlat et al. 2015). It was also recorded in 2012 that Africa has the potential to produce 62.5 TWh energy from generated waste which is about 9.5% of the entire power consumption which is 661.5 TWh as recorded in 2010 (Scarlat et al. 2015).

Some African nations are making great effort at pursuing green energy like harnessing waste to energy potentials like Ethiopia who is constructing a present-day incineration equipment in Addis Ababa which has a power production capacity of 50 MW. In 2013, a biogas pilot project was done in Ikosi market in Lagos, Nigeria which is about 10Kw WtE. Though this project has not proven to be sustainable over time (UNEP 2018). It is also noted that in Africa, there is a great potential for degradable waste like industrial biomass in which utilises technologies like anaerobic digestion and LFG recovery. For this to be fully effective, they have to think about the fact that the organic waste has a lot of moisture in it which means that they should seriously consider using WtE methods like anaerobic digestion like the local biogas project carried out in Rwanda (UNEP 2018).

2.3.2 Waste from disasters

In most African nations, the most frequent form of disasters come from drought and conflicts which could result in people moving from one place to another in search of safety. For example, in 2014, 3.7 million refugees was recorded in Sub Saharan Africa and the number keeps rising (UNHCR 2015). These refugees are hosted in small tents in camps where there no effective provision of waste management service and no waste management infrastructure. Oftentimes, solid waste is usually

buried at corners in the camps or burned with no regulation (Bjerregaard and Meekings 2008). About 45,000 refugees from Liberia entered Ghana and were kept in the Buduburam refugee center between 1990 to 2003 (Omata 2012). This settlement has a good waste collection structures which is not the case for other camps like the Saharawi camp in Algeria with above 250,000 inhabitants with poor leaving conditions since 1979.

2.3.3 Hazardous waste

A good number of African nations are participating in international conventions on cross-border movement of hazardous waste, though there are no good and effective structures services that are put in place to manage hazardous waste from homes, industries and commercial areas around African nations. Due to lack of data, the size and composition of hazardous waste that is generated in Africa is hard to determine with accuracy (UNEP 2015) and there are little or no functional structures to manage hazardous waste from homes. As a result, hazardous waste from homes like paints, batteries, cleaning chemicals, pesticides are flushed down the drain to the soil which can potentially cause significant environmental or human health effect (Edokpayi et al. 2017, Mmereki et al. 2017).

In developed nations, there are stringent rules for the collection , treatment and release of hazardous waste from municipalities and industries while in developing countries, there are no good structures to manage it. These differences stem from the legislations put in place and as a result, hazardous waste is transported to nations with weak occupational safety and guidelines, weak environmental laws, and weak governance and monitoring (ISWA 2011:3). Here hazardous waste is transported illegally from developed nations to African nations since it is inexpensive and are usually done without treatment. For example, in the 1980s Italy shipped 18000 barrels of hazardous waste to Koko, Nigeria and Norway shipped 15,000 tonnes to Guinea (Mott 2016). It was as a result of the fact that some developed nations and African nations were concerned about these illegal dumping of hazardous waste by developed nations that the Basel Convention and the Bamako Convention was created (Schluep et al. 2012).

The increased generation of hazardous waste in African nations arises from various sources, including electronic waste, medical waste, and agricultural waste. In response, African countries are gradually halting the cross-border movement of hazardous waste, a shift that has left some nations, with limited market potential, struggling to improve their local waste management systems. For instance, the electronic waste recycling center in Nairobi, Kenya, was unable to secure approval to import enough e-waste to remain profitable (Mott, 2016). As a result, it is critical for African nations to reduce hazardous waste transportation across borders and focus on developing local markets to achieve sufficient economies of scale. This would facilitate investments in specialized waste equipment and structures to enable proper recycling, treatment, and disposal (Mott, 2016). Achieving this requires fostering a conducive environment through sound regulations and policies, strong institutions, effective waste administration, stringent enforcement of legislation, and systems that encourage private-sector investment.

2.3.4 Medical waste

There is very little knowledge on medical waste in Africa. It was recorded that 67,740 medical centers across Africa generated an estimate of 282,447 tonnes of medical waste annually (Udofia et al 2013). Due to increased standard of living in African nations, medical waste generated is rising. Algeria and South Africa which are upper and middle income nations produced 30,000 and 46,291 tonnes of medical waste annually respectively (UNEP, 2018).

The portion of hazardous waste from the medical waste ranges between 10-25%. Hazardous medical waste in Africa is high due to bad handling of the waste leading to the pollution of the non hazardous portion of the medical waste (Udofia et al. 2015).

In Africa, medical waste management is made up of open dumping, unguarded releases from incineration and bad management of waste treatment facilities. Acquiring other technologies for the treatment of waste and good landfills in many nations needs to a greater extend a more exclusive capital funding in technology and structure more than what is presently happening (UNEP, 2018)

2.3.5 Agricultural chemicals and outdated pesticides

The major economic performance of many African nations is agriculture. Many governments in Africa have been making efforts to increase the production of food by using more inputs for agriculture like pesticides and fertilizers. Most of the pesticides and agricultural chemicals used are outdated mostly because of poor stock control, insufficient organization, buying of poor products, excess donations, pesticide bans and economic interest (FAO 2017). Records show that about 50,000 tonnes of outdated pesticides have been piled up in the Sub-Saharan African region (WHO 2014). In (figure16) we see the quantity of outdated pesticides that have been piled up in open areas in African nations in 2008; The highest amount of outdated pesticides was piled up in Tanzania, next is South Africa and then Eritrea.

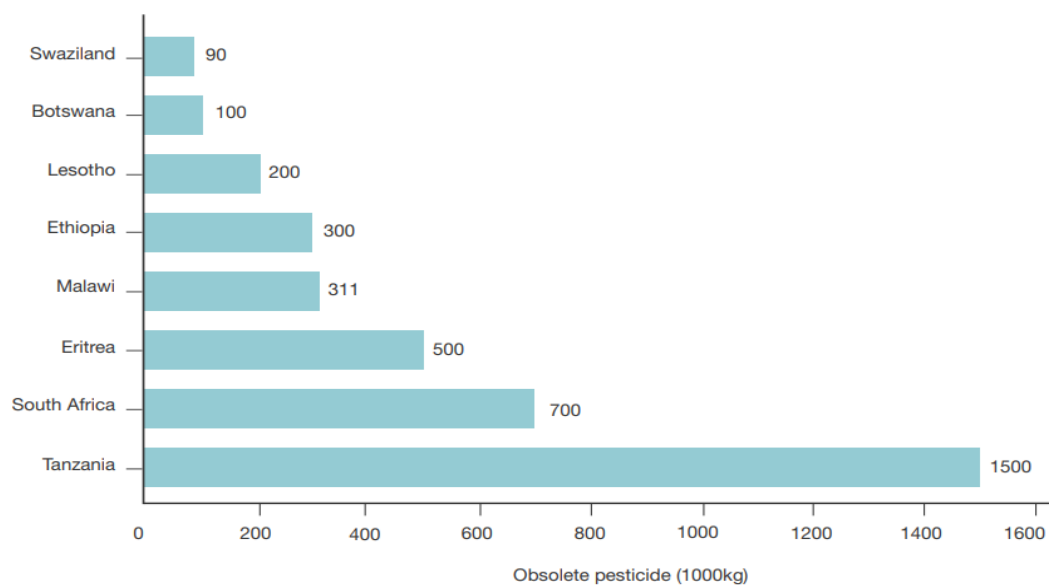


Figure 15 Amount of pesticides in African Countries that are out of date.

Source: WHO (2014)

2.3.6 Electronic waste

Africa generated approximately 2.2 million tonnes of electronic waste in 2016. Out of which 3 countries generated the highest; Egypt generated 0.5Mt, South Africa and Algeria generated 0.3Mt. In Africa, per capita generation of electronic waste is 1.9kg yearly. Comparatively, it is 16.6kg in Europe and 11.6 kg in America (Baldé et al. 2015). There is very small knowledge on Africa's collection rate. Although, the generation of electronic waste per capita ranges considerably across

African nations (Figure 17) .The generation of electronic waste per capita for Seychelles is 11.5kg, Libya is 11.0 kg and Mauritius is 8.6 kg (Baldé et al. 2017).

The amount of electronic waste is rapidly rising in Africa due to the rise of EEE demand and supply. For Example, the amount of cell phones and computers has risen by factors of 10 and 100 respectively (Schluep et al. 2012). Moreso, these EEE has a short lifespan due to fast technological changes (UNEP, 2015) and/or importation of used products (Schluep et al. 2012). In Senegal, Uganda and South Africa, electronic waste is projected to rise by a factor of 2 to 8 in the next decades (Bello et al. 2016). According to the 2022 statistics from the Global E-waste Monitor (2024), Africa generated 3.5 billion kilograms of e-waste locally. Additionally, it was recorded that 546 million kilograms of e-waste were imported into Africa through both controlled and uncontrolled means. This significant volume of imported e-waste exacerbates the already existing waste management challenges in the region.Nations in West Africa, particularly Nigeria and Ghana, experience high volumes of direct imports of used electrical and electronic equipment (EEE)(Table 5), a situation largely driven by the lack of stringent laws and regulations that restrict or discourage the importation of such materials. Nigeria, for example, generated 500 million kg of e-waste in 2022, and is the largest importer of used EEE on the continent(Global E-waste Monitor,2024).

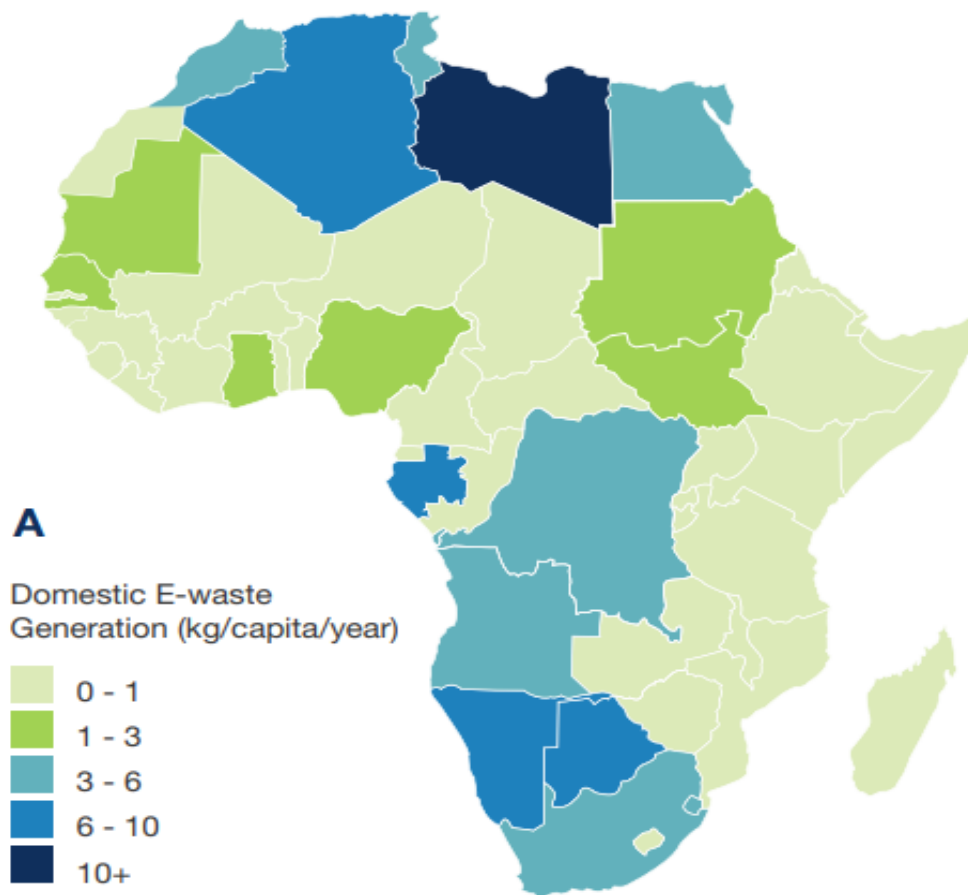


Figure 16 Amount of e-waste created in Africa locally.
Source: Baldé et al. 2017.

Table 5 Import of electronic and electrical equipment, generation and use of e-waste data for some African nations.

Country	Year	EEE imports tonnes per year	EEE in use tonnes per annum	E-waste generated Tonnes per year
Benin	2009	16 000	55 000	9 700
Côte d'Ivoire	2009	25 000	100 000	15 000
Ghana	2009	215 000	984 000	179 000
Liberia	2009	3 500	17 000	N/A
Nigeria	2010	1 200 000	6 800 000	1 100 000

Source: Schlupe et al. (2012)

All these difficulties in effectively managing electronic waste is as a result of the lack of good structure to efficiently manage electronic waste, lack of legislation that deals with electronic waste effectively and a framework for end-of-life product. Additionally, there is a significant shortfall in mass education and public awareness regarding the risks and issues associated with the uncontrolled import of near-end-of-life and end-of-life electrical and electronic equipment (EEE). This combination of factors hampers the region's ability to manage e-waste sustainably.. The only nations that got a validated for the electronic waste legislation was Madagascar in 2015, Kenya in 2016 and Ghana in 2016. Nations like South Africa, Cameroon and Zambia are still developing their legislation (UNEP 2018).

