CIRCULAR MATERIALS MANAGEMENT AND PLASTIC WASTE REDUCTION IN DAR ES SALAAM, TANZANIA

by

RACHEL JOHNSON

(Under the Direction of Jenna Jambeck)

ABSTRACT

Dar es Salaam, Tanzania, is the fastest-growing city in East Africa, which has resulted in an increase in waste generation, creating management challenges. Plastic pollution is especially concerning in rapidly expanding markets and economically developing areas. The purpose of this research is to identify opportunities to optimize plastic packaging and materials circularity in Dar es Salaam by utilizing the Circularity Assessment Protocol (CAP), for the first time on the African mainland continent, in collaboration with local organization Nipe Fagio. A total of 10,147 litter items were logged with Debris Tracker and plastic comprised 65% of these items. 62% of the plastic fast-moving consumer goods (FMCG) surveyed in stores are manufactured in Tanzania, providing an opportunity for local discussions around packaging and Extended Producer Responsibility (EPR). Opportunities to amplify circularity were identified through the CAP, and along with the current zero waste initiatives, provide information and lessons learned for other cities.

Index words: Plastic Pollution, Circular Economy, 3, Informal Waste Management, Africa, Material Recovery, Extended Producer Responsibility

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By

RACHEL JOHNSON

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by

RACHEL JOHNSON

Major Professor:	Jenna Jambeck
Committee:	Christina Fuller
	Alysha Helmrich

Electronic Version Approved:

Ron Walcott
Vice Provost for Graduate Education and Dean of the Graduate School
The University of Georgia
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DEDICATION

At the start of my graduate journey, my mother found a poem that I wrote about recycling when I was around 8-years old. This work, and my continual pursuit of a better environment, have been focused on achieving the dream that my younger self set out to do in my poem, and what so many other children around the globe have also set out to accomplish as well. There is still work to be done, but I hope one day a child can write about how the world is clean instead of how they must clean up the planet.

Recycling Poem

Reuse, Reduce, Recycle

Everything we use

Come on let's go

You and I

Can make a difference

Let clean this planet up

It's the right thing to do to the earth

Now get your friends to help along the way

Go green let's save the earth

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GLOSSARY

CAP	Circularity Assessment Protocol
CE	Circular Economy
CIL	Circularity Informatics Lab
CBO	Community Based Organization
DRS	Deposit Return Scheme
EPR	Extended Producer Responsibility
FMCG	Fast-Moving Consumer Goods
HDPE	High Density Polyethylene
GDP	Gross Domestic Product
INC	Intergovernmental Negotiating Committee
LIP	Local Implementation Partner
MDT	Marine Debris Tracker
MLP	Multilayer Plastic
MPs	Microplastics
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MT	Metric Tons
MMT	Million Metric Tons
NGO	Non-government organization

NMI	New Materials Institute
NOAA	National Oceanic and Atmospheric Administration (US)
PCR	Post-Consumer Recycled
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PPE	Personal Protective Equipment
PS	Polystyrene
RCC	Refuse Collection Charge
rPET	Recycled Polyethylene Terephthalate
SUP	Single-Use Plastic
SWM	Solid Waste Managament
TPD	Tons per day
UGA	University of Georgia
UO	Urban Ocean
WtE	Waste to Energy

CHAPTER 1

INTRODUCTION

1.1 Plastic Pollution

1.1.1 Plastic Production

Plastic first came into existence in the 1860s as a replacement for ivory, but did not become popular until World War II, when it became an essential material for military equipment. Since the end of WWII, plastic production is predominately made from fossil fuels and has replaced various materials. Global plastic resins and fibers production increased from 2 Mt in 1950 to 380 Mt in 2015, totaling 8,300 Mt of virgin plastic (Geyer et al., 2017). At the same time, a cumulative 6,300 Mt of plastic waste has been generated as of 2015, with only 9% recycled, 12% incinerated, and 79% landfilled or ending up in the natural environment (Geyer et al., 2017). With business as usual, by 2050, 12,000 Mt of plastic will end up in landfills or the environment. In coastal regions (within 50 km from the coast) of 192 countries, 99.5 Mt of plastic waste has been generated (Jambeck et al., 2015). 31.9 million Mt of the 99.5 Mt was classified as mismanaged, with an estimated 4.8 to 12.7 million Mt entering the ocean in 2010 (Jambeck et al., 2015).

