DEVELOPMENT OF THE RECYCLING PRACTICES OF MUNICIPAL SOLID WASTE IN KENYA

Lappeenranta–Lahti University of Technology LUT

Bachelor's Programme in Technology and Engineering Science

Bachelor's thesis

2025

Sheilline Jepkemboi

Examiner: Professor, D.Sc. (Tech.) Mika Horttanainen

Supervisor: M.Sc. (Tech.) Amirmehrab Falsafi

ABSTRACT

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Keywords: Municipal solid waste, Recycling practices, Kenya, Developing countries, Developed countries and challenges.

Municipal solid waste management (MSWM) is a key environmental and economic challenge globally, particularly in developing countries such as Kenya. This study examines the development of recycling practices in Kenya's MSWM system through the assessment of existing practices, identifying key challenges, and comparing them with global best practices. Based on secondary data from government reports, academic publications, policy documents, and international organizations, qualitative and quantitative analyses were used. The study reveals that despite major advances from initiatives like the ban of plastic bags and private recycling companies, recycling rates remain relatively low in Kenya compared to developed countries. Challenges that contribute to low recycling rates or poor waste management (WM) are inadequate infrastructure, weak policy enforcement, low public awareness, and inefficient technological investments. The study highlights best practices from Germany and proposes evidence-based recommendations, including strengthening policy implementation, public awareness in recycling, Deposit refund system, ban of landfilling and standardized color-coded system to facilitate waste sorting. Enhancing Kenya's MSW recycling system is essential for environmental sustainability, economic development, and health protection.

ABBREVIATIONS

MSW	Municipal Solid Waste
MSWM	Municipal solid waste management
REI	Recycling Economic Information
NEMA	National Environmental Management Authority
PET	polyethylene terephthalate
GHG	greenhouse gas
WM	waste management
NAMA	Nationally Appropriate Mitigation Action
EU	European Union
KNBS	Kenya National Bureau of Statistics
GDP	Gross domestic product
CBO	community-based organizations
PAKPRO	Kenya transitioned to the Packaging Producer Responsibility Organization
NGOs	Non-governmental Organizations
WEEE	Electrical and Electronic Equipment
CBD	Central Business Districts

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1 Introduction

Municipal solid waste (MSW) is waste generated from households, commercial, public institutions, and industries. It consists of different items such as paper, rubber, plastic, metal, food remains, furniture, packaging, and clothing (Pandey et al., 2022). MSWM remains a challenge to most countries globally. The potential increase in the generation of MSW is caused by rapid urbanization, industrialization, and population increase (Zhang et al., 2024). According to the World Bank (2018), annual global waste production is expected to rise from 2.01 billion metric tons in 2016 to 3.40 billion metric tons by 2050, with the highest increase occurring in developing countries. Most developed countries use advanced waste management techniques, including recycling, composting, and waste-to-energy recovery, supported by strong policies and public participation (Kaza et al., 2018).

However, developing countries, like Kenya, face challenges in waste management (WM) such as inadequate infrastructure, weak policy enforcement, and limited public awareness of recycling. Kenya produces large quantities of MSW, for instance, Nairobi, the capital city alone produces over 2,400 metric tons daily, and little of this is recycled (World Bank, 2021). Most waste is dumped in open dumpsites like Dandora dumpsite located in Nairobi which is considered the largest dumpsite in East Africa. Dandora dumpsite varies in size in various sources such as the The EastAfrica (2020), states Dandora dumpsite covers over 12.14 hectares and causes air, soil, and water contamination, posing severe health risks to nearby residents (The EastAfrican, 2020). Other sources state that Dandora dumpsite cover 46 hectares (Oluoko-Odingo and Mutisya, 2019). While waste collectors in the informal economy contribute much to recycling, little or no support from formal economy systems is evident to support these efforts (Heinrich-Böll-Stiftung, 2022).

Kenya's WM sector is inefficient due to poor waste segregation, inadequate infrastructure, lack of strict policies and government support (Sibanda, Obange and Awuor, 2017). Understanding the development of waste recycling in Kenya is crucial to identify opportunities for improvement. Earlier studies on WM provides an insight into the state of recycling in Kenya and further explain lessons learned from international best practices.

This research is important to help in understanding how WM and recycling contribute towards waste reduction and pollution control (Kaza et al., 2018), and urgent need to address environmental challenges.

Poor WM such as littering, open dumpsites and uncontrolled landfills, contributes to environmental degradation and health risks. These practices release toxins that contaminate water and degrade the quality of soil. Additionally, open burning of waste releases fine particulate matter, which can cause severe respiratory and cardiovascular problems. Waste left to rot or disposed of in unmanaged dumpsites attracts insects and rodents, which are associated with diseases like malaria and cholera (Gebrekidan et al., 2024).

Efficient WM is not only essential for environmental sustainability but also economic stability of a country. Efficient WM is advantages to a country's economy, such as job creation and cost saving. Reducing waste generation and efficient WM reduces the government expenditure on waste collection, transportation, and disposal. This enables the country to redirect funds to other sectors. Recycling, composting, and material recovery generates employment opportunities in both formal and informal sectors. Landfilling the organic waste emits methane, a potent greenhouse gas (GHG) that is a leading cause of global warming. Climate change is intensified by poor WM through increased carbon emissions (Ackerman, 2000).

This study also provides an in-depth understanding of existing problems, highlights the gaps in current policies and practices, and offers recommendations to improve MSW recycling in Kenya. Countries with effective recycling programs have demonstrated significant reductions in landfill use, lower pollution levels, and economic benefits through resource recovery (Wilson, Velis and Cheeseman, 2006).