Projects on electronic waste like the E-Waste Management Initiative (East Africa), has created a lot of awareness and improved knowledge for so many African leaders and the international society. This has lead to the declaration made in Nairobi on sound environmental management of electronic and electrical waste, the declaration made in Durban on electronic waste management in Africa, the Abuja platform on electronic waste and the Call for action on E-waste in Africa (UNEP 2018).. In 2012, UN Environmental headquarters in Nairobi organized the first Pan-African Forum on electronic waste to analyse the project findings (SBC, 2011) and identify key areas requiring intervention in the management of e-waste across the continent.

All of these documents and actions have been of good help in advancing the topic of electronic waste in national action plans in Kenya, Ghana, Nigeria, South Africa and Tanzania for example (Mogilska et al. 2012). Presently, there is an intense drive to implement some rules to guard illegal movement of electronic waste. Some African nations like Egypt, Nigeria are thinking of setting up new regulations for electronic waste for example, new rules in Egypt have stopped working EEE that is above 5 years old from being imported. (Heacock et al. 2016). Although, if a total ban is implemented, it can reduce the legal transportation of electronic waste to areas where there is efficient recycling infrastructure.

In order for African nations to deal with these challenges, they need to come up with and implement good legislations and regulation to handle the rising transportation of electronic waste across borders and utilised EEE and also support extended producer responsibility (EPR). They also need to set up a good structure for material recovery. General education and creating awareness is also very essential to implement legislations on electronic waste and maintaining the infrastructures on electronic waste.

Even though the transportation of electronic waste across African nations can form another source of income for their economies (especially countries that have a well structured recycling and energy

recovery systems), it must be carried out in a way that does not lead to illegal release of end-of-life items in dumpyards in Africa. In addition, cross border transport of waste to local recycling centers should encourage recycling of the entire product, and not just parts of it.

In conclusion, there is very little, dependable, detailed geographic data and knowledge on the amount, constitution, origin, and handling of solid waste in Africa which makes it very challenging to outline, assess and record local, national and regional waste handling structures. Though African cities generate lesser per capita waste compared to developed nations, waste management services needed does not match up with the supply.

Poor waste services and structure in Africa is due to the following reasons;

- Political unwillingness and economic incapability to finance waste services and structures.
- Poor governance and environmental policies
- Poor implementation and assessment of legislation.
- Unavailability of skilled labour force both in the private and public areas.
- Poor public knowledge about the dangers and opportunities of waste.
- Taking on the wrong technologies
- Unavailable end-use markets for waste reuse, recycle and recovery.

The Generation of solid waste is projected to rise considerably in the coming century which put pressure on already pressured municipal waste structures. For African nations to be able to reduce waste generation and improve the reuse, recycle and recovery of waste, they must set up good structures now. They must eliminate unguarded dumping of waste and open burning of waste and instead develop more of sanitary landfills.

CHAPTER THREE - METHODOLOGY

3.1 Introduction

This section explains the methods of this research with the objective of understanding the innovations, trends, opportunities and challenges of waste management in African nations from looking at what is happening in these case study countries.

This research focuses on assessing waste management practices in Nigeria, Kenya, and Rwanda, with a particular emphasis on comparing them. The comparison will help to identify the gaps and suggest good approaches.

The motivation for choosing these nations is that, Kenya and Rwanda are two of the leading nations in Africa with regard to waste management, portraying good examples for other African nations to follow while Nigeria eventhough still struggling, portrays the effort they are making to address the waste issues in their nation.

3.2 Data collection

Data was collected from primary and secondary sources like academic articles, government reports, NGO reports, news sources. Search engines like Web of science, Google chrome, Google Scholar, Research gate was used for the search. A total of 184 peer-reviewed journals, articles, blogs, reports and organizational/ governmental website was reviewed as seen in figure 18. Key words for the search included; innovative waste management, Solid waste management ,waste management in Africa, waste management in Rwanda, waste management in Kenya, waste management in Nigeria, comparative analysis of waste management. The focus was on comparing initiatives of waste management in Rwanda, Kenya and Nigeria.

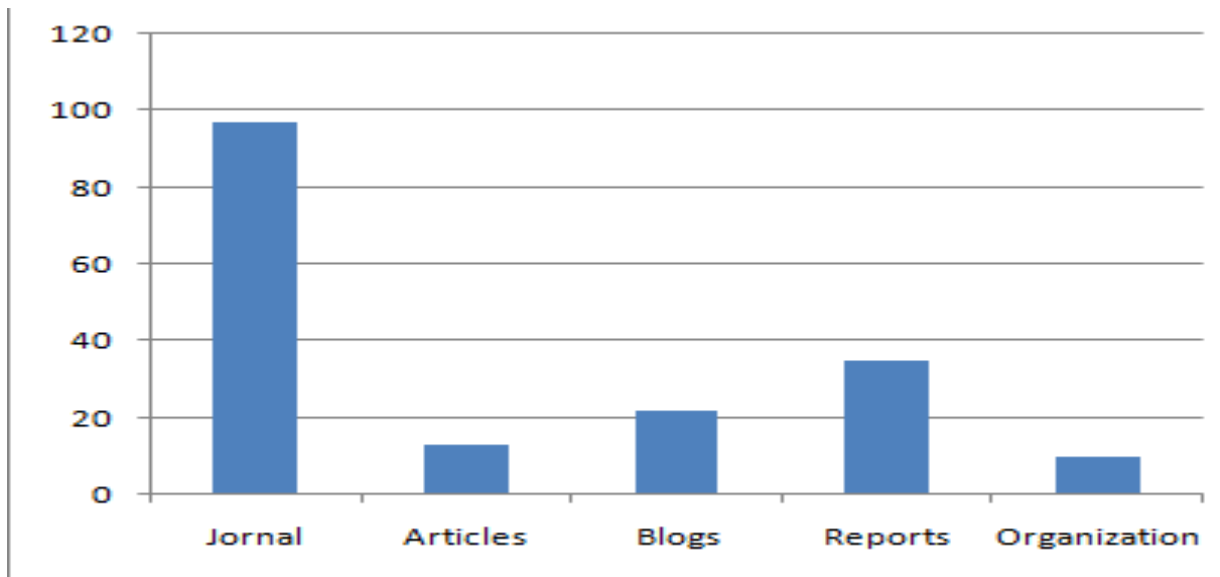


Figure 17 Peer-reviewed journals, aticles, blogs, reports and organizational/ governmental website reviewed.

3.3 Approach of study

This research adopted the comparative review approach which entails comparing and contrasting varying literature review studies to locate what the differences and similarities are to gain insights of the current state of affairs Kaluza (2023). The chosen approach successfully achieved the study's objectives as it involves analyzing trends, current happening and projecting the future

A comparative analysis was done between Kenya, Rwanda and Nigeria based on their policies, waste management actions, initiatives and innovations, successes, and challenges was carried out.

A typical characteristics of the comparative analysis research approach is that it helps to compare and contrast various sets of data aiding in the identification of patterns relationships and potential areas for further exploration.

With the comparative analysis research approach , we are able to compare and contrast so that we can have a better understanding for good decisionmaking Urmita (2022). A typical example of a study that has utilised this approach is a comparative study done by Bansal et al (2018) on tools used for data analysis so as to identify the best tool to be used for analysing data.

Using the comparative analysis research approach will give a deeper understanding of the strengths and weaknesses of the policies, waste management initiatives and innovations of the case study countries in order for there to be better decision making about the future for these countries and for Africa as a whole Kaluza (2023).

The research will compare and contrast the institutional and legal frameworks for solid waste management in the case study nations, waste management innovations and their implementation, as well as the successes, challenges, and opportunities each country faces. Additionally, it will assess the potential for future advancements in solid waste management in these regions.

3.4 Data analysis

Compare the data collected to find similarities and differences in waste management practices and innovations in the three countries. Investigate the factors that contribute to the success and challenges encountered by waste management initiatives in each country.

3.5 Case studies

A thorough examination was conducted on waste management policies actions and initiatives in the case study countries. This analysis assessed the strengths, weaknesses, opportunities and threats of these initiatives identifying the most effective actions and key lessons learned.

3.6 Synthesis

The synthesis of the findings from data analysis and case studies led to the identification of overarching themes and trends in waste management practices and innovations in Africa.

3.7 Discussion

The findings' impacts on waste management in Africa were discussed along with its potential for boosting successful initiatives. Additionally, there were discussions on the necessity for increased research and actions in the African waste management sector.

The literature review project presented the main discoveries and based on case studies of Kenya Rwanda and Nigeria conclusions were drawn about the future of waste management in Africa.

CHAPTER FOUR

PRESENTATION OF RESULTS AND DISCUSSION

4.1 Description of study nations

4.1.1 Kenya



Figure 18 The Republic of Kenya

Source: Ominde. S. Hongo Et. Al. (2024)

The nation of Kenya is found in East Africa. Kenya shares border with Ethiopia and South Sudan to the North, Tanzania to the South, Uganda and Lake Victoria to the West, Somalia and Indian Ocean to the east. It is inhabited by more than 50 million people with different landscapes, wildlife and culture (Ntarangwi, M. , Ominde et al, 2024). The capital of Kenya is Nairobi, and the political system of the nation is diverse with many parties. The economy of Kenya is the biggest in East Africa and their main economic sector is agriculture, manufacturing and tourism. Corruption, poverty and environmental challenges are some of the biggest issues faced by the country (Ntarangwi, M. , Ominde et al, 2024). Even though Kenya has taken bold steps towards encouraging sustainable waste

management actions especially via the circular economy approach purposed at curbing waste and encouraging the utilization of resources(Ngari, W. 2023).

4.1.2 Rwanda



Figure 19 The Map of Rwanda

Source: H. Dieudonne. Et. Al. (2022).

Rwanda is located in East Africa with a population of more than 13 million inhabitants. The capital of Rwanda is Kigali found in the center of the nation on the river of Ruganwa. The nation is boarded to the North by Uganda, to the South by Burundi, to the West by the democratic republic of Congo and to the east by Tanzania (Clay, D et al 2024). Rwanda a country situated at an average altitude of 1 250 m is land-locked. In 2012 the population of Kigali was 1 132 686. The growth rate since 2002 has been 2.6% per annum and using this to project forward to 2017 the population estimate is 1 280 000. Despite having the highest population density in the region with 460 people/km² Kigali's population is just a fraction of the country's total population. However it serves as the economic center for the entire country (Kabera, T. Et al 2019)

The economy of Rwanda has shown resilience irrespective of the fact that the economic environment has been a challenge, even though they have made good advancement in different areas like the health and education sectors through the amendments of their policies and initiatives. The growth rate of the economy has been on the rise steadily and they have come up with a seven year national strategy for Transformation(NST1) which a plans they have put in place to assist the nation to attain the United Nations Sustainable Development Goals (SDGs) as a means to help them become a middle and high income nation by the year 2035 and 2050 respectively (Rogers Kayihura 2023).

The nation is also very involved with environmental sustainability. In 2008, Rwanda put a ban on plastic bags and single-use plastics in 2020. Rwanda also comes up as the 9th safest nation in the world by the World Economic Forum. The nation has a promising tourism sector and a diverse culture (Visit Rwanda, 2024)

4.1.3 Nigeria



Figure 20 The Map of Nigeria
Source: Osunwehinmi, Folayemi (2023)

Nigeria is a nation found in West Africa, bordered to the north by Niger, to the South by Gulf of Guinea to the east by Cameroon and Chad and the west by the Republic of Benin (Osunwehinmi, Folayemi 2023) Nigeria has the highest population in Africa of about 233.9 million inhabitants and is growing at a 2.1 % growth rate per year (World population review 2024). Globally, it is recorded to be the 6th most populous nation in the world with urban growth rate of 5.51% yearly for the past 50 years (World population review 2024). Nigeria, just like other SSA nations is facing a serious waste management issue due to population increase and lifestyle changes (Debrah et al. 2022). In Nigeria, the gap between the rich and the poor is very wide and as a result, some parts of the urban population find it hard to pay for basic needs like water and sanitation (World Bank, 2000) and as result, most of the people live in slums. Even though Nigeria's GDP in 2023 was recorded at \$17.75 trillion, with a yearly growth rate of 6.22%, more than 70% of the population still survives on less than \$1 per day (National Bureau of Statistics, 2024). This economic disparity has been argued to contribute significantly to the rise of urban slums, where inadequate infrastructure and poor living conditions

prevail. One sector heavily impacted by these economic challenges is waste management, as many people cannot afford to pay for waste collection and disposal services (Agunwamba, 1998; Achankeng, 2003). This lack of affordability has exacerbated issues related to waste mismanagement, further hindering efforts to improve urban sanitation and public health in Nigeria.