A recent UNEP report estimates that globally, around 400 million metric tons of plastic are produced yearly (UNEP, 2021). Since the 1950s, plastic packaging has been the most predominant sector of plastic use. Factors that have increased plastic packaging include (1)

globalization and (2) food distribution and protection (Walker-Franklin & Jambeck, 2023). Plastic packaging is light but durable, decreases transportation costs, and allows companies to make aesthetically pleasing packaging that is recognizable. Compared to other plastic items, plastic packaging has the shortest use life (Geyer et al., 2017). Since plastic is produced from fossil fuels, increased production of plastics may result in increased extraction of fossil fuels. In 2018, the International Energy Agency (IEA) published a report on the future of petrochemicals and found that it will be the most significant driver of global oil consumption. Petrochemicals will account for a third of the growth in oil demand by 2030 and half by 2050 (IEA, 2018). Increased plastic production and consumption have highlighted limitations in our solid waste infrastructure, as plastic began to litter the environment, becoming a global issue. The United Nations Intergovernmental Negotiating Committee (INC) has been working on a Global Plastic Agreement to establish a legally binding international agreement to combat plastic pollution and address the full lifecycle of plastic, including production, design, and disposal. The goal was to have a legally binding treaty by 2024, but negotiations are still underway, and the next session is planned for August 2025 in Geneva, Switzerland (INC, 2025).

1.1.2 Plastic Pollution Globally

As countries and international bodies make individual efforts towards reducing plastic production, it's essential to understand the significance of plastic pollution. Plastic pollution results from the production and consumption of single-use plastics (SUP) and improper waste management at the end of life. IUCN estimates the world average per capita waste generation is 29 kg/year (IUCN-EA-QUANTIS, 2020). Approximately 19-23 million tonnes of plastic leak

into the aquatic environment from land-based sources through rivers and lakes yearly (UNEP, 2021). The 2024 Ocean Conservancy report, which published data from the 2023 International Coastal Cleanup, collected 7,963,571 lbs. of debris (Ocean Conservancy, 2024). The top items identified during the clean-up in order of quantity were cigarette butts, beverage bottles, bottle caps, food wrappers (candy, chips, etc.), grocery bags (plastic), other bags (plastics), food containers (plastic), cups and plates (plastic), straws/stirrers (plastic), and cups and plates (paper). They also collected 2,372,966 items less than 2.5 cm in size, known as macroplastics, which are any plastic fragments larger than 5 mm. There were over 400,000 more macroplastic identified than the topmost recognizable item collected which was cigarette butts.

Combating plastic pollution is not an easy feat, as plastic has become a transboundary issue. Pictures and stories of animals being ensnared in plastic or accidentally consuming plastic mistaking it for their food have become familiar cautionary tales about the dangers of plastic pollution (Zachos, 2018). However, many of these items are more visible than the new danger. Plastics do not degrade but fragment into smaller pieces and pollute the air, water, and soil (Lamichhane et al., 2023). These smaller pieces of plastic are commonly referred to as microplastics. Microplastics are plastic fragments smaller than 5 millimeters (mm) and have recently garnered a lot of global concern (NOAA, 2023). There are two sources of microplastics: Primary and Secondary. Primary microplastics are manufactured plastic pellets used to create plastic or microbeads (ex. in personal care products). Secondary microplastics are fragments from larger plastic items that are fragmented due to exposure to the sun, heat, wind, and waves. Microfibers come from fabrics, rope, or furniture made from synthetic materials and are secondary microplastics (NOAA, 2023). Due to microplastics' smaller nature, there is growing

concern about the effects that microplastics can have on the climate, environment, and human health (Mamun et al., 2023; Schmidt et al., 2024; Yee et al., 2021).

Given the quantities of plastic waste generated and its durability and long-life, it is a monumental challenge. In fact, Borrelle et al. (2020) found that efforts to reduce plastic emissions by 2050 would require a tremendous amount of work because simply increasing waste management capacity would not suffice. Society needs to begin valuing plastic instead of viewing it as waste if they are unwilling to cease all production and use of plastic items completely (Borrelle et al., 2020).

1.1.3 Plastic Pollution in Africa

Africa is rapidly growing, reaching 1.5 billion people in 2024, and is estimated to reach between 3.5 billion and 4.0 billion by 2100 (United Nations Population Division, 2024). Five of the eight countries expected to account for more than half of future population growth are in Africa: the Democratic Republic of Congo, Egypt, Ethiopia, Nigeria, and the United Republic of Tanzania (Sinha & Getachew, 2024). In addition to a growing population, Africa's waste generation is increasing. In 2012, it was estimated that Africa's total waste generation rate was 125 Mt/year, 65% of which came from Sub-Saharan Africa (UNEP, 2018a). In 2012, Africa's average waste generation rate per person was 0.78 kg/day, which is expected to increase to 0.99 kg/day by 2025 (UNEP, 2018a). Increases in the waste generation rate in Africa are driven by population growth, rapid urbanization, a growing middle class, changing consumption habits, and global waste trade and trafficking (UNEP, 2018a).