This study aims to explore the development of MSW recycling practices in Kenya, with emphasis on urban areas such as Nairobi, Mombasa, and Kisumu. The primary objective of this study is to assess the current state of MSW recycling in Kenya, Specific objectives include:

- Identify the challenges hindering the adoption of recycling practices in Kenya.

- Compare Kenya's MSW recycling practices with developed countries and identify potential improvement.
- Propose evidence-based policy recommendations to strengthen Kenya's waste management.

1.1 Methodology

The data was obtained from secondary sources to study the development of MSW recycling practices in Kenya. It involved collection, screening, and selecting of data, while focusing on relevance, credibility and up-to-date sources aligning with the objectives.
Both qualitative and quantitative data were used to provide a comprehensive understanding of MSW recycling practices in Kenya.

Table 1. Secondary data sources and references used in the study.

Data source	Reference
Government Reports	(NEMA, 2023)(NEMA, 2015)(KNBS, 2023)
NGOs / Private organizations	(Taka Taka Solutions)
Case studies	(Samantarai and Dutta, 2024)
International organizations	(UNEP, 2024; World Bank, 2018a; World Bank, 2018b; World Bank, 2021)
Policy documents	(National Environment Management Authority (NEMA) , 2022)
Academic journals	(Henry, Yongsheng and Jun, 2006; Wilson, Velis and Cheeseman, 2006)
Newspaper	(Nation, 2025; The EastAfrican, 2020)
Statistical data	(Statista, 2024a; Statista, 2024b; Statista, 2025)

Qualitative data included case studies and policy documents such as NEMA reports, and sustainable WM Act 2022, provided a regulatory framework. and quantitative data such as government statistics (KNBS) and Statista provide the amount of waste generated, recycled,

recovered, and collected. While global best WM practices shall be analyzed for comparison, research efforts shall focus most on challenges and solutions within the socio-economic and regulatory framework of Kenya (National Environment Management Authority (NEMA) , 2022). The limitations in this research were lack of data related to how recycling has developed in Kenya and fraction of different waste recycled and the evolving nature of recycling practices in Kenya. Despite these limitations, the study provided the percentage of recycled materials, amount of waste generated and different companies recycling rates in Kenya.

2 Recycling practices globally

In 2016, Globally, 33% of MSW were disposed in open dumpsite, 25% in landfill (unspecified), 13.5% recycled, 11% incinerated, 7.7% sanitary landfills, 5.5% underwent composting, 4% controlled landfill and 0.3% others as shown in the figure 2 (Kaza et al., 2018) This highlights major inefficiencies in global waste treatment systems, with open dumping and poorly managed landfilling still common in most regions.

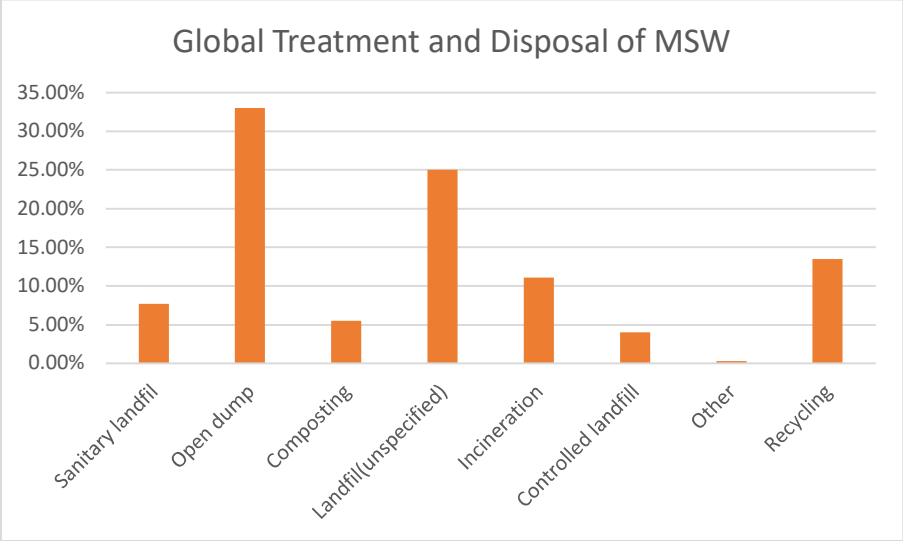

Figure 1. Global treatment and disposal of MSW Source: (Kaza et al., 2018).

According to Statista (2025) United state was the leading producer of MSW which generated 200 million metric tons as per the latest statistics. United States is leading in MSW generation due to increased population, urbanization, and rising culture in throw-away, influenced by consumerism. Paper and cardboards being the highest share of all waste materials entering the United States (Statista, 2024c).