4.2 Legislative framework.

According to Wilson et al. (2013), effective waste management policies and frameworks are important for sustainable development and environmental protection. A comparative analysis of policies and frameworks governing waste management in these three African countries: Rwanda, Kenya and Nigeria was done by examining the similarities and differences in their approaches.

Similarly, all three nations are advised to shift from a linear approach to waste management to a circular one where waste is viewed as a valuable resource that can be effectively managed, says Ombogo (2023). Uche (2023) also stated that these nations encounter similar obstacles and difficulties in waste management which impede the realization of a circular economy, while NEMA (2014) shared that currently, there is a common focus on transforming waste into valuable assets through efficient and circular management systems.

Rwanda has made good progress in waste management with an emphasis on sustainable practices and circular economy, as reported by the Republic of Rwanda (2021). More so, Rwanda has implemented a holistic approach that focuses on waste reduction, recycling and proper disposal. The National Waste Management Strategy (NWMS) was developed to guide policy implementation and promote sustainable waste management practices Mukama et al. (2018), Ogutu, et al. (2023). Ntakirutimana et al. (2019) further said that the framework emphasizes public participation, private sector involvement and the inclusion of informal waste collectors into formal waste management systems.

Moreso, the GGGI shared that Rwanda has enacted policies to encourage waste to resources initiatives so as to be able to transform organic and plastic waste into valuable resources, and also to enhance the collection of electronic waste and raise awareness in the community. These policies have been carried out in partnership with; the Ministry of Environment City of Kigali, Ministry of Infrastructure and the Global Green Growth Institute.

Also, Twagirayezu (2021) recorded that an E-waste policy was developed with the aim to reduce environmental degradation and climate change impact. This was done by reducing the generation of hazardous waste and controlling the disposal of Electrical and Electronic Equipment (EEE) through legal and regulatory frameworks, seeking to comply with national and international agreements and conventions. Even though the current law is seen to be broad and lacks a comprehensive approach to e-waste management. To protect both the environment and public health, this framework needs to be revised and expanded to include specific regulations for e-waste.

Anirudh et al. (2016) noted that Rwanda has implemented a strategy for managing solid waste at the national level. He also mentioned that this strategy aims to promote sustainable practices such as waste reduction, reuse, recycling and recovery. The strategy highlights the importance of proper waste collection, transportation and disposal as well as the involvement of the public in waste management. Meanwhile, Ogutu et al. (2023) expressed that, the government is supportive of initiatives that promote circular economy and sustainability. The number of waste management and recycling companies has grown rapidly with these firms recycling 70–80 percent of Rwanda's plastic waste. Additionally, Hakuzimana (2021) pointed out in his research that, the country has enforced a ban on single-use plastics resulting in a notable decrease in plastic waste, not leaving behind the

Environmental Impact Assessment (EIA) guidelines for waste management have been created by the Rwanda Environmental Management Authority (REMA) in order to establish a structure for supervising the implementation of EIA in Rwanda and highlight the significance of an effective waste management system in order to avert pollution and damage to humans animals wildlife and the environment as recorded by the Republic of Rwanda (2009).

Additionally, Kenya implemented the Bamako Convention in 1991 to prohibit the import of hazardous and radioactive waste. The convention also restricts the disposal of hazardous waste in oceans and inland waters and promotes the reduction and regulation of cross-border movements of hazardous waste within Africa. Additionally the goal of the convention is to enhance environmentally sound management of hazardous waste in Africa and foster collaboration among African countries.

In conclusion Rwanda's waste management policies prioritize sustainable practices like circular economy and waste valorization (Ogotu. et al. 2023). The implementation of a nationwide ban on single-use plastics and the emergence of recycling companies highlight the country's progress. Nevertheless, Rwanda continues to face obstacles in maintaining proper waste collection and disposal facilities as well as the necessary infrastructure for waste management and recycling Hakuzimana(2021).

On the other hand, Ntakirutimana et. al. (2019) explained in his reasearch that, Kenya faces numerous challenges in waste management due to rapid urbanization and population growth. According to the government of Kenya (2020), the country's waste management policies are primarily governed by the Environmental Management and Coordination Act (EMCA) and the National Environmental Management Authority (NEMA). The Waste Management Regulations of 2006 provide guidelines for waste collection transportation and disposal. NEMA(2014) also collaborates with local authorities and stakeholders to ensure effective waste management practices. However, Ongondo et al. (2019) emphasised that the implementation of these policies is hindered by inadequate funding, limited infrastructure and weak enforcement. He added that, Kenya has made efforts to promote recycling and waste sorting but there is a need for stronger collaboration between government agencies, private sector entities and communities to address the existing gaps. According to Article 42 of the Constitution of Kenya (2010) every individual has the right to a clean and healthy environment. The State is obligated to eliminate any processes or activities that may pose a threat to the environment. Furthermore waste management responsibilities were decentralized to the 47 counties. In addition, reports from Nwachukwu & Shisanya (2007) outlined Kenya's commitment to the Paris Agreement which involves reducing emissions by 30% by 2030 compared to the "business as usual" scenario. The waste sector is seen as a crucial area for mitigation efforts.

More so, in 2016, Mukama et al. (2018) reported that the Ministry of Environment and Natural Resources created a proposal for a Circular Economy Solid Waste Management approach in urban areas. This proposal includes waste sorting, the establishment of recycling points, recycling 600 tonnes of waste daily, and implementing composting facilities for organic waste treatment. Additionally, reports from Nwachukwu & Shisanya (2007) stated that the National Climate Change Action Plan for 2018-2022 mandates the government to create a comprehensive waste management policy aimed at reducing waste through prevention, reduction, recycling, and reuse. The aim is to decrease greenhouse gas emissions by implementing circular waste management strategies and utilizing engineered landfills. Kenya's Vision 2030 plan also includes a Solid Waste Management project, which involves relocating the Dandora dumpsite in Nairobi and establishing waste

management systems in five major municipalities. This highlights the concerted effort by Kenya to integrate sustainable waste management strategies with broader national environmental goals.

Also, according to reports from NEMA (2015), the National Waste Management Strategy was introduced in 2015. The primary goal of the National Solid Waste Management Strategy is to establish a society focused on the 7R principles: Reduce, Rethink Refuse, Recycle, Reuse, Repair and Refill. This aims to decrease waste production and increase the value obtained from waste materials. The goal for strategy is to attain 30% waste recovery and 70% controlled dumping by 2020, 50% waste recovery and 50% semi-landfilling by 2025 and 80% waste recovery and 20% disposal to landfills by 2030 NEMA (2015). So far, there has been some progress report since the implementation began. Rates of formal waste collection increased and is targeted to reach 80% in major cities by 2022. There has been progress in cities like Nairobi, Mombasa, and Kisumu. Additionally, progress has been made with resource recovery with recycling rates increasing by 5-10% in cities like Nairobi, due to improved public involvement. This strategy has also made progress with the creation of jobs in waste collection and recycling, especially in the small companies NEMA (2015).

Kenya has also put into place a prohibition on the production trade shipping and bringing in of plastic bags Gazette (2017) which came into force in August 2017 and has played a significant role in reducing waste production. So far, reports about the progress of the ban has been impressive with compliance reaching about 80% and further rising to about 95% by the year 2021. This compliance has resulted to notable improvements in cleanliness in the cities and a decrease in drainage system blockages from plastic bags. There are studies that have observed a reduction in the number of animals that have ingested plastics Griffin & Karasik (2022).

Meanwhile, according to Maryjane (2023) research work, Nigeria has developed a multi-tiered approach which involves the federal, state and local governments that is designed to deal with difficult problems arising from waste management. She also said that, the nation has approved many international conventions and treaties like the Bamako convention on the ban of importation of hazardous waste into Africa and the Basel convention on hazardous waste, which has an effect on local legislations

Abiola (2018) further expressed that, Nigeria is dealing with significant waste management challenges particularly in urban areas as the country generates a significant amount of waste and improper disposal practices are prevalent. Ogheneruemu et al. (2018) pointed out that Nigeria's waste management policies and frameworks are basically controlled by the National Environmental Standards and Regulations Enforcement Agency (NESREA). Maryjane (2023) added that there are four important laws that guide waste management in Nigeria. They include:

- The National Policy on the Environment, 1989 (Revised in 1999 and 2016) which talked about managing the environment in a sustainable way, focusing on the circular economy plan.
- The Environmental Impact Assessment (EIA) Act, 1992 which stresses that, the potential environmental impacts of a project should be processed before a project is carried out.
- Harmful Waste (Special Criminal Provisions) Act, 1998 which discourages the disposal of harmful waste into the environment (land and water bodies) leading to dead, injury or other physical and mental damage.
- National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, 2007 which is created to charge concerned agencies with the role of preserving and developing the environment and issues related to the environment. This framework is

responsible for the enforcement of existing laws and regulations designed for environmental protection.

- National Environmental (Electronic/Electrical department) Regulations, 2011 which is about the management of electronic and electrical waste and the prohibition of transboundary movements of electronic waste.

Debrah et al. (2022) also said that in 2014 Nigeria adopted EPR as a national policy and issued guidelines for its implementation through NESREA. These guidelines have undergone several revisions with the latest being the EPR Guidance document in 2020. This document outlines the roles of key stakeholders for different product categories included in the EPR scheme and the targets for collection and recycling. Additionally, the National Environmental (Electrical and Electronic Sector) Regulation was updated in 2022 to mandate EPR subscriptions and prohibit inadequate e-waste treatment. Nigeria has also established various EPR frameworks like ARBR FBRA and EPRON for different sectors.

Though Nigeria has a thorough policy and legal framework for waste management as stated by Ogheneruemu et al. (2018), the implementation of these regulations are weak because of poor public awareness, inadequate funds, and insufficient infrastructure. These shortcomings have contributed to poor waste management actions such as open dumping and burning. The country's waste collection infrastructure and recycling facilities are severely lacking, characterized by an absence of good collection services and an inadequate, poorly arranged collection system (Ogheneruemu et al., 2018). Moreover, the recycling sector in Nigeria is primarily managed by the informal sector, which operates with little oversight from governmental authorities, further limiting the effectiveness of waste management. Ugochukwu et al. (2020) highlighted the need for more investment in waste management infrastructure, public awareness campaigns, and private sector involvement to enhance waste management actions in the country. Some positive efforts have been made, especially in Lagos State, one of Nigeria's largest cities, where initiatives such as waste collection and recycling programs have been introduced (Ogunwale, 2017). However, despite these steps, there is still a significant need for better waste management infrastructure and more public awareness across the country to address its waste challenges comprehensively.

Comparing the waste management policies and frameworks of Rwanda, Kenya and Nigeria reveals both similarities and differences. Mukama et. al. (2018) pointed out that, Rwanda stands out for its comprehensive waste management strategy which focuses on waste reduction, reuse and recycling. He also added that, they have demonstrated strong political commitment resulting in efficient waste management practices. The integration of informal waste collectors and partnerships with international organizations has contributed to its success.

More so, Rwanda and Kenya have executed powerful policies like bans on plastics which has greatly affected the quantity of waste generated as expressed by Clarisse & Bosco (2012). Meanwhile, though Nigeria and Kenya's frameworks are thorough, they face challenges with enforcement and compliance from the public.

Ntarikutimana. et. al (2019) added that, Rwanda has a special model for community involvement which is one of the reasons for its success in waste management. Nigeria and Kenya, can learn from Rwanda in order to boost their public participation.

All case study nations encountered difficulties in building efficient waste management infrastructure and implementing their regulations. Nigeria, most especially, is dealing with insufficient systems for waste collection and illegal dumping as pointed out by Ombogo (2023)

In conclusion waste management policies and frameworks vary in efficiency and implementation strategies in Rwanda, Kenya and Nigeria. Rwanda's comprehensive strategy, Kenya's regulatory frameworks and Nigeria's ongoing efforts highlight the importance of addressing waste management

challenges. By learning from each other's experiences and adopting best practices these countries can work towards sustainable waste management systems and a healthier environment.

4.3 Waste Management Initiatives and Innovations

Godfrey et al. (2019) pointed out that, Rwanda, Nigeria, and Kenya have taken on different methods to handle the rising challenges with waste management in these nations. These countries have shown devotion to resource recovery, preserving the environment and the adoption of sustainable actions. Each nation uses different methods that is unique to their social and economic situation, though they share the same goal of advancing waste management and decreasing environmental degradation. This report shows how these nations are making efforts to improve their waste management systems in order to bring about more environmental and sustainable development.

4.3.1 Rwanda's waste management initiatives and innovations

According to Mukama. et. al (2018), Rwanda has come up as one of the pioneer when it comes to waste management in Africa. According to his research, the government has enforced many initiatives to support sustainable waste management. For example, they have taken on the “zero waste” policy that stresses on reducing waste and resource recovery. The setting up of waste separation systems and recycling facilities has played a great role in reaching these goals Mukama. et. al (2018). More so, Rwanda has embarked on innovative methods like biogas production from organic waste and decentralized composting (Tigabu et al 2015). These initiatives has decreased impact on the environment and also brought some opportunities for the economy of Rwanda.