In Sub-Saharan Africa, 57% of the waste is categorized as organic, followed by 9% paper/cardboard, 13% plastic, 4% glass, 4% metals, and 13% other materials (UNEP, 2018a). Higher organic content is typical for countries in the global south. In 2015, with a population of 1.3 billion, Africa produced 5% and consumed 4% of the global plastic waste volume (Sadan & Kock, 2022). Africa's plastic waste consumption was 16 kg per person compared to the worldwide average of 45 kg per person (Sadan & Kock, 2022). In 2020, the International Union for Conservation of Nature (IUCN) published its Plastic Pollution Hotspotting results and found that plastic waste generation in Africa spans from 6 to 41 kg/capita/year (Pucino et al., 2020).

Plastic pollution can leak into the environment at various stages in its lifespan. The moment most often discussed is the end-of-life and how it is managed. In Africa, while there is low waste generation per capita, the demand for waste services is unmet (UNEP, 2018a). The average waste collection rate in Sub-Saharan Africa was 44% in 2012 and can vary from less than 20% to above 90%. The average waste collection rate is estimated to increase to 69% by 2025 (UNEP, 2018a). The most common waste disposal method in Africa is uncontrolled and controlled dumping. Urban centers in Africa commonly have door-to-door waste collection, and these centers are often categorized by good waste collection and transport services. In most African countries, the state or municipality provides the infrastructure and collection services. However, these entities often do not have the technological or financial capacity to provide services to all residents. In cities where the municipality services have been limited, many partner with private companies or community-based organizations (CBO) to improve waste collection services. The informal sector also plays a vital role in Africa's collection of waste.

Recycling rates are lower than waste collection, with an average recycling rate of 4% (UNEP, 2018a).

While negotiations for a global plastic treaty continue, regional policy and institutions are addressing plastic pollution in Africa. There are various agreements and organizations focused on improving recycling, trade routes, marine litter, and human and environmental health (Sadan & Kock, 2022). This includes the African Ministerial Conference on the Environment, African Union Plastic Pollution Initiative, Regional Seas Program in Africa, and the Agreement Establishing the African Continental Free Trade Area. In 2015, the African Union published Agenda 2063: The Africa We Want, a master plan for social and economic development on the continent through a series of five ten-year implementation plans. There are seven aspirations, and the first aspiration states, "A prosperous Africa based on inclusive growth and sustainable development" (African Union, 2015a). Under this aspiration is the goal to establish an environmentally sustainable and climate-resilient economy and communities, along with establishing a blue economy. In the first ten-year implementation plan, African cities committed to recycling at least 50% of urban waste by 2023 (African Union, 2015b). The second ten-year implementation plan for 2024-2033 stated the development and implementation of policies to improve urban waste recycling, but did not outline a specific percentage (African Union, 2024). These policies and institutions establish the importance of addressing plastic pollution and waste management on a continental level.

The Bamako Convention is a treaty of African nations that went into effect in 1998 and focused on prohibiting the import of hazardous waste into Africa. It was derived from the Basel Convention Article 11. In 2020, the Bamako Convention was amended to include all forms of

plastic waste. It also encouraged countries that have not enacted bans on plastic bags or single-use plastics (SUPs) to do so. As of February 2023, 30 out of the 54 African countries have ratified the Bamako Convention. On a national level, 37 countries have passed legislation that bans various types of plastic. The first ban was passed in 2005 by Eritrea, an East African country, and it banned plastic bags. In 2018, the United Nations Environment Programme (UNEP) published a "Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations" (UNEP, 2018b). The report identified 34 countries that have banned or limited plastic bag manufacturing, import, free distribution, and/or use (UNEP, 2018b). Zimbabwe and Burkina Faso are the only countries that have banned the manufacturing, import, free distribution, and/or use of other SUPs (UNEP, 2018b). They have also banned SUP bags. Since the UNEP report's publication, desktop research has not identified any additional countries that have banned plastic.

The UNEP report also identified countries that passed legislation addressing Extended Producer Responsibility (EPR) legislation. The report found that eight African countries have EPR or special regulations on the return and disposal of plastic bags (UNEP, 2018b). The Organization for Economic Co-operation and Development (OECD) defined EPR in their updated guidelines "as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's lifecycle, including the shifting of physical and/or financial responsibility, fully or partially, towards upstream producers for treatment or disposal of post-consumer products, and providing incentives to producers to incorporate environmental considerations in the design of their products (OECD, 2016)." Zimbabwe, Togo, Mali, Côte d'Ivoire, Senegal, and Tunisia specifically outlined EPR and

special regulations on return or disposal. Since the UNEP publication, South Africa has updated its National Environmental Waste Management Act to include EPR regulation under Section 18. The regulations went into effect on May 5th, 2021, after amendments were made to the initial November 2020 law. The new mandatory EPR legislation requires packaging producers to (IEA, 2025):

- register through the South African Waste Information Centre website;
- either establish their own EPR scheme, join an existing one, or appoint a producer responsibility organization (PRO) to manage their responsibilities; and
- conduct lifecycle assessments of their products within five years of implementation and implement environmental labelling within three years.