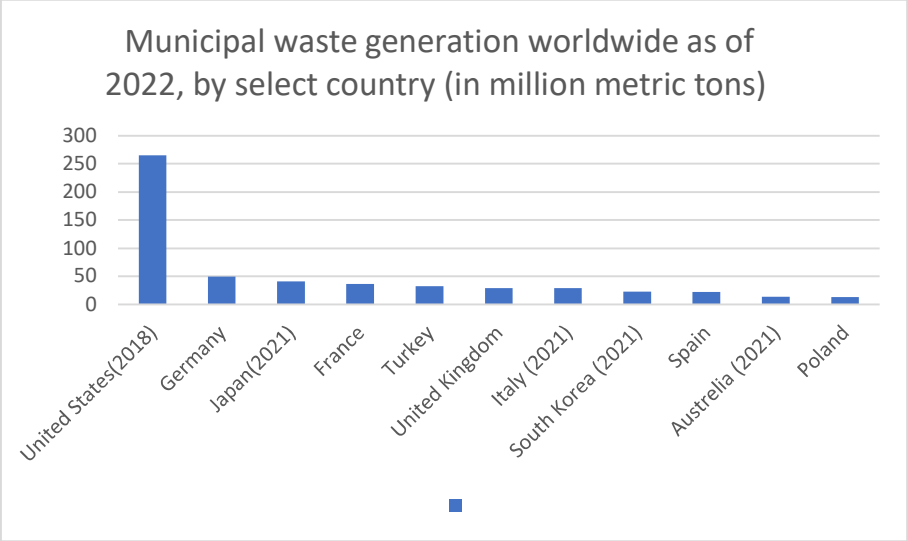

Figure 2. Municipal waste generated worldwide as of 2022 selected countries (in million metric tons) *(Statista, 2025)*.

MSWM in most countries is the responsibility of the local authorities and about 70% of the countries have established policies and regulations to govern and oversee WM. These frameworks are essential for ensuring proper waste collection, disposal, recycling, and environmental protection. However, the effectiveness of these policies often depends on the availability of resources, infrastructure and institutional capacity (Kaza et al., 2018).

2.1 Recycling practices in Developed Countries

Recycling practices in developed countries have been evolving due to evolving policies, education, and environmental crises (Moloney and Doolan, 2016). In 1960s developed countries focused on disposed waste but with time the focus changed to reducing waste generation at the source, minimizing hazardous waste, and enhancing recycling and recovery practices (Nikzad and Ghosh, 2019). Most developed countries have established WM and recycling systems supported by advanced technologies, public participation, and strong policies (Mmereki, Baldwin and Li, 2016). WM varies in different countries, In Europe, recycling rates have been increasing due to the targets put in place on recycling and in the process towards circular economy.

In 2022, Europe overall recycling rate was 44%, while the most recycled waste was packaging waste at 65%, followed by MW 49%, e-waste at 32%. Europe has set a target to recycle 60% by 2030 for reuse and recycling of MSW (statists 2021). Countries like Austria, Germany, Slovenia, and Bulgaria have already achieved the recycling target set by EU as part of its broader strategy for circular economy or exceed the recycling target. Germany is leading with 69% recycling rate and Romania with 12% recycling rate as the country that recycle the least (European Environmental Agency (EEA), 2024).

2.1.1 Germany

Germany is one of the leading countries in European Union (EU) in terms of recycling, with an estimated recycling rate of 69.1%, in 2022 (Statista, 2024a). Germany Recycling rates have been increasing as from 2001, and 2014 they recycled 64% surpassing the EU recycling target of 50%, incineration 37% and landfilling about 0% (Patel et al., 2000).

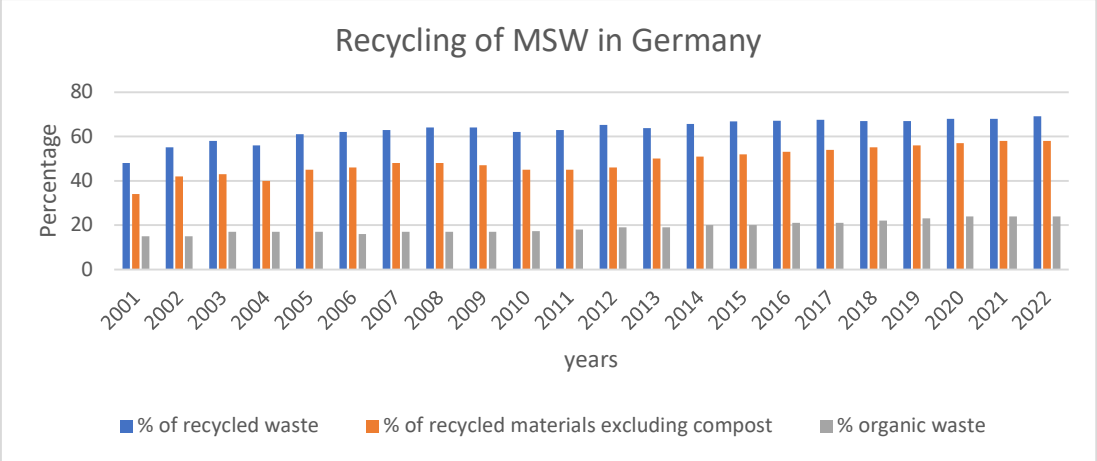

Figure 3. Recycling of MSW in Germany 2001-2022 (Eurostat, 2025) and *(CEWEP , 2020)*

Germany's high recycling rate is due to its strong polices, public awareness in recycling, Deposit refund system designed for plastic bottles, cans, and glass bottles with deposit refund. These bottles and cans with deposit refund can be returned through automated machines available in supermarkets. This was to reduce one-way use bottles, encourage recycling and prevent consumers from littering (Cave, 2017).

Germany also introduced initiatives to limit untreated MSW landfill disposal as early as 1993. In 2005, Germany fully banned the landfilling of unpretreated residual household and industrial waste. Before any waste is disposed of in landfills it must first be pre-treated through either mechanical, biological, or thermal processing. In addition, Germany employs a standardized color-coded system to facilitate waste sorting at the source, and each bin is for specific waste (Cave, 2017). Below is a table showing colour and type of waste (Cave, 2017a).