Additionally, Hitayezu (2023) pointed out in his report that the government of Rwanda is embarking on a 14-year circular economy plan launched in 2022. The plan will focus on effective management of waste and clean production technologies. The plan includes; encouraging the segregation of waste from the source, developing regulations that will make waste management easy and incorporating principles of circular economy into educational programs and vocational trainings. The purpose of this plan is to decrease waste sent to landfill by 50% by 2030 and decrease the consumption of single-use plastics by 80% by 2030 by instituting bans, incentives and public awareness campaigns. The plan also plans to increase recycling rates by 30% by 2027 and 60% by 2035. This will be done by improving the infrastructure to sort, process and recycle the materials in different cities. The vision is to establish a recycling facility that has the ability to recycle more than 50,000 tonnes of waste annually. The goal is for this strategy to be able to create about 200,000 green jobs by 2035 basically in the areas of waste management, recycling and sustainable manufacturing. For this to be a success, the government plans to involve about 90% of the population in urban areas through campaigns and educational programs.

As a result, GIZ (2023) produced a report about the Waste and Circular Economy (WCE) project that was launched by the government of Rwanda to encourage circular economy actions in the waste sector. The purpose of the project is to increase recycling rates and develop effective systems for waste management. This project aims to increase the rate of recycling of non-organic waste by 30% by 2025 and 40% by 2030. This initiative involves collaborating with local stakeholders to bring about innovative solutions like smart technology for the collection and monitoring of waste and for the advancement of waste sorting and recycling infrastructure. Additionally, progress made with this project will reflect quantitative procurements, particularly in Kigali, where the volume of waste

collected daily amounts to about 800 tonnes with very small amounts of recycling and composting activities.

The GGGI (2024) has also launched a new project "Waste to Resources" in partnership with the Ministry of Environment in Kigali with the goal of utilizing organic and plastic waste, improving the collection of electronic waste and raising awareness in the community. The plan is to reduce carbondioxide emissions by 15,320 metric tonnes yearly, create 74 green jobs and improve the assessment of solid waste service for 250,000 Rwandans. So far, this project has been able to establish waste valorization facilities to convert organic and hazardous waste to meaningful resources, thereby reducing the amount of waste sent to landfill, thus reducing greenhouse gas emissions. The project has also established a bio-waste processing facility in Kigali to transform organic waste to compost and biofuel. Other achievements include collaborations with local businesses to recycle special types of waste like plastics and e-waste to valuable products.

Anirudh et al (2019) shared in their final report that there are several companies that specialize in recycling with a focus on paper and plastics. They highlighted Trust Industries, a paper treatment and recycling company that converts paper waste into toilet paper. Additionally, various organizations are making efforts to recycle plastic waste by transforming a combination of high- and low-density plastics into furniture, household items, and materials for industrial agriculture.

More so, in 2008, Rwanda instituted a ban on the manufacturing, importation or selling of plastic bags and single used plastics. Anyone using plastic bags as an exception, is supposed to carry a written authorization along with it. This ban has reduced plastic waste generated by 80%. The ban brought up so many controversies as some people were happy with it, while others were not. Iraguha et al (2022). Report from REMA (2021) says that via recycling initiatives, about 1,200 tonnes of plastic bottles got collected.

Meanwhile, according to reports from the Republic of Rwanda (2016), the Ministry of Youth and ICT in conjunction with the Ministry of Trade and Industry has conducted initial awareness campaigns for E-waste management among governmental institutions. However there is still a need to expand this awareness to the private sector and other civil communities, and also strengthen collaboration and partnerships with local and international agencies and manufacturers to improve knowledge and skills for E-waste management and control. This will help address the current skills gap in E-waste handling and disposal. To address this issue the policy proposes the introduction of E-waste management skills in Technical Vocational schools (TVET). These schools can establish centers where electronic equipment is refurbished and reused providing hands-on technical experience for TVET students. This approach will also extend the lifespan and usability of discarded electronic devices.

Tigabu et al (2015) wrote a paper that analyzed the growth of technical innovation system for bio-digestion in Rwanda. He noted that the Centre for Innovation and Technology Transfer (CITT) and the Kigali Institute of Science and Technology (KIST) initiated a biogas plant (bio-digester) in the 1990s, starting with schools and prisons. This initiative was later adopted by government and non-governmental organizations, becoming part of the nation's action plan for clean energy sources in 2002. Nes (2015) final report from further investigation recorded that in 2005, the MININFRA of the Republic of Rwanda (ROR) had a memorandum of understanding with the Netherlands Development Organization (NDO) to start a National Domestic Biogas Program (NDBP) that started in 2006, with the goal of installing 15,000 units of domestic digesters by the end of 2012 says Mazimpaka(2023). In 2008, Ndahimana and Dekelver (2007) noted that the Rwandan government received funding from the Netherlands Directorate-General of Development Cooperation (DGIS) through GTZ-Rwanda,

which enabled the installation of over 390 biogas systems. However, by 2012, reports from the FAO (2021) indicated that only 1,800 biogas systems had been installed in various cities across Rwanda. This figure is significantly lower than the projections made in 2006. Currently, Rwanda is making more investments in biogas projects and as at 2021, they had installed about 40,000 biogas digesters, providing cooking energy to about 200,000 people FAO (2021).

Furthermore, to prepare for the expected increase in population in Kigali, the capital of Rwanda, *ECA Energy*(2023) recorded that the authorities are planning to establish a smart waste management system in collaboration with Smart Africa Secretariat an organization under the African Union as well as the Rwandan Ministry of ICT and Innovation. The government of Rwanda is currently seeking a company to carry out this project by December 2020. Upon selection, the government will enter into a contract with the chosen company to implement the intelligent waste management solution. The system, which will undergo a pilot phase with a budget of \$100,000, will be responsible for the collection, transportation, treatment, recycling, and disposal of waste.

The Government of the Republic of Rwanda (2024) also launched a Smart Waste Management and Collection pilot project in collaboration with the Ministry of ICT and Innovation (MINICT), the City of Kigali, the Rwanda Information Society Authority (RISA), Smart Africa, and the Norwegian Development Agency (NORAD). This project was launched as part of Rwanda's Smart Cities initiatives. The project's objective is to improve solid waste management practices through the use of technology and innovation.

Lastly, Adem (2022) wrote a report on how Rwanda has implemented a deposit system for PET bottles which would be operated through a mobile application. This app would serve multiple purposes including communication, education, rewards and entertainment for the citizens of Kigali. It would inform them about the proper methods and locations for disposing of used bottles in shops and collection centers. It is expected that, the app will facilitate more than one million transaction yearly once it has been fully adopted in urban areas. The program will motivate citizens by rewarding them with about 5-10 Rwandan Francs for every bottle returned. This initiative is projected to attain a 90% collection rate for PET bottles. This anticipation is drawn from the success rates of other projects as they anticipate huge public involvement for this to be a success. According to the pilot study, the rate of participation will be about 60% in Kigali within three months of testing and hopefully, increases to 70-75% by the end of the second year of the program. Rwanda aims to decrease plastic waste in urban areas by 70-80% in five years through the implementation of this project and decrease the volume of PET bottles by 30% with the first year in areas where people make more use of the app. The project is also projected to create about 1,000 jobs in the process of collecting and recycling PET bottles.

4.3.2 Kenya's Waste management initiatives and innovations

Kenya like Rwanda has recognized the importance of effective waste management and has implemented several initiatives to address the issue. Haregu et al. (2017) recorded that, the country has established waste management policies and regulations aimed at promoting sustainable practices. One notable initiative is the establishment of the National Environment Management Authority (NEMA) which oversees waste management activities Government of Kenya (2020).

Debrah et al. (2022) noted that the National Waste Management Policy encourages better waste management by following the waste hierarchy and circular economy ideas focusing on waste prevention reduction reuse recycling and composting. As a result, Debrah et al. (2022) added that, the

In 2017, the Ministry of Environment and Natural Resources in Kenya launched a project called Nationally Appropriate Mitigation Action (NAMA), focusing on a Circular Economy (CE) approach to municipal solid waste management in urban areas. The goal is to shift focus from releasing large amounts of waste to disposal sites and instead do more of recycling. The goal is to enhance waste management actions in Kenya for 15 years. The aim of the project is to reduce municipal solid waste by 30% by 2030 via improved waste management actions and community involvement, recycle 60% of waste so as to reduce waste in landfills and create about 15,000 jobs the area of waste management (collection, sorting, recycling and composting) Global Plastics Policy Centre (2024). So far, the project has been able to establish 16 recycling plants and 15 composting centers to treat and recycle waste.

The Republic of Kenya is currently practicing a community waste management initiatives led by community organizations youth and women's groups focus on collecting sorting and improving the reuse and recycling of waste. These efforts provide employment opportunities for community members especially women and youth. However they encounter obstacles such as inadequate infrastructure (collection points transfer stations material recovery facilities) limited access to markets for recyclable materials insufficient training and restricted financial resources.

Also, Mkabane (2023) reported that, the Republic of Kenya under the supervision of the ministry of environment has also invested in waste-to-energy projects such as the Nairobi Integrated Solid Waste Management Project which converts waste into electricity and many other waste to energy projects that are being carried out in Kenya. The project is projected to generate 45 megawatts of electricity by the time it is completed in 2026 and at the same time, deal with the issue of waste in Nairobi. It is also forecasted to bring about 1,000 jobs from the beginning stages. This project will decrease the volume of waste in the Dandora landfill which has been a huge source of pollution in Nairobi.

To this effect, The African Development bank (2019) approved a grant to Asticom Kenya Ltd to construct a 10 megawatt grid connected municipal waste to energy plant in Kiber which is a suburb in Nairobi. The aim of the project is to use municipal solid waste to generate electricity by converting the waste to biogas/fuel ethanol. Additionally innovative approaches like community-based recycling programs and waste separation at the source have been implemented to enhance waste management practices.

In a study, Lumadede(2021) reported that the Kenya Ministry of Energy has made numerous efforts to promote biogas use, including implementing promotional frameworks, conducting research, developing training programs, and raising public awareness. Despite these efforts, the adoption of biogas technology has been slow due to the continued reliance on wood fuels. However, government initiatives such as zero-rating biogas plant equipment and public forums have spurred growth in the sector. As a result, approximately 20,000 biogas units have been installed nationwide, with significant contributions from the Kenya Biogas Partnership Program (17,000 units), private entrepreneurs (2,000 units), and energy centers (1,000 units) (Lumadede, 2021).

In 2002, Richard J. Palczynski reported on a community-based composting project that was supervised by Peters in Nairobi, Kenya, in 1994 and 1995. The initiative, funded by the Canadian International Development Agency (CIDA), focused on composting organic waste in informal settlements, with women's groups playing a key role. These composting activities were aimed at improving environmental conditions in the community and generating income from selling the compost.

The study used participatory research techniques to evaluate the project, revealing significant environmental benefits, such as:

- Improved soil health
- Increased opportunities for urban agriculture
- Enhanced drainage within communities

However, the project was less successful in achieving its secondary goal of income generation from compost sales.

More so, Dugbazah et al (2021) in their study said that, Kenya is implementing technologies to improve waste disposal and management methods. They mentioned the Taka Taka, company in Kenya, who is carrying out a waste management project which involves; waste collection sorting, composting, plastic recycling and buying waste from pickers. The project is able to collect 90 tonnes of waste daily and sort 40% of the waste collected in Nairobi. This project has made waste collection services more affordable in low-income areas by increasing the recycling system to about 95% of all waste collected. Additionally, this project has created job opportunities for women and young people. Moreover it has reduced Kenya's gas emissions resulting in a clean and healthy environment. The advanced waste collection and processing system also utilizes modern screening technology to separate recyclable materials efficiently.

Additionally, Digwatch (2023) made a report about the ICT Authority launching the E-Waste Kenya Project with the goal of gathering 100 000 electronic gadgets from different public entities like State Corporations Universities and TVET institutions within this fiscal year. The National Environmental Management Authority (NEMA) and the Public Procurement Regulatory Authority (PPRA) are also involved in this initiative. Not leaving out the E-Waste Initiative Kenya (2015) which was established to manage electronic waste in the informal sector in Kenya offering a safe disposal solution nationwide. Their activities include raising public awareness, empowering technicians, ensuring occupational health and safety and forming partnerships.

The UN Habitat (2022) reported that, Kenya has introduced various waste management innovations such as utilizing artificial intelligence (AI) to enhance solid waste management in the Nairobi Metropolitan Region. The goal is to enhance waste management, encourage recycling and promote awareness of proper waste disposal practices. The AI technology brings together stakeholders in a secure online platform streamlining waste disposal collection and recycling processes for tenant property owners landlords and waste management service providers. It addresses waste management concerns, handles complaints and requests for refuse and recycling bags and supports safe waste collection and recycling. The technology also facilitates communication and coordination among stakeholders through reporting and analytics.