Table 2. Color-coded bin system in Germany *(Cave, 2017)*

Colour	Waste
Black	Residual waste
Blue	Paper, magazines, books, cardboards
Brown or Green	Bio-waste
Yellow	Recyclable materials
Grey	Non-recyclable waste

2.1.2 United states

According to EPA (2020) United States generated 292.4 million ton of MSW in the year 2018, which is equivalent to 0.0022 tons per person daily. 69 million tons and 25 million tons was recycled and compost, respectively. However, 146.2 million tons, which accounts for 50% of MSW generated ended up in landfills, highlighting that most waste is disposed in landfills. Trends in recycling since 2005-2018 as shown in the figure 4, indicates paper and cardboard have been the most recycled materials and the need to enhance recycling of other MSW such as plastics, metal, glass, rubber, and textile.

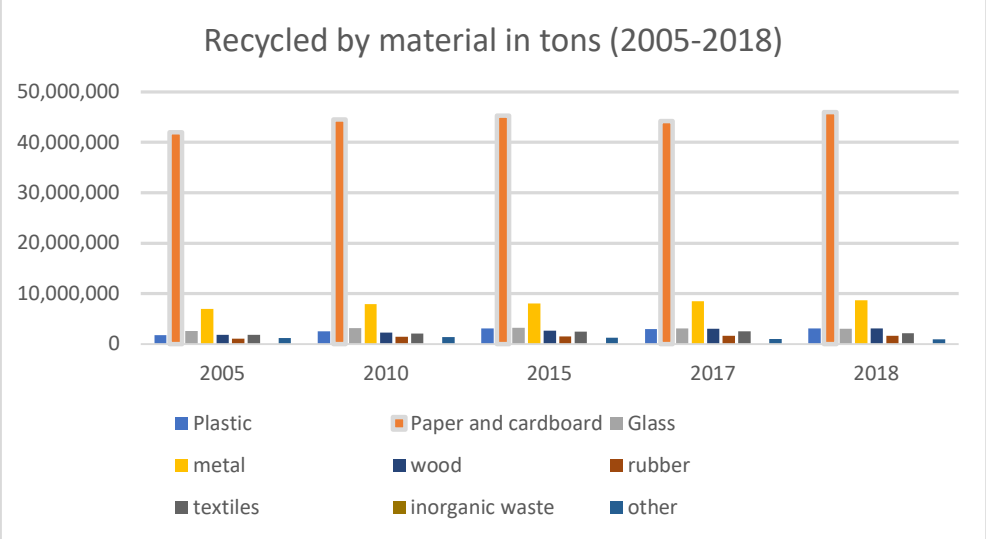

Figure 4. Trends of recycling in United State 2005-2018 in tons *(EPA, 2020)*

Figure 5 shows MSW generated by material in the year 2018, paper, and cardboards which include boxes, milk cartons, packaging, paper cups and plates, office paper, newspapers and tissue paper being the most generated material compared to other MSW. This shows the widespread use in offices, households, and commercial packaging.

Figure 5. Total of 292.4 million tons of MSW generated in United State by material in 2018 *(EPA, 2020)*

Figure 6 shows material recycled by percentage of the total materials recycled which was approximately 69 million. Paper and cardboard being the most recycled with a percentage of 66.54. According, to American Forest and Paper Association (2023), Cardboards have high recycling rates because they are easily recycled and goal that was set in 1990s to improve recycling of paper and most people recycle daily.

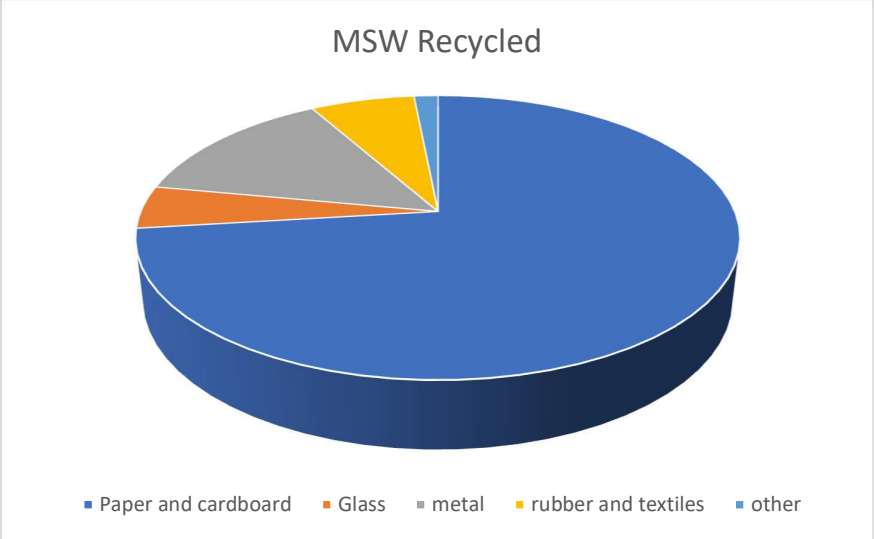

Figure 6. MW recycled material in United States in percentage *(EPA, 2020)*

United states recycling of waste is important not only in environmental protection but also economic development, since it helps in creation of jobs and tax revenues and according to Recycling Economic Information (REI) Report, in the United States recycling and reuse activities in a year supported 757,000 jobs, $36.6 billion wages and $6.7 billion tax revenues. On a smaller scale, for every 1,000 tons of recycled material, 1.57 jobs are created, along with $76,000 in wages and $14,101 in tax revenue. Recycling varies by state and city in the Us. It focuses on curb side recycling, bottle deposit programs, and e-waste recycling. There are three main steps of recycling in the US: collecting, processing, and remanufacturing. This highlights the benefits of MSW recycling, which are economic development, environmental sustainability, and resource efficiency.

2.2 Recycling Practices in Developing Countries

In developing countries, most MSW are disposed in open dumpsites, open burning, and landfills, which are labour intensive treatment, simple and convenient (Fernando and Zutshi, 2023). MSWM in developing countries are not effectively implemented, despite their existence, and is evident in the gap between policy and practices of MSWM (Fernando and Zutshi, 2023). In most developing countries separation of MSW is not done, and this is the leading cause of MSW disposed in landfills and low recycling rate in developing countries. Collection of MSW in developing countries is inefficient due to time gap in collection schedules, lack of good trucks and lack of reporting (Fernando and Zutshi, 2023).

2.2.1 India

India generates approximately 70 million tons of MSW annually and is expected to generate 165 million tons by 2030, and 436 million tons by 2050 annually (Meena et al., 2023a). However, recycling rates for several types of waste remain low, rarely exceeding 30%, making landfilling the most common disposal method. India's recycling rate is influenced by informal sector which contributes to waste recycling and reuse at source, approximately

15% and 15% during collection of waste (Di Maria et al., 2020). For example, only 20% of plastic waste was recycled in in the year 2019, while the rest often ends up in landfills. Other waste treatment methods in the country include incineration and composting, and as of 2023, 73 treatments plants were under construction (Statista, 2024d).

Waste segregation in India is a challenge, since MSW are collected when mixed and the reason of lack of segregation in India is due to lack of public awareness and advancement in waste separation models. Segregations of waste at the source is essential for efficient recycling (Meena et al., 2023b).

2.2.2 South Africa

According to Statista (2023), South Africa generated 1.77 million metric tons of MSW in the year 2017, and the MSW were deposed in landfills meaning none were recycled or recovered. Waste collection and transportation are the costly in most developing countries, South Africa is not exempted, households whose waste are collected weekly, put their waste in black bags or wheelie bin during collection day for local waste collector to collect (Chimuka and Ogola, 2015). Waste pickers sort through waste prior to collection to harvest valuable recyclables, which play a significant role in reducing waste, with earnings of R50-R85.92 per day (Viljoen, Blaauw and Schenck, 2018).

Although landfills are not ideal, they are better than environmental pollution by uncontrolled dumping or burning, which remains a major issue, especially among rural communities (Kaza et al., 2018). South Africa face challenges, due to depends on landfills. Most landfills are full, and others are almost full. To prolong these landfills waste should be diverted to another area because when landfills are full, they pose environmental challenges and health risks (Department of Environmental Affairs, 2018).

3 Overview of municipal solid waste management in Kenya

Kenya is a country in East Africa with an estimated population of 52.4 million according to Kenya National Bureau of Statistics (KNBS) and Kenya's gross domestic product (GDP) per capital 2025 is 2186.58 U. S dollars (Statista, 2024b). Kenya faces challenges in managing MSW due the continuous growth in urbanization, population growth and industrialization. Urban areas such as Nairobi, Kisumu, Nakuru, Mombasa, and Eldoret have insufficient waste collection, disposal, and recycling practices. Kenya generates an estimate of 8 million tons of waste annually, which is equivalent to 22,000 tons daily and 70% is collected and the remaining 30% of uncollected waste are often dumped illegally in open spaces, drainage systems, along roads or burned in open space. Nairobi alone generates an estimate of 2,400 tons daily and 20% of the total 2,400 tons of waste generated in Nairobi are plastics and only 45% of the plastics are recycled (NEMA, 2023).

Figure 7 shows estimated waste generated, recovered from general waste for reuse, recycling, or composting, collected, and uncollected per day in major cities and Thika town. Nairobi generates the highest amount. Waste collected and uncollected for Kisumu city is unknown.

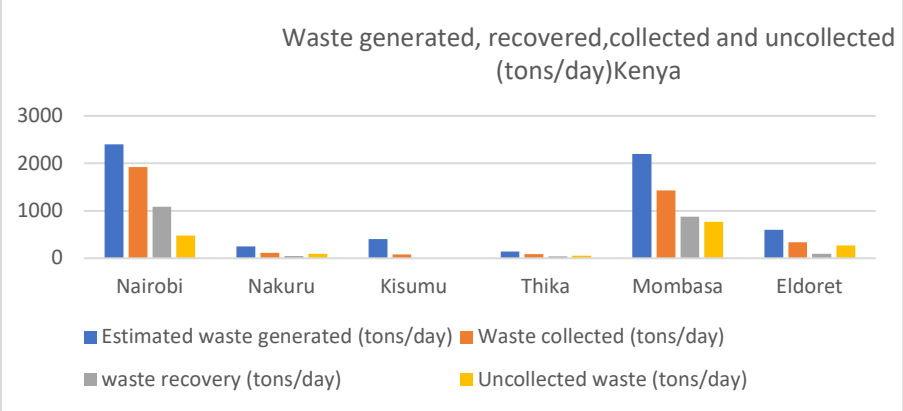

Figure 7. Estimated waste generated, recovered, collected and uncollected in Kenya per city Source *(Koech, Munene and Ghosh, 2019)*.