More so, Ngari (2023) has shown that, the private sector plays a key role in waste management through public-private partnerships to support sustainable practices and reduce pollution. Safaricom, a top telecommunications company, collaborates with WeeCenter, an e-waste management company in Nairobi to handle e-waste from its operations.

4.3.3 Nigeria's waste management initiatives and innovations

In a research carried out by Ezeah & Roberts (2012), they pointed out that, Nigeria faces significant waste management challenges due to its large population and rapid urbanization. However the government has initiated various programs to tackle this issue.

A report from UNEP (2019) states that the organization is working with the Global Environment Facility and the Government of Nigeria to promote CE through recycling to reduce waste. This partnership focuses on sustainable CE methods for managing electronic waste in Nigeria aiming to tackle environmental and health issues caused by current practices. The report further stated that the project intends to handle 500,000 tonnes of electronic waste each year and urges electronic manufacturers to take responsibility for their products' disposal and comply with relevant laws.

More so, Ajibesin (2023) explored circular economy projects that Nigeria is carrying out like; Kaltani, which is a company that specializes in clean-tech plastic recycling and waste management, with a mission to combat the global plastic crisis. Their focus is on implementing scalable solutions to reduce PET, PE, and PP plastic pollution as well as managing municipal solidwaste. Kaltani works closely with post-consumer waste collectors and post-productionwaste suppliers to gather various types of plastics, including:PET: water and soda bottles,PE: cooking oil containers, shampoo and soap bottles, laundry detergents, pure water sachets,PP: bottle tops, margarine tubs, yogurt cups.To support their efforts, Kaltani has secured \$4million in funding, which will allow them to expand their production capacity to 15,000tonnes per year, aiming to create a significant impact on plastic waste reduction globally.

Ajibesin (2023) also talked about Wecyclers which is a profitable social enterprise which has a unique program that offers rewards for recycling motivating individuals in impoverished areas to benefit from recyclable materials. Their system relies on a fleet of cost-effective cargo bikes known as "wecycles " which collectors utilize to gather recyclable waste from homes and transport it to sorting centers in Lagos. Participants earn points for each kilogram of waste recycled which can be exchanged for essential items like food and household goods. By leveraging mobile technology and cargo bikes Wecyclers aims to establish an affordable waste management network while encouraging the adoption of recycling practices. And lastly the Recycle points which is a social enterprise that encourages waste recycling by rewarding consumers with "Points" for their recyclable materials. These points can be used to shop for household items in the iRecycle store. The collected materials are processed at Collection and Sorting HUBs (CoSoHUB) before being sold to manufacturing plants for the production of various items like polyester, fiber, carpets, hangers, pegs, aluminum ingots and craft papers.

The establishment of the Federal Ministry of Environment and the National Environmental Standards and Regulations Enforcement Agency (NESREA) has played a crucial role in regulating waste management practices Tawfiq (2012). Nubi et al. (2022) analysed waste to energy options in Nigeria and reported that Nigeria has also embraced innovative solutions including waste-to-energy projects and the introduction of waste sorting and recycling centers. Ahen et al. (2021) further explained that the nation is conducting a lead pilot project in Abujah aiming at generating a minimum of 50MW of electricity from waste. Despite these efforts there is still a need for more comprehensive waste management strategies to address the country's growing waste problem as reported by Ahen et al. (2021)

In addition, Oando (2021) in his assessment reported that the NREEP pilot projects in Nigeria which includes a waste-to-energy plant and an anaerobic digester plant. The proposed waste-to-energy plant in Ikorodu Industrial Estate and the surrounding areas in Lagos State along with the 12 MW Biogas plant installed for the ikosi fruit market in 2013 by the government and MES are no longer active. The Ebonyi State Government has taken over the UNIDO demonstration biomass gasifier power plant located at the UNIDO Mini-industrial cluster which is designed to generate 5.5 Megawatt electricity using rice husk and other waste materials.

More so, in Nigeria Rigasa et al. (2016) recorded that local residents are being encouraged to take part in waste segregation and recycling through community-based recycling programs. These programs typically involve collaborations between communities NGOs and waste management firms.

Thompson et al (2013) created a waste management system in Ondo state Nigeria to address waste management issues. This system utilizing GIS technology managed waste bin allocation and relocation facilitated public-authority communication and enabled recyclable waste separation.

In a literature review study carried out by Nwosu et al, (2020), it was revealed that a recycling and treatment Project (OSIWRTP) was launched in Nigeria, with the aim of transforming waste to valuable products. So far the project is able to recover and recycle paper, plastics, metals and glass.

Lastly, a sanitation awareness campaign was carried out across Nigeria starting in the mid-1980s and still ongoing today. These initiatives was conducted by the local authorities in collaboration with the department of health and education, groups in the community, and the media. This led to a huge reduction in littering and increased waste management actions at the level of the community.

4.3.4 Comparative analysis

These countries have embraced innovative waste-to-energy technologies in order to develop sustainable solutions to the problem of waste management while at the same time producing energy Mburu et al.(2020). They are also committed to developing waste management programs that are community based, coming up with recycling initiatives, and enforce extended producer responsibility programs Agunwamba (2003). Additionally, these nations recognize the significance of public awareness and participation in the management of waste.

Though, comparing the landscape of waste management in these three nations, many key differences are seen. Rwanda has experienced significant advancement in waste management especially via the "Vision 2020" initiative as reported by Majumdar et al. (2019). They have a more centralized and organized system of managing waste that stresses on the recycling of waste and waste-to-energy initiatives with the utilization of innovative technologies. On the other hand, Kenya and Nigeria experience a more decentralized and informal systems of managing waste which greatly rely on open dumping and open burning Otieno & Kubasu (2018), Ogwueleka (2009). Mwesigye et al. (2016) added that, Kenya is dealing with many challenges like insufficient infrastructure, inadequate funding, and lack of public awareness. He suggested that these nations need to adopt sustainable waste management actions like recycling, waste separation, and composting in order to decrease the quantity of waste disposed in landfills and reduce the pollution of the environment.

Kofoworola (2007) pointed out that, Nigeria also face a huge challenge because of inadequate infrastructure and limited support from the government. He suggested that, Nigeria needs to make waste management a priority by providing adequate funding, enhancing waste collection systems and encouraging campaigns that bring about public awareness. In addition, the country should implement waste-to-energy technologies to help reduce the burden of waste management while generating renewable energy.

One factor that sets apart environmental quality management in Rwanda from that in Nigeria and Kenya is Rwanda's notable political devotion to sustainability and its functional participation in public-private partnerships Nduhungirehe et al.(2019). This overall devotion has authorized Rwanda to finance essential infrastructure and technology needed to enhance waste oversight traditions Nduhungirehe et al.(2019), unlike in Nigeria and Kenya, where the lack of political support and financial resources makes it hard to manage waste Otieno & Kubasu (2018), Ogwueleka (2009).

Table 6 Timeline of waste management initiatives in Rwanda, Kenya and Nigeria

Year/ Country	Rwanda	Kenya	Nigeria	References
2007		NEMA became operational under the Environmental Management and Coordination Act (EMCA) and established Kenya's framework for the protection of the environment including the regulations on waste management.	The National Environmental Standards and Regulations Enforcement Agency (NESREA) was launched to implement environmental laws and enable sustainable waste management actions.	Government of Kenya. (1999)/ Ogheneruemu et al. (2018)
2008	Rwanda instituted the ban on plastic bags via the "Law N° 57/2008 of 10/09/2008." Prohibiting the importation, production, utilization and selling of plastic bags leading to a huge reduction of plastic pollution			Hakuzimana (2021)

2010	Rwanda came up with a national community clean up and development day called the Umuganda day which lead to an improvement in community participation in waste management.	Kenya launched the National Climate Change and Response Strategy (NCCRS) to deal with waste matters through recycling and resource efficiency in order to decrease the emission of greenhouse gas		Majumdar et al. (2019)/ Government of Kenya. (2010).
2011		The Taka Taka company was launched in Kenya which has been carrying out waste management projects involving waste collection, sorting, composting, plastic recycling and buying of waste from pickers		Dugbazah et al. (2021)
2012			Lagos started the Waste-to-Wealth initiative, to promote recycling and resource recovery.	Adenaike, F., & Omotosho, A. (2020).

2014			Nigeria adopted the Extended Producer Responsibility (EPR) program in collaborations with NESREA to ensure that manufacturers take responsibility for the waste generated throughout their production process Lagos launches recycling banks and recycling programs that are based on incentives	Maryjane (2023)/ Alphonse (2024).
2015	The ministry of Environment in Rwanda, Instituted the national waste management policy to encourage sustainable waste management actions in order to reduce waste, improve recycling, composting and and coming up with a good system for managing waste.	The National Waste Management strategy was launched in Kenya to handle the increasing generation of waste especially in rural areas through recycling and sustainable waste actions through out different municipalities	NESREA adopted e-waste regulations to manage the release and recycling of electronic waste.	Mukama et al. (2018)/ Okposin, A. (2019)/ Maryjane (2023)
2016	Rwanda started the first e-waste recycling center in East Africa which is able to process about 10,000 tonnes of e-waste yearly. The aim is to deal with the problem of e-waste while bringing employment opportunities.		An innovative recycling company called Wecyclers launched a unique program that uses low cost cargo bicycles to collect waste in urban areas via reward-based participation	Government of Rwanda. (2017)/ Ajibesin (2023)
2017	Rwanda engaged in a circular economy and green initiatives under the vision 2050 and the Green Growth and	Kenya instituted a ban on the importation and use of single-use plastic bags which is one of the the strictest bans in the world. This is greatly		Government of Rwanda. (2011)/ Debrah et al. (2022)

	Climate Resilience Strategy (GGCRS). This plan stresses on sustainable management of waste and conservation of resources.	reduced plastic pollution by 70%. The ministry of Environment and Natural resources in Kenya launched a project called Nationally Appropriate Mitigation Action (NAMA), focusing on a Circular Economy (CE) approach to municipal solid waste management in urban areas		
2018	The Republic of Rwanda launched a smart waste management and collection pilot project in partnership with the Ministry of ICT and Innovation in order to improve solid waste management practices via technology and innovation	Kenya launched the National Climate Change Action Plan (NCCAP) 2018-2022 to curb the emission of greenhouse gas with circular waste management pointed out as the most important	Nigeria adopted the principles of circular economy in collaboration with World Bank and UNIDO to enhance circular waste management	Republic of Rwanda (2024)/ Nwachukwu & Shisanya (2007)/ Ikeah, C. K. (2022).
2019		Kenya came up with the sustainable Waste Management Bill with the purpose of establishing a thorough legislative framework for the management of waste.	A Nigerian recycling company called Kaltini started an initiative to recycle plastic waste and decrease pollution	Government of Kenya (2021)/ Ajibesin (2023)
2020	The GGGI launched a Waste to Resource project in partnership with the ministry of Environment to improve recycling and raise awareness	The Nairobi Integrated Solid Waste Management project was launched by the Nairobi Metropolitan Services (NMS) so as to transform waste to energy with the intentions of processing about 1,000 tonnes of waste in a day to produce electricity and		GGGI (2024)/ Government of Kenya (2021)/ UN Habitat (2022)

		<p>decrease dependence on landfills</p> <p>Kenya has introduced Artificial Intelligence to enhance solid waste management in Nairobi Metropolitan region</p>		
2021	<p>Rwanda has implemented a deposit and return system for PET bottles to enhance recycling and limit plastic waste. The program is carried out via mobile app to make it possible for people to consume return PET bottles and get a reward in return</p>	<p>The government of Kenya implemented the Extended Producer Responsibility (EPR) regulations to ensure that producers take responsibility for the waste they produce in their production process. In collaboration with the world bank and other organizations, Kenya has established projects to convert plastic waste into sustainable products like the project of an entrepreneur who created building products from recycled plastics</p>	<p>Nigeria carried out waste-to-energy pilot projects in Lagos and Abuja to transform municipal waste to electricity</p> <p>Nigeria adopted a National Solid Waste Management Policy to give a standard method of collecting waste, recycling and managing landfills</p>	<p>Adem (2022)/ Government of Kenya (2021)/ World Bank. (2020)/ Oando (2021)/ Maryjane (2023)</p>
2022	<p>Rwanda embarks on a 14- year circular economy plan to encourage sustainable production and consumption</p>	<p>The National Sustainable Waste Management Policy was approved stating goals to discard open dumping, promote circular economy practices and enhance the collection of waste</p>		<p>Hiayezu (2023)/ Government of Kenya (2021)</p>
2023	<p>The Waste and Circular Economy project launched by the government of Rwanda to encourage waste management and recycling in a sustainable way</p>	<p>The KCIC launched a Sustainable Waste and Innovative Financing Towards a Green Economy Transition Program (SWIFT) to fund, train and provide access to market to innovators of waste management in the areas of recycling, upcycling</p>	<p>□ Nigeria launched partnership with the National Plastics Action Partnership (NPAP) to decrease plastic pollution especially single-used plastics and promoting recycling</p>	<p>GIZ GIZ (2023)/ Kenya Climate Innovation Center (2024)/ Global Plastic Action Partnership. (2024). Okubanjo et al. (2023)</p>

		and circular economy solutions	<input type="checkbox"/> Nigeria started trying outsmart waste management technologies, like applications that track waste and IoT-enabled bins, to enhance efficiency in the collection of waste in urban areas	
2024	The Rwandan government has also come up with a Smart Waste Information and Tracking System (SWITS) to digitize the collection, and monitoring of waste in rural areas using sensors and mobile technologies.	Kenya started smart waste management pilot projects in partnership with technology partners which utilizes IoT-enabled bins and data analytics to improve waste collection routes, enhancing efficiency and decreasing cost of operation.	<input type="checkbox"/> Nigeria adopts new digital platforms like Scrapays mobile solutions to enable connection between waste generators, collectors and recyclers in order to streamline the process of waste collection	Republic of Rwanda (2024)/ Government of Kenya (2021)/ Onur et al. (2024).