Local authorities, informal collectors, and private companies are responsible for collecting and disposal of MSW within the assigned service area. Through the National Environmental Management Authority (NEMA) the country government have implemented policies and regulations to protect waste management (Ngunju, 2018).

3.1 Challenges

According to Fie-Consult (2023) Waste is commonly disposed in open dumpsites and landfills which are not compacted or covered, and this is due to lack of infrastructure or poor management. This poses environmental and health risk, such as attracting animals and insects that carry diseases, bad odours and methane released contributes to formation of ozone layer which reduces air quality and causes climate change. Another challenge is recycling since waste is not sorted.

Corruption and political interference disrupt the consistent enforcement of regulations, causing inefficiencies in MSWM. Another significant challenge is lack of public awareness on impacts of WM which hander's effective WM, Lack of strong law enforcement on WM has contributed to littering and illegal dumping (Amugsi, Muindi and Mberu, 2022).
The country struggles with poor servicing of waste collection vehicles and insufficient disposal facilities, leading to poor WM service (Henry, Yongsheng and Jun 2006).

Transportation of MSW in open truck and handcarts is a challenge in Kenya, since it causes littering, bad odour, waste pickers sometimes pick waste from moving trucks causing littering (Ikiara, Karanja and Davies, 2004).

3.2 Current recycling practices in Kenya

According to NEMA (2015) Waste segregation in Kenya remains a challenge where most waste is generated from households, market stalls, urban centers, towns, institutions, and industrial zones. Most households do not segregate their waste, and minimal segregation in Central Business Districts (CBDs), industries and institutions. Various stakeholders do

collection and transportation of waste. In CBDs County governments are responsible for collecting waste in public areas such as the CBDs, streets, and markets. whereas private waste collection companies often operate under complete agreements or licenses from the country and have a monopoly on residential waste collection at a fee. In poor and informal settlements, community-based organizations (CBOs) and organized groups collect waste. Waste collectors are licensed by county governments to collect waste in targeted areas.

The National Environment Management Authority (NEMA) also gives waste transporters annual licenses under the WM Regulations of 2006. Other waste transporters still operate illegally, though, without meeting the standards. Transportation of waste is mostly by open trucks, handcarts, donkeys' carts, and others; this means of transport causes littering. Technologies for waste treatment are not fully adopted in Kenya, though efforts are being put in place to improve treatment processes. Open dumpsites are commonly used in the country to dispose of domestic and municipal waste, even though the practice is not (NEMA, 2015).

3.3 Plastics

Kenya generates 0.5-1.3million tons of plastic waste annually and only 8% of this waste was recycled as of 2023, meaning majority were not effectively managed (Samantarai and Dutta, 2024). The rest were either dumped into landfills, littered or burned, leading to harmful air pollution. Plastic WM remains to be a great issue in Kenya, Despite the banning of plastic bags for household and commercial use in 2017, which aimed to reduce the environmental impact of non-biodegradable plastics and was identified as the primary cause of drainage blockages during heavy rainy seasons which lead to urban flooding, water contamination and disease outbreaks like cholera and malaria. Penalties of up to four years imprisonment or fines were imposed if the ban was violated (Luzze, 2023).

Companies like EcoPost, Gjenge makers, PETCO Kenya and others recycle plastics.

- EcoPost, founded by Lorna Rutto in 2009, manufactures durable fencing posts from plastic waste that are 100% recycled. Initially started with over 5 tons per month of recycled plastics and has then increased to 30 tons per month. It offers an eco-friendly alternative to timber

fencing post and (Paukwa, 2025). In the next 10 years EcoPost aims to recycle 20,900 tons and work with other organizations to attain objectives. The company not only addresses the issue of plastic pollution but also unemployment, impacts of climate change and deforestation (Koech, Munene and Ghosh, 2019).

- Gjenge makers organization founded by Nzambi Matee recycles plastic waste into a range of durable construction products such as paving blocks, tiles, and manhole covers. The company combines sand with plastics, to produce construction materials that are not only durable and weather resistant but also visually appealing (Islam, Islam and Hossain, 2025). Gjenge makers recycles about 0.5tons of plastics waste per day to make 500-1000 plastic bricks per day, which are stronger than concrete. In 2021 it recycled 20tons of plastics and produced 10,000-15,000 plastic bricks daily. Gjenge makers not only contribute to circular economy but also employment and construction industry (Yuliawatia, Eriyantib and Prabhawatic, 2023).

- PETCO Kenya is polyethylene terephthalate (PET) recycling company found in 2018 adopted from PETCO South African model. PETCO focuses on managing and promoting the recycling of PET plastic. The process of recycling PET starts from collection, and the collected PET undergoes sorting to separate PET from contaminants like caps, labels, and non-recyclable plastics. The sorted PET is then washed, shredded, and separated by floating. Clean flakes are rinsed and dried and finally converted into raw materials like pellets, which are used to manufacture products such as reusable carry bags, roof insulations, polyester carpets, fibre filling, and brush bristles. PETCO Kenya transitioned to the Packaging Producer Responsibility Organization (PAKPRO). This transition reflects on a broader commitment to managing all non-hazardous packaging materials (KEPSA, 2023).

3.3.1 Taka Taka Solution

The increasing number of informal sectors are central to the recovery of recyclable materials such as plastics, paper, glass, and metals. There are various recycling WM companies in Kenya, majority are in Nairobi, such as Taka Taka solutions. Taka Taka Solutions is one of the largest recycling companies that recycle 95% of the total waste they

manage, and they manage more than 60 tons of waste daily collected from commercial and household. It also generates jobs and has more than 350 employees (Taka Taka Solutions). The collected waste is transported to a sorting plant where workers sort using convey belts and other machines to sort waste differently such as paper, metal, glass, carboard, textiles and other materials.

Figure 8 shows the percentage of organic, plastic, other recyclables such as (paper, metal, glass, and textiles), hazardous and residual waste after sorting waste collated by Taka Taka Solution.

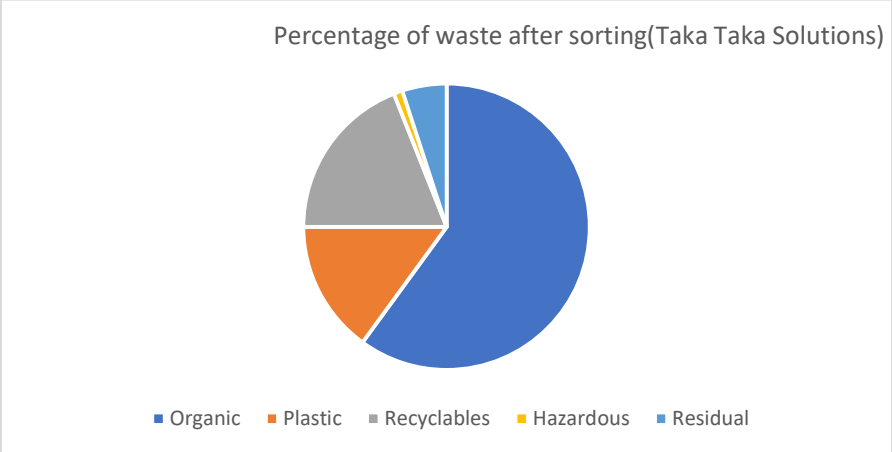

Figure 8. Percentage of sorted waste in different fraction by Taka Taka Solutions *(Taka Taka Solutions)*

After sorting Organic waste is the highest at 60% followed by recyclables and hazardous waste is only 1%. After sorting the waste, they are compacted for easy storage and transportation to their own plants. Organic waste is transported to composting plants where they sort in multiple steps to remove non-compostable materials, frequently turning to achieve aeration they are set in windrows and after three months they are sieved and quality checked. Plastics are transported to plastic recycling plants where they are first pre-sorted and checked for quality control, crushed into small flakes, washed, rinsed, dried, label removed and finally melted to pellets. The rest (metal, glass, paper) are processed into raw materials.

Table 3. WM journey of Taka Taka solutions

Year	Staff	Waste treated in tons per year
2011	10	500
2013	25	3,000
2014	50	6,000
2015	80	12,000
2016	120	20,000
2017	180	30,000
2019	250	40,000
2020	350	60,000

Table 1 shows the journey of WM by Taka Taka solutions. Treated waste, and staff have been increasing since 2011.

3.3.2 Konza Technopolis

Konza has introduced an automatic suction solid waste collection system which serves approximately 28,000 residents and manages up to 40 tons of solid waste daily in four waste categories: paper, plastic, mixed waste, and organic waste. It comprises 100 waste inlets located near residentials and office buildings, connected to pipes system that uses vacuum suction technology to transport waste to the central waste terminal. This method reduces environmental emissions because it eliminates the use of trucks collection (Nation, 2025).

These recycling practices reflect Kenya's commitment to environmental sustainability. Recycling in Kenya is still evolving with government regulations, private-sector innovations, and community involvement driving progress. Regards of challenges such as low collection and sorting rates, lack of infrastructure, and public participation, Kenya continues to make strides towards circular economy.

4 Key stakeholders and their role

According to Ndonye (2022) Stakeholders are people, institutions or a group who are directly or indirectly affected by MSW. Successful MSWM relays on different stakeholders with clearly defined responsibilities. Various stakeholders have distinct roles and responsibilities depending on country. In Kenya there are several stakeholders such as the local authority who are responsible for collection of waste within their assigned service area, transportation, and disposal. They also ensure that waste is collected timely. Local authority ensures that trucks and vehicles that transport waste are licensed by NEMA. They also ensure the dumpsite is safe by fencing, spreading, and covering waste to prevent waste from spreading and managing security at dumpsite.

Additionally, local authorities ensure waste is weighed and recorded. For adequate access to dumpsite the local authority ensure roads are good within the dumpsite. However, Kenya still faces inefficient collection and disposal of waste, for example 30%-40% waste is uncollected in Nairobi and 45% in Nakuru are uncollected ,18% recovered while the rest disposed to the environment.

NEMA, is the national government agency under the Ministry of Environment and Natural Resources, responsible for environmental and MSWM. NEMA formulates policies and legislations related to MSWM across the country and providing information to the public on regulations to follow for efficient WM. The agency holds public awareness events. It enforces laws related to WM (Ndonye, 2022).

The public plays a vital role as stakeholders in MSWM, particularly in urban areas. As the primary generators of MSW, the public can influence the success of segregation, and waste reduction through awareness and daily practices (Ndonye, 2022). Private sectors play a vital role in MSWM, and their role is collection, transportation, recycling, and disposal of solid waste. Most privet sectors engage in recycling and making profit being their driving force (Oyake-Ombis).