In summary, a comparative analysis of waste management in Kenya, Rwanda and Nigeria brings out the significance of a holistic and integrated method of dealing with waste management issues faced by African nations. Even though each nation is dealing with their unique issue, Rwanda's successful waste management systems shows that it is possible for other African nations to embrace innovative and sustainable waste management actions. Africa need to invest more in infrastructure, technology and public-private partnerships because it is important in the future of waste management in African nations. In order for Africa to bring about a sustainable future for the management of waste, they need to focus on; providing adequate funding and resources, implementing public awareness campaigns to educate the people about the significance of reducing waste and waste disposal, come up with effective systems for waste collections, encourage recycling and composting facilities and intergrate waste-to-energy technologies. All these will help Africa deal with it's waste management issues.

4.4 Barriers and challenges

According to Ayeleru and Diaz (2017), African nations struggle with different challenges as they make attempts to a improve their waste management actions including Rwanda, Kenya and Nigeria. Key challenges includes; inadequate implementation of policy and regulation, poor infrastructure and resources, rapid population increase and urbanization, dominance of the informal sector, poor public awareness and participation and ineffective technical know-how. This study will look at these

obstacles hindering the advancement of waste management in Kenya, Rwanda and Nigeria while giving a complete knowledge of the future of waste management in Africa.

4.4.1 Inadequate implementation of policies and regulations

The absence of comprehensive and well-enforced policies and regulation is very a significant challenge to proper management of waste in African countries Abila & Kantola (2013), Nzeadibe & Ajaero (2010). Wilson et al. (2013) added that they lack a good and transparent institutional framework that is needed for efficient governance in managing waste. Some of the policies are outdated, poorly enforced and don't address local issues leading to a fragmented and poor approach with little cooperation amongst the stakeholders. Godfrey (2019) noted that the lack of regulations hinders the transition from traditional waste management to a circular economy model. Mudu et al. (2020) emphasized that inadequate national policies and regulations impede local governments' ability to effectively manage waste activities, making it difficult to regulate and oversee optimal disposal options, especially when policies focus on national goals. Outdated policies combined with weak enforcement fail to drive significant improvements in waste management services, hampering community participation in waste segregation at the household level. Yukalang et al. (2017) also pointed out that the government's failure to implement environmental laws has led to a lackadaisical behaviour regarding waste management, lowering its effectiveness.

Although Kenya is drafting numerous national policies and goals for enhancing the solid waste management (SWM) sector, Nkubitu (2022) says its potential efficacy and future are compromised by inadequate policy clarity and insufficient sustainable waste management policy implementation as added by Dickson et al. (2022). He went further to say that, it is partially due to the government's lack of political will, insufficient financial and human capacity, political interference, corruption, and inadequate public participation. Diaz (2017) recorded that these factors contribute to the challenge of enhancing waste management because the non-enforcement of waste management regulations makes it difficult.

According to Iraguha et al. (2022), Rwanda is also dealing with difficulties regarding compliance and implementation of regulations for waste management, especially when it comes to monitoring and controlling activities through out the nation. Setyono (2022) pointed out that Rwanda has an insufficiently holistic implementation approach on waste management issues in the nation.

Meanwhile, Adebayo et al. (2021) in their studies said that, Nigeria does not have good policy and regulatory framework, which is a huge obstacle for innovative waste management. They added that, the nation's policy and regulations linked to waste management are usually outdated, insufficient and poorly implemented, which is a great setback for Nigeria to come up with solutions for innovative waste management. Beatrice & Jussi (2013) also highlighted the fact that they lack a well structured policy and their policies do not fit into the sustainable development goal of fruition and depletion in waste management by motivating the 3R's of managing waste. i.e reduce, reuse and recycle.

4.4.2 Lack of infrastructure and funding

Bello et al. (2016) identified insufficient financial resources and infrastructure as major barriers to innovative waste management in Africa. Many African countries encounter economic challenges leading to budgetary insufficiency for waste management operations, which compel the adoption of antiquated and unproductive waste management strategies. This lack of financial investments

constrains the assimilation of advanced and environmentally responsive waste management techniques. Van Niekerk et al. (2019) argued that waste management activities are frequently decentralized to local governments and municipal councils, augmenting financial restrictions. The financial constraints stem from national governments' truncated financial provisions to constitute necessary capital projects, operational expenses, and personnel training for effective waste management. The insufficiency also adversely impacts waste administration departments' employees, as noted by C40 (2016), as well as inadequate waste collection vehicles, bins, and recycling systems, thereby sabotaging large-scale systems' development.

The World Bank (2018b) added that, adopting expensive models for managing waste from high income nations is not practical because of financial difficulties. Instead, they should develop solutions that are tailored locally. Due to insufficient funds, African cities have given out waste management services to the private operators who offer better services to neighbourhoods that are able to pay for their service Niekerk et al. (2019).

In Kenya, Paes et al. (2019) and Sibanda et al. (2017) said that, inadequate finances limits the funds given to the local authorities for the management of waste leading to waste management systems that are not developed and most of the time, unsustainable. The Ministry of Environment and Forestry (2019) added that inadequate funding brings about a shortage of waste treatment and recovery facilities, low collection rates and absence of engineered landfills. M'Nkubitu (2022) also said that inadequate assistance from the government for community-based initiatives reduces donor and investor confidence, and as a result, these initiatives are stopped prematurely as soon as their initial funding gets finished.

In Rwanda, Ndahimana (2020) noted a lack of modernization and financial constraints in waste management systems which makes implementation of new technologies challenging. NLS Waste Services (2023) also observed insufficient waste recycling capabilities, collection services, disposal options, and high expenses of disposal. Inadequate trained personnel impede the effectiveness of waste management operations and due to inadequate funds, the Rwanda is unable to properly develop its waste management infrastructure and improve on public awareness campaigns and training programs.

In Nigeria, Agunwamba (2003) expounded on the insufficiency of waste collection infrastructures and equipment, leading to inefficient waste collection, transportation and disposal. As a result, waste is accumulated causing degradation of the environment. Palczynski (2002) further reported a lack of skilled personnel in Nigeria to implement international waste management ideals. Onwughara et al. (2010) argued that inadequate funding due to budgetary limitations hinders the country from implementing technology innovations that could optimize service delivery.

4.4.3 Inadequate public awareness and public participation

Debrah et al. (2021) observed significant gaps in educational programs related to waste management across many African nations such as Rwanda, Zimbabwe and Nigeria. This includes a shortage of community-based training on the circular economy and how to store, isolate or dispose electronic waste, food waste, plastics in garbage bags and agricultural biomass. Abila et al. (2015); Nzeadibe & Ajaero, (2010) pointed out that it has been due to inadequate publicity and public participation which have contributed in hindering the waste management towards complete sustainability. Many

communities don't have a good knowledge of the significance of good waste disposal and recycling, leading to their unwillingness to accept waste management initiatives.

While citizens maybe exposed to recycling and sustainable waste activities as noted by Bolaane (2006), this does not essentially lead into active involvement toward environmental initiatives. Inadequate knowledge has stopped communities from completely accepting waste management innovations leading to limited participation in the decision-making process. This lack of involvement has encouraged an irresponsible attitude towards pollution and waste challenges.

Many studies by NEMA (2015), Ndahimana et al. (2020), and Ogwueleka (2009), observed that, Rwandans, Kenyans and Nigerians have limited awareness about the importance and benefits of efficiently managing waste. This has caused poor practices like littering, dumping, and unwillingness to participate in waste management initiatives for the good of the environment. Limited awareness about the separation of waste and lead to the collection of mixed waste which reduces the prospects for resource recovery. Feline et al. (2023) also noted that, there is little success in educating people in Rwanda about waste management. Similarly, Ogwueleka (2009) pointed out that though awareness campaign has been launched in Nigeria to encourage recycling, they still don't have an education plan that is well-structured and sustainable.

M'Nkubitu (2022) suggested that awareness concerning the management of waste can be encouraged via school programs. According to her report, people often have a negative view of products that have been recycled, thereby discouraging efforts made in recovering waste. However, if private sectors can increase awareness, people will have more appreciation for recycled goods thereby encouraging resource recovery.

4.4.4 Lack of technical and human capacity

Moreover, like most African nations, these nations are facing a lack of proper technologies and tools for waste management. Guerrero et al. (2013) assert that due to insufficient funding, these countries use outdated and inefficient waste collection, transportation, and disposal methods, which negatively impact environmental conditions and generate a threat to public health. For instance, NEMA (2015) noted that in Kenya, composting is a common practice due to the lack of sufficient funding. However, the machine quality is low, which results in poor compost turnover after use. In Rwanda, Iraguha (2013) highlighted that similar technologies used due to insufficient funding limiting the desirable equipment. Guerrero et al.(2013) also claimed that these nations are not able to access modern technologies and tools, like recycling facilities and composting and waste-to-energy equipment. For example, based on Iraguha (2022), Rwanda has no waste-to-energy equipment that can provide modern facilities due to outdated equipment.

Mmerekiki et al. (2016) highlighted the inadequate availability of skilled personnel which includes; technicians, engineers and waste management professionals which hinders proper planning, execution and monitoring of waste management programs. According to Oroye (2020), this problem is compounded by an insufficient possession of special training or education which happens mostly in Nigeria. Ferronato et al. (2019) and Kirama et al. also pointed out that there is inadequate trained personnels in the waste management and planning sectors in both the private and government sectors. Other African nations like; Angola, Burundi, the Central African Republic, and Liberia also have similar issues with inadequate technically trained personnels in circular economy practices EPA (2022).

Aparcana (2017) explained that the majority of professionals choose to work on sectors such as banking or insurance and in NGOs since it is better paid and fulfilling than waste management sector. Pastor et al. (2021) stressed that trained personnels in waste management are needed. To tackle the issue of waste management and attain Sustainable Development Goals (SDGs) 3, 6, 11, and 12, it is very important that trained personnels are incorporated into the waste management process as suggested by Filho et al. (2022).

4.4.5 The lack of political will and investment

Bressanelli et. al. (2015) has identified absence of political will as one of the main hindrance in delivering sustainable waste management solutions. Wilson and Velis (2015) noted inadequate support for waste management in many developing countries due to frequently insufficient political commitment, which underlines the need of more strenuous efforts at this level.

According to UNEP's 2022 report, African nations need approximately between 6-42 billion USD to develop large-scale recycling and recovery plants. Ali (2021) observed that, entrepreneurs don't easily invest in circular economy related projects because of high cost of getting waste management technologies. They prefer to invest in the linear economy model since it brings fast returns on investment. Munir (2021) argued that, if African leaders understand the difficulties of transitioning to a circular economy, they will be able to set aside more resources to manage waste.

Fernando (2019) highlighted that, stakeholders prefer a cheaper option of waste disposal methods like open dumps, engineered landfills, which impacts the environment, public health and environment negatively. A study from world Bank (2012) said that poor waste management actions lead to huge financial losses in 18 African countries including; Rwanda, Ghana, Zambia, Nigeria, and Kenya. More so, nations like Niger, Mauritania, Mozambique, Burkina Faso, and Madagascar lose USD 5.5 billion yearly because of lack of sanitation.

According to Yeasmin et al. (2017), Entrepreneurs prefer to invest in infrastructural projects like schools and roads rather than investing in sustainable development projects, irrespective of the benefits. . Ibrahim et al. (2020) further noted that, very few political leaders express the willingness to invest in environmental projects.

4.6 Opportunities

According to Guerrero et al 2013, waste management poses a significant challenge for many African nations, including Rwanda, Kenya, and Nigeria. However, Debrah et al 2022 in their study noted that, these nations also offer opportunities for innovative solutions and a shift towards a circular economy perspective, which could address environmental concerns, create green jobs, and promote sustainable development.

The government of Rwanda (2020) has shown a strong dedication to rationalizing its waste management system and accepting circular economy principles. The circular economy initiatives utilised by Rwanda, has the opportunity to create employment in the recycling, upcycling and remanufacturing sector by 112-15% yearly. This increase is projected to bring about an increase in GDP by \$4.5 million by 2030.

In accordance with UN-habitat's (2022) study, Rwanda intends to renew the present Nduba landfill into a Resource Recovery Centers where waste processing, treatment, and recycling can be carried out. This initiative has the potential to convert organic waste (which is more than 65% of solid waste) which gives opportunities for biogas and compost production. This can be used in urban areas to produce renewable energy and agricultural applications. If waste to energy initiatives are also improved, it could create about 15,000 jobs in cities as reported by GGGI (2023). It could also empower the informal waste sector by employing more than 30% of the people currently working in the chain of waste management sector.

Moreover, according to the government of Rwanda, (2020), the nation's commitment to sustainable development, environmentally friendly growth and greenhouse gas emission reduction offers opportunities for new waste management systems implement, including cutting-edge recycling technology and waste-to-energy solutions.

Moreover, RDIS (2018) pointed out that, the fact that more people are becoming aware and interested in sustainable development in Rwanda, is an opportunity to enhance innovative waste actions. The government and local authorities can take advantage of this growing awareness by actively collaborating with the communities by educating them on the importance of good waste management. This method can encourage improved public collaboration and aid for initiatives that are centered on reduction, recycling and composting of waste. By drawing from this heightened environmental awareness, the nation can potentially increase the acquisition of more sustainable waste management actions.

Meanwhile, in Kenya, waste management initiatives that are innovative are providing huge opportunities for the growth of the economy, creation of jobs and sustainability. For instance, the Sustainable Waste Innovation for a Future in Transition (SWIFT) program offered by the Kenya Climate Innovation Center, aided by the IKEA Foundation. The aim of this program is to encourage the advancement of small and medium-sized enterprises (SMEs) in the area of waste management focusing on 110 SMEs in a period of three years. The program projected impact involves revenue generation of about \$10 million across the cities, job creation of more than 2,000 directly and 4,000 indirectly and profiting more than 5,000 households Kenya Climate Innovation. (2024

Additionally, World Bank Group. (2021) reported that, other entrepreneurs are contributing to this area in addition to what SWIFT is doing. An example is a Kenyan entrepreneur who is using plastic materials to create building materials that are affordable and sustainable. This does not only reduce pollution by plastics but also gives construction options that are cost-effective. This shows a wider pattern in Kenya where innovative methods in the management of waste are becoming more profitable for the environment and economic growth. Joined efforts from the public and private sectors shows the possibility for innovative waste management to decrease plastic pollution, advance the circular economy, and develop opportunities for the economy of Kenya

The Stratbase ADR Institute (2013) has reported that collaborations involving environmental management have shown promising outcomes in the past. This suggests that involving the private sector could bring not only financial resources but also valuable industry expertise to the table. Such expertise has been recognized as beneficial in developing solutions that are technology-driven for solid waste management in Kenya's urban areas. Previous experiences have demonstrated the prospects of private sector involvement in solid waste management and environmental protection efforts. These findings underscore the importance of leveraging private sector partnerships to enhance waste management practices and environmental conservation in Kenya.

Dickson et al. (2022) further emphasize the potential benefits of education and awareness in solid waste management. They argue that educating individuals and stakeholders can enhance the application of policies and regulations regarding solid waste management. Furthermore, this education can motivate people to actively participate in reducing, reusing, and recycling solid waste, contributing to a healthier future.

Kigozi et al. (2014) underscore Kenya's potential to embracing alternative waste treatment technologies as a solution to inefficient disposal practices, such as open burning and waste dumping at the Dandora site. They propose anaerobic digestion, pyrolysis, and gasification as viable technologies for converting organic waste into valuable products like biogas, biofuels, and charcoal. These advanced treatment strategies gives dual benefits: they decrease landfill waste and produce renewable energy and industrial byproducts, which could aid multiple sectors.

Additionally, Onyango et al. (2019) emphasize the possibilities for innovation incorporating Kenya's informal waste sector into the formal waste management framework. The informal sector greatly contributes to waste collection and recycling, employing many people and small enterprises. By formalizing and supporting this sector, Kenya could make use of its existing knowledge base and infrastructure to enhance waste management efficiency. This integration also presents an avenue for new economic possibilities for marginalized communities, thus encouraging inclusivity while enhancing waste management effectiveness.

According to the Ministry of Environment and Natural Resources (2016), there is a huge market opportunity for compost in Kenya. Presently, demand is more than 100,000 tonnes yearly, while yearly production is at 10,000 tonnes. This huge difference gives an opportunity for people to come up with initiatives that are similar to the Pilisaru Project or Waste Concern to fill. Even though to be able to make use of the whole value chain from compost production to consumer access, many aspects marketing aspects need to be confronted. Private or local institutions engaging in compost production has to think about collaborating with fertilizer distributors to make use of current networks for more distribution. The government can also buy in bulk and redistribute to its institutions. In order to improve accessibility and affordability for farmers, the government can apply market-based instruments like subsidies to decrease cost of production. More so, raising awareness about the positive aspects of compost can possibly enhance people's willingness to buy. This educational method help stir up demand and aid the growth of market for compost in Kenya.

Lastly, according to M'Nkubitu's (2022), plants such as Sofi Organics, Taka Taka Solutions and Sanergy, present valuable potentials for both national and local governments in Kenya. These plants can act as consultants when circular economy models for the management of organic waste is being developed. These companies can also assist in the transition to circular economy models and assist in the development of suitable and pragmatic policies. Partnerships from these businesses can boost the government's confidence to reach out and attract international aid and make such businesses landmarks from which others can emulate their practices.

Akanji et al. (2023) underscore Nigeria's notable prospects to develop circular economy business models by taking advantage of several waste streams, such as plastics, e-waste, organic waste, textiles, and scrap metals. They proposed that viewing waste as an important resource permits the creation of new business models and value chains that are focused waste collection, processing, and reuse, in line with circular economy principles. Nwachukwuet al. (2022) further emphasize that these

waste streams contain considerable amounts good for recycling and resource recovery solutions, presenting extensive possibilities for resource-efficient industries.

Moreover, Ezeudu et al. (2019) identify innovation prospects in incorporating Nigeria's informal waste sector into formal waste management systems. Given the country's huge informal waste-picking and recycling workforce, formalizing and integrating these workers could boost recycling rates, enhance material production for recycling industries, and create jobs that ameliorate livelihoods. Developing inclusive waste management models that make use of the existing informal networks and improve working conditions could greatly enhance waste management efficiency. Additionally, Scrapays (2023) highlights the prospects of digital and technological solutions in Nigeria's waste sector, including digital platforms, mobile applications, and tracking systems. These tools can optimize waste collection, enable tracking and payments, and connect stakeholders across the waste value chain. Companies like Scrapays are already promoting the transformative possibilities of tech-enabled approaches, showing how digital incorporation can improve the organization, transparency, and effectiveness of waste management in Nigeria.

Furthermore, Kaltani (2023) and Magoum (2023) highlight the significant role of innovative startups and entrepreneurs in Nigeria's waste recycling, upcycling, and circular economy sectors. This trend offers a promising opportunity to drive sustainable waste management solutions across the nation. Companies like Wecyclers, known for their incentive-based recycling model, and Kaltani, which focuses on plastic recycling, exemplify impactful, locally-driven innovations in waste management. These startups showcase how locally adapted circular economy models can add to both environmental sustainability and social development.

To maximize the potential of these innovative ventures, assisting incubation, funding, and market access is important. By offering resources for capacity building and scaling, such initiatives can improve market competitiveness and increase the reach of these solutions. Support given to entrepreneurs can aid in the establishment of a robust ecosystem for circular economy innovations, encouraging more local actors to enter and sustain waste management industries while dealing with serious environmental challenges in Nigeria.

UNIDO (2022) also highlights the opportunity to develop and enforce supportive policies and regulations that enable circular economy actions, like extended producer responsibility (EPR) schemes. Creating an appropriate policy environment can encourage private sector participation and investment in waste management innovations.

The World Bank (2021) reports on the potential for building models for innovative public-private partnership for waste collection, recycling, and waste-to-energy projects. These partnerships could help introduce new technologies and attract investments to modernize waste infrastructure. There's also room for innovative strategies to increase public awareness, drive change of attitude towards waste segregation and recycling, and encourage circular consumption patterns among Nigerian consumers. Education and awareness campaigns, joined with motivative schemes, could play an important role in changing waste management actions at from the basic level.

Finally, there's an opportunity to develop low-cost, locally appropriate waste management technologies and approaches tailored to the Nigerian context, especially for challenging waste streams like e-waste and medical waste.

In summary, Rwanda, Kenya, and Nigeria are dealing with serious waste management obstacles. However, according to Debrah. et.al.(2022), they also create various possibilities for innovative approaches and a move toward a circular economic model. These countries can promote environmentally friendly development, generate green careers, entice investment, and tackle urgent environmental concerns by embracing these prospects through legislative updates, collaborations between the public and private sectors, entrepreneurship, and the adoption of technology, as well as capacity building advertising campaigns. Simultaneously, these steps may assist in unlocking the economic potential of waste valorization.

4.7 The way forward

Summarily UNEP (2018) recommends a multifaceted approach to waste management in Africa, including Nigeria, Rwanda, and Kenya, which is a combination of technological improvements, policy advancements, community participation, and adoption of practices that have worked in the western world, adapting it to the African context. The paper addresses ways to deal with waste management issues in the three nations in order to prepare for future rise in waste generated in the years ahead.

4.7.1 Embracing technological innovations

An important aspect of innovative waste management includes embracing technology-driven solutions as noted by Taiwo (2010). An example is how mobile applications are being used to help with the collection, scheduling and reporting of waste. This is gradually becoming a popular tool to enhance waste management efficiency and at the same time engaging the citizens. Ebinabo et al. (2023) pointed out that, in Nigeria, Scrapays encourage recycling using a monetary reward system. This approach not only boost the reduction of waste, but also aids to provide a sustainable environment by channelling materials that can be recycled away from landfills. If similar technological innovations are expanded all over Nigeria, it could greatly enhance waste management actions, reduce cost of operations and boost service delivery.

More so, UNEP (2018) propose that incorporating data analytics and real-time monitoring can enhance the collection of waste by recongnizing high-waste areas and streamlining collection routes. This technological method falls in line with innovative initiatives seen across Africa, where nations are increasingly embracing smart solutions for waste management issues. For instance, in Rwanda, the Ministry of ICT and Innovation (MINICT,2024) started the Smart Waste Management Pilot Project in Kigali. This project makes use of IoT-enabled bins that monitor fill levels in real-time and notify waste collectors when bins are full, making sure that waste is collected on time and overflow issues are decreased. These solar-powered, eco-friendly stations also feature surveillance cameras to improve waste collection monitoring and efficiency. Rwanda's smart waste management project demonstrate the possibility of digital innovation to enhance urban waste management, decrease environmental impact, and encourage resource-efficient practices across the region.

Similarly, the UN-Habitat (2022) reported that Kenya's adoption of artificial intelligence (AI) is a great way to revolutionize waste management by connecting stakeholders through a centralized online platform, automating the disposal, collection, and recycling of waste. This will go a long way to incentivize residents to increase recycling and raise awareness of proper waste management, in order to reduce waste generation and improve recycling rates. UNEP (2018) also proporsed that, cities need

to begin with basic technology that require minimum capital, labour-intensive and that are accepted in the community.

Eurostat (2022) stated that an alternative innovative method is to leverage waste-to-energy (WTE) techniques. These establishments transform non-recyclable waste into power or warmth, curbing fossil fuel dependency and offering a renewable energy resource. Sweden and Denmark have realized success in adopting WTE systems Eurostat (2022). Transitioning to these systems in Africa and factoring in regional waste composition and infrastructure could be an effective solution to waste management challenges

4.7.2 Promoting circular economy principles

Debrah et al. (2022) stressed that the adoption of circular economy is a very important step for sustainable development in these nations and Africa as a whole. This plan puts more focus on the reuse and recycling of products for waste reduction. Kenya has experienced remarkable advancement in this area, especially with the plastic bag ban that was established in 2017 Wasike (2024). An example is the company called Taka taka solutions which recycles 95% of collected waste and convert it into usable products for local manufacturers and compost organic waste. The company also collaborate with specialized recycling partners where they send other materials like glass and paper for recycling. The method has been very useful in decreasing plastic waste. Other nations can emulate this strategy UN-habitat (2022).

Debrah et al. (2022) also highlight Rwanda's efforts to develop circular economy initiatives so as to treat waste as a resource, encourage recycling and decrease dependence on landfill. An example is the GGGI (2021) project who's aim is to set up a sorting and recycling company at Nduba dumpsite to enhance the separation of waste and recycling in order to decrease waste sent to landfills. Fundings provided for such infrastructure can aid the nation to provide green jobs, generate income from waste and reduce greenhouse gas emissions.