Non-governmental Organizations (NGOs) and (CBOs) contributes to access to MSWM and sanitation services. NGOs raise awareness, advocacy, and education. NGOs face challenges such as funding and if they receive funds from doners they are regulated on purpose of fund. Informal sector (waste pickers) plays a crucial role in recycling of MSW, they recover recyclable materials that have been disposed to generate income, while also reducing the amount of waste to be collected, transported and disposed, hence saving the municipal resources and overall cost of MSWM (Agamuthu, 2010). High unemployment rate in Kenya and limited access to education are reasons that drive individuals into informal waste picking as means of livelihood (Kariuki, Bates and Magana, 2019).

5 Analysis of the development in MSW recycling in Kenya

Development of recycling practices of MSW varies between developing and developed countries. This analysis focuses on successful practises of developed countries and their applicability to Kenya's context, highlighting gaps and opportunities for development. Developed countries like Germany have achieved high recycling rates through mandatory waste segregation (color-coded bins), Landfill ban, European circular economy action plan of 60% MW recycling by 2030, deposit refund system for bottles, cans, and glasses. This is evident in the figure 3 that shows recycling rates have been increasing since 2001.
Kenya has implemented policies like plastic ban and sustainable WM Act (2022), but enforcing these policies is still a challenge, compared with developing countries like Germany whose policies are well enforced such as Green dot scheme and deposit refund schemes that have successfully promoted high recycling rates in Germany.

Despite challenges that Kenya face, private recycling companies like Gjenge Makers that recycle 20tons daily, EcoPost recycle 30 tons per month and Taka Taka solutions collects over 60 tons daily, recycle 95% of the collected waste and many other companies that have not been mentioned in this study, since there are over 100 companies in Kenya that involve in WM and these recycling companies demonstrates potential recycling in Kenya, but their operation is limited compared to waste that is generated daily. Konza Technopolis automated waste collection system able to manage up to 40 tons of waste demonstrate potential for smart WM but lack scalability, due to insufficient funds or inadequate infrastructure.

According to Desmond and Asamba (2019) Nationally Appropriate Mitigation Action (NAMA) on circular economy for MSW proposed a transformative approach to urban WM. Instead of collecting and disposing of waste NAMA aims to redirect 90% of collected waste to recycling and composting targeting up to 600 tons of waste to recycle daily, which accounts for 25% of Nairobi's wate generated daily. The approach will help in the reduction of MSW and increase recycling rates. Additionally, Waste of Electrical and Electronic Equipment (WEEE) is a company in Nairobi Kenya that offers training and disposing of e-

waste safely accordance with NEMA waste regulations. WEEE handled 200tons of which is equivalent to 1% of the total e-waste produced in Kenya. Highlighting the need to expand WEE companies.

Kenya's major cities generate more MSW daily and a significant amount of MSW is not collected as illustrated in figure 7, while Thika town generates less MSW with higher MSW collected relative to what is generated. Kisumu city with incomplete data shows poor data collection and tracking, which hinder effective planning of MSWM. Cities like Kisumu should invest in collection facilities and improve data collection.

Kenya's MSW recycling is still evolving from informal sector like waste pickers and structured polices, private recycling companies and Konza Technopolis with automated waste collection system. However, challenges like weak policy enforcement, limited scalability of technology, insufficient public awareness, and lack of infrastructure slow down development of recycling practices in Kenya. To accelerate the development of MSW recycling practices, Kenya should adopt strategies to strengthen policies, promote public participation, support private innovation and inclusion of informal workers.

6 Conclusions and Recommendations

MSW in Kenya remains a critical challenge, driven by rapid urbanization, population growth, and insufficient infrastructure. Kenya recycles less compared to what they generated. Nairobi for example generates 2400 tons but recycle only 45% of the total. Open dumpsite, such as Dandora, dominates as waste dispose site, causing environmental degradation, health risks, and GHG emissions. Globally, developed countries like Germany demonstrates high recycling rates through robust policies and advanced infrastructure. Kenya recycling sector is promising through innovative private companies. Companies like Taka Taka solutions, Ecopost, PETCO, Gjenge Makers and many other companies around the country highlights the potential for circular economy models. Konza Technopolis automated waste system is a good example of technological advancements though scalability remains limited.

These are recommendations for better and an increase in recycling rates in Kenya.

- Strengthen policy enforcement like enforcing the sustainable WM Act (2002) that establish clear penalties for non-compliance and allocate resources for monitoring. Introduce extended producer responsibility laws to mandate producers to manage post-consumer waste. Legally recognize informal waste pickers and provider them with safety gear and fair wages.
- Enhance public awareness and participation: Promote waste segregation and benefits of recycling and proper WM through social media, workshops, and partner with NGOs to reach many people. Integrate in curricula to foster long term change and early understanding of WM.
- Kenya should emulate Germany color-coded bins: The county government with the help of licenced providers to provide enough bins to help in segregation of waste at the source. Those collection point to be maintained and collected on time to avoid overflow of waste.
- Counties should provide proper waste transportation to dumpsites, landfills, or treatment facilities. The trucks should be enclosed and always serviced.
- Close or ban unsanitary dumpsites and replace with sanitary dumpsites which are frequently compacted and covered to avoid environmental pollution.

- Adopt Germany Green Dot labelling system for recyclable products and implement PET bottle deposit schemes to achieve return rates.

  Kenya's success is dependent on adopting best practices from around the world with solutions tailored to its socio-economic conditions. Prioritizing policy reform, technological innovation, public participation and involve stakeholder can help Kenya avoid environmental harm, reduce landfill reliance, and maximize economic gains through job creation and resource recovery. Addressing these challenges is essential not only for sustainable development but also for protection of public health and combating climate change.

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