According to Taiwo (2010), reusing and recycling can greatly decrease waste sent to landfills, thereby reducing costs and mitigating negative environmental impact to the soil, air and water. Nigeria for example is developing recycling infrastructure and entrepreneurship to assist businesses that utilise recycling materials as explained by Ebinabo et al. (2023). Initiatives like srapays promote entrepreneurship in the sector of waste, thereby increasing the creation of jobs and growing the economy.

The idea of 'zero waste' in cities, supported by Avfall Sverige (2021), has become very popular at the global level and can be adjusted into African contexts. This method stresses on waste reduction, reuse and recycling for the purpose of limiting the amount of waste sent to landfills and incinerators. Bolaane (2006) demonstrates that establishing recycling centers that are accessible and providing financial incentives are important tools to enhancing solid waste management systems (SWMS). When recycling is made formal, it can create informal employment opportunities McAllister (2015), and at the same time, saving money and resources for the municipalities.

4.7.3 Strengthening policy frameworks

It is very important that all three nations improve on their policy frameworks and on the implementation of their regulations on waste. Bartone (1993) suggests that efforts should focus on establishing solid waste-related laws, ordinances, and regulations, alongside defining inspection and implementation procedures at national, state, and local levels. Effective enforcement requires authorities to have the capacity to monitor compliance, implement regulations efficiently, and ensure broad public support.

Although Rwanda and Kenya have made progress with plastic bans and e-waste regulations, the Kenya Climate Innovation Center (KCIC) (2024) indicates the need for more comprehensive waste management policies and stronger enforcement mechanisms. Additionally, these regulations should be extended to other single-use plastics and materials that are harmful to the environment. In Nigeria, the development and enforcement of robust waste management regulations—including waste segregation, recycling, and proper disposal methods—could yield significant benefits. In addition, Zadawa et al. (2015) proposed that Extended Producer Responsibility (EPR) programs should be implemented to hold companies accountable for their product lifecycle including disposal. This will bring about more sustainable waste management practices.

An article written by Oteng-Ababio (2011) observed that officials from African nations don't take waste minimization plans seriously, thus more waste is dispatched to landfills. This greatly increases the cost of waste management. He proposed that the state should come in to encourage recycling, reuse, consumer awareness and campaigns in towns that lack such initiatives. Municipalities can also promote Extended Producer Responsibility (EPR) programs by stopping the disposal and incineration of goods that can be recycled.

Kumar et al. (2022) suggested that African nations can adopt the well-established EPR programs from western nations, modify it and adapt it into the African context. This can cause companies to design more sustainable products and assist the general efforts made in waste management. More so, O'Connell (2011) that incentives should be provided to manufacturers by increasing the cost of extracting raw materials and involving manufacturers in the disposal expenses to urge them to reduce waste. This method will increase producer's accountability, thereby reducing waste. As consumers become more knowledgeable about the significance of reducing waste, they may start to buy products made from recyclable materials so that they can reuse and recycle their products rather than dispose of it.

Lastly, Zadawa et al. (2015) proposed that, local governments can look at options for funding like local taxes to aid initiatives in waste management. Additionally, international partnerships and transfer of technology can give nations like Nigeria the training and resources needed to enforce advanced solutions in waste management. Though these EPR programs require good regulation enforcement by the municipalities and active collaboration from the public.

4.7.4 Community engagement and education

McAllister (2015) posits that community involvement and public awareness are critical for successful waste management practices. Public education on the best ways to dispose of waste, the significance

of recycling and the environment's impact on waste can result to substantial change in behaviour. World Habitat (2017) showcases the Dajopen Waste Management team in Kitale Town, Kenya, as a good example. The group educates members of the community on bin collection, waste processing, and the creation of compost, briquettes, and recycled roofing tiles as valuable goods. These community recycling programs serve as examples of how local populations can solve waste issues.

Similarly, Musa (2020) stresses that it is important for Nigeria to consider the significance of utilizing public awareness programs and environmental education programs to change people's behaviours and attitudes regarding waste management. Educating people about the significance of good disposal and recycling can promote a sustainable culture. Bolaane (2006) added that policies on recycling should encourage people-centered approaches with public education serving as the basic driver to enhance participation from the public.

Mrayyan and Hamdi (2006) also show a positive relationship between public awareness and good management of solid waste. Their study showed that environmental awareness programs can greatly influence public knowledge and enhance waste management practices, especially in attaining waste separation. This can play a great role in reducing pollution from solid waste.

Jessica McAllister (2015) emphasizes that successful waste management plans are often as a result of active community involvement. A good example of this in Rwanda is the "Umuganda Day" initiative, a monthly event where people convene to clean streets and collect waste, showing the impact of organized community participation. Building on such efforts, the Global Green Growth Institute (GGGI) (2024) suggests that Rwanda could improve these initiatives by adding the frequency of community clean-ups and establishing environmental education programs in schools. These measures could promote a powerful environmental ethos from a young age, cultivating long-term sustainable behaviors.

In Kenya, Wasike (2024) highlights an innovative initiative in Dandora, the Taka Bank, that rewards people who bring recyclable waste to collection points. These tokens can be redeemed for essential goods, incentivizing participation in waste management while providing tangible rewards to the community. This approach not only sustains clean neighborhoods but also empowers the people economically.

Similarly, Musa (2020) suggests that Nigeria could profit from adopting community-based waste management programs like neighborhood clean-ups and waste segregation efforts. By closely working with local communities and using public awareness campaigns and school-based environmental education programs, Nigeria can promote long-lasting transitions toward sustainable waste practices. Incorporating environmental education into school curricula, from the elementary level, and using low-cost awareness methods, like seminars, workshops, and newsletters, can greatly improve public awareness and responsibility. As McAllister (2015) further explains, making use of community resources like media, community groups, elected officials, and interested organizations—can offer necessary aid for waste management. Even though municipalities are responsible for waste services, they rely on community involvement to sustain good and sustainable waste management outcomes.

Milea (2009) also suggested that public campaigns should highlight residents' responsibility for waste and the importance of collective community efforts to address waste issues. This motivation and information campaign should be fueled with means to facilitate community participation.

Additionally, Simelane & Mohee (2012) proposed that communities should be responsible to collect and dispose of their waste. This strategy stresses that communities should help each other so as to reduce the cost of managing waste and increase local interest in waste reuse. This strategy emphasis on community participation in the reuse of waste items. Economic and socio-psychological incentives can be used as a tool to influence people's behaviour Bolaane (2006),Mrayyan and Hamdi (2006), and Milea (2009). Though socio-psychological incentives may work in the long run, joining them with economic incentives, educational campaigns and more community involvement can be a successful method in African nations, says McAllister (2015).

4.7.5 Addressing informal waste sectors

Confronting the informal waste sector is important for promoting effective waste management in Africa, as Osho (2016) notes. In countries like Nigeria, the informal sector plays an important role in the collection and recycling of waste. Formalizing and regulating this sector could not only improve safety and efficiency but also working conditions for informal waste workers. This formalization can advance the broader waste management system, making it more organized and sustainable.

According to Zadawa et al. (2015), recognizing and involving the efforts of informal waste workers, like the cart pushers, scavengers, and resource merchants, within formal waste management frameworks can bring more sustainable and inclusive results. Providing these workers with training and resources can elevate their skill levels and economic opportunities, helping to create a more inclusive and effective system.

4.7.6 Promoting waste-to-resource initiatives

UNEP (2018) report suggests that there is a huge potential in waste-to-energy investments. Methods like composting organic waste, developing a market for recycled materials and creating waste-to-energy technologies can bring economic gain, at the same time mitigate environmental harm. These strategies aid broader sustainable development goals and can increase job opportunities within the green economy. African nations can also look at successful practices in the western world, modify it and adapt it according to their context.

4.7.7 Leveraging public-private partnerships

According to Debrah et al (2022), It is important for there to be partnership between the governments, private sector and NGO's in order to bring about innovation in waste management. Public-private collaborations can lead to more investments in infrastructure, advance the creation of new technologies and augment successful initiatives. An example is the "Switch Africa Green" project that was adopted by Ghana, Nigeria and Kenya with the aim of attaining green economic goals via such partnerships. Another example from the UN Habitat. (2022) report is the Integrated Waste Management for Improved Livelihoods (INWAMI) project in Kenya which aims to develop a complete waste management system that creates jobs and improve livelihoods UN Habitat (2022). Public-private collaborations such as this can lead to investments, aid in the development of new technologies and aid in augmenting successful ideas. Similarly, the Waste and Circular Economy (WCE) project, which is part of the Rwandan-German Climate and Development Partnership, permits both the private and public sector to enforce circular economy practices in Rwanda's waste sector GIZ (2023). These collaborations provide funds to aid sustainable solutions, and assist circular economy practices.

According to Kruljac, (2012) the government can also partner with the private sector by privatizing waste management activities fully or partially, then they can now play the regulatory role. He added that, decentralizing Solid Waste Management Services (SWMS) necessitates a redistribution of powers and capacities, often requiring a revised organizational structure. Another research by Zhu et al., (2008) added that, in many developing countries, private sector involvement is increasingly seen as a cost-effective solution for waste management. Private sector engagement in waste recovery can generate revenue to fund aspects of waste management, including policy enforcement.

More so, a study in Kumasi, Ghana, carried out by Asase et al., (2009), identified privatization as a promising solution to institutional constraints in waste management. Private sector participation in waste collection can complement waste diversion programs in collaboration with the informal recycling sector. However, researchers argue that private sector involvement would be more effective in a competitive environment with mechanisms for performance monitoring and accountability

Lastly, Western countries have well-established partnerships between municipalities and private waste management companies, a model that African countries could adapt to improve the efficiency of waste collection and processing.

4.7.8 Focusing on e-waste management

According to report from UNEP (2018) study, e-waste management has become increasingly important due to the growing use of electronic devices. These nations should establish proper e-waste collection and recycling programs. Report from Republic of Kenya (2019) notes that Kenya has made strides in this area by implementing regulations that focus on the quality and energy efficiency of electronic appliances. Similarly, Rwanda is advancing e-waste management by enhancing collection efforts and improving the regulatory environment for recycling. Report from GGGI (2012) states that Rwanda is making strides in electronic waste (e-waste) management by establishing specialized recycling facilities and partnering with electronics manufacturers through take-back programs. These initiatives aim to make sure of safe disposal and recycling of e-waste, decreasing environmental harm and supporting resource recovery. More so, in order to safeguard public health and the environment, there is need for effective management of hazardous waste. For example, the "Waste to Resources" project aims to improve the management of hazardous waste via technical assistance and transfer of technology.

Summarily, the UNEP (2018) study proposes that to advance waste management in Rwanda, Kenya and Nigeria, there is need for diverse approach which involves policy advancement, technological innovation, community involvement and strategic collaborations. If circular economy principles are adopted, regulations are improved, new technology is used, public-private collaboration is improved, these countries can deal with their waste management issues effectively. Though the challenges faced by each nation is unique, they can still learn from successful initiatives and adapt them to their local contexts. This can bring great improvements like Rwanda's complete e-waste management approach and Kenya's ban on plastic bags.

CHAPTER FIVE - CONCLUSION

This extensive literature review on solid waste management (SWM) in Africa, with a focus on Nigeria, Kenya and Rwanda, emphasize the significant policies, innovations and issues affecting the future of waste management in these areas. With increase urbanization and population growth, it becomes more complex to manage waste sustainably. This study utilizes the comparative analysis research approach to point out and compare policies, innovations, challenges and opportunities for advancement in these countries.

From the result, Rwanda has a vigorous regulatory framework and has enforced a nation-wide ban on plastic bags which demonstrates the effectiveness of powerful leadership from the government and community participation in causing change. Kenya has incorporated technology, especially artificial intelligence and e-waste management which points out the possibility for innovation to handle issues related to waste. Meanwhile, despite the fact that Nigeria is faced with infrastructural and economic difficulties, they are still making strides in implementing circular economy models. This offers huge economic possibilities and at the same time, dealing with environmental concerns.

The results also show that, all three countries are persistently confronted with similar difficulties, which includes; limited funds, inadequate public awareness, lack of a comprehensive data to help decision-making. Nonetheless, the study expresses promising approaches that if augmented through out Africa, could improve environmental sustainability and public health results. These methods include; technological innovations, policy reforms, community participation and incorporation of the informal waste sector into the formal system.

As Africa advance in their journey of waste management, the insights from Rwanda, Kenya and Nigeria provides important knowledge and a potential road map for other countries to emulate. Important recommendations include;

1. Increasing endeavours in collecting and analysing data in order to guide effective policy and infrastructural development.
2. Ameliorating regulations to aid circular economy principles and extended producer responsibility.
3. Intensifying public-private collaborations to enhance innovation and expand investment in the waste management sector.
4. Strengthening public education and awareness to boost responsible waste management actions.
5. Developing locally tailored technologies and solutions to address Africa's unique waste management challenges.

Even though faced with challenges, these nations have shown through their progress that it is possible to attain effective and sustainable waste management across Africa. By making use of these knowledge and improving collaboration amongst African nations, Africa can move towards a future that is more sustainable and environmentally responsible.

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