Before the legalization of EPR in South Africa, seven existing voluntary PRO organizations for various packaging materials helped establish EPR in South Africa: Petco for PET, Polyco for Polyolefins (PP, HDPE, LDPE/LLDPE, and Multi-layer), Polystyrene Association for Polystyrene, Southern African Vinyl Association (Sava) for vinyl, The Glass Recycling Co. for glass, METPAC-SA for metal packaging, and the Fibre Circle for paper.

Efforts are being made in Africa to address waste management and plastic pollution through regional policies and institutions, as well as national policies. These efforts establish the importance placed on these two issues. However, there are limitations to the effectiveness of these policies. Sadan and Kock (2022) analyzed policies in Africa and identified regional and national policy gaps. At a regional level, there is a lack of continent-wide vision and targets to address plastic pollution and a lack of research and knowledge to inform circular plastics

economy policy to address plastic pollution. It was also noted that there is a lack of effective enforcement of plastic waste trade regulations across Africa. At a national level, there are few or no clear national targets for transitioning to a circular plastics economy. There is more focus on downstream waste management instead of upstream. Similarly to a regional lack of data, there is a limited amount of data nationally. Lastly, there are limited resources for the effective implementation of policies, strategies, and plans.

1.1.4 Megacity by 2030: Dar es Salaam, Tanzania

The United Republic of Tanzania is located on the coast of East Africa and faces the Indian Ocean. It shares its borders with Kenya, Uganda, Rwanda, Burundi, the Democratic Republic of Congo, Zambia, Malawi, and Mozambique. Tanzania (formerly known as Tanganyika) gained independence from the United Kingdom on December 9th, 1961. In April 1964, Tanganyika merged with Zanzibar, and in October of that year, the newly merged country adopted its current name, the United Republic of Tanzania. Tanzania is known for its beautiful nature, with almost a third of the country's nearly 950,000 sq-km land mass dedicated to National Parks. These include the Serengeti, Mount Kilimanjaro (Africa's tallest mountain), Ngorongoro Crater, and Lake Tanganyika (the second-largest lake in the World).

One of Tanzania's fastest-growing cities is Dar es Salaam, located on the country's coast; it was also the capital until 1996, when it was replaced with Dodoma. The city is estimated to become a megacity with a population greater than 10 million by 2030 (United Nations, 2014). Based on the 2022 census, Dar es Salaam has a population of 5,383,729, accounting for 8.7% of the country's total population (Ministry of Finance and Planning, 2022). World Population

Review estimates that Dar es Salaam's population in 2022 was 7.4 million and estimates its population in 2024 was 8.2 million based on the United Nations World Urbanization Prospects (World Population Review, 2025). Dar es Salaam estimated per capita waste generation rate is between 0.8 to 1.0 kg/cap/day (DCC, 2016). Based on Dar es Salaam's estimated 2024 population, Dar es Salaam generates 6,560 and 8,200 tons of waste a day. Additionally, Dar es Salaam reports that only 40% of all waste generated is collected and disposed of at the Pugu dumpsite, the only operational dumpsite in Dar es Salaam (URT, 2018). The remaining 60% of the waste is illegally burned, buried, or dumped. Thus, there are large quantities of waste that are not being properly managed in Dar es Salaam. The IUCN also found that plastic waste generation per capita in Dar es Salaam is 30 kg/cap/year, which is higher than Tanzania's average plastic waste generation per capita of 5.7 kg/cap/year (IUCN-EA-QUANTIS, 2020). In 2030, when Dar es Salaam has an estimated population of over 10 million, the city will generate 822 tons/day of plastic.

1.1.5 Circular Economy

Given the quantities of plastic waste generated and its durability and long life, landfilling and recycling are not enough to properly handle this material. In fact, Borrelle et al. (2020) found that efforts to reduce plastic emissions by 2050 is not as simple as increasing waste management capacity. In the same paper Borelle, emphasis that society needs to begin valuing plastic instead of viewing it as waste, if they are unwilling to cease all production and use of plastic items completely (Borrelle et al., 2020). The Circular Economy (CE) has been viewed as a solution towards not only tackling plastic pollution but also waste in general. The Circular Economy is defined as a system where materials never become waste through maintenance, reuse,

refurbishment, remanufacture, recycling, and composting (Ellen MacArthur Foundation). In the United Nations 2023 "Conference of European Statisticians Guidelines for Measuring Circular Economy" establishes CE as an economy where (UNECE, 2023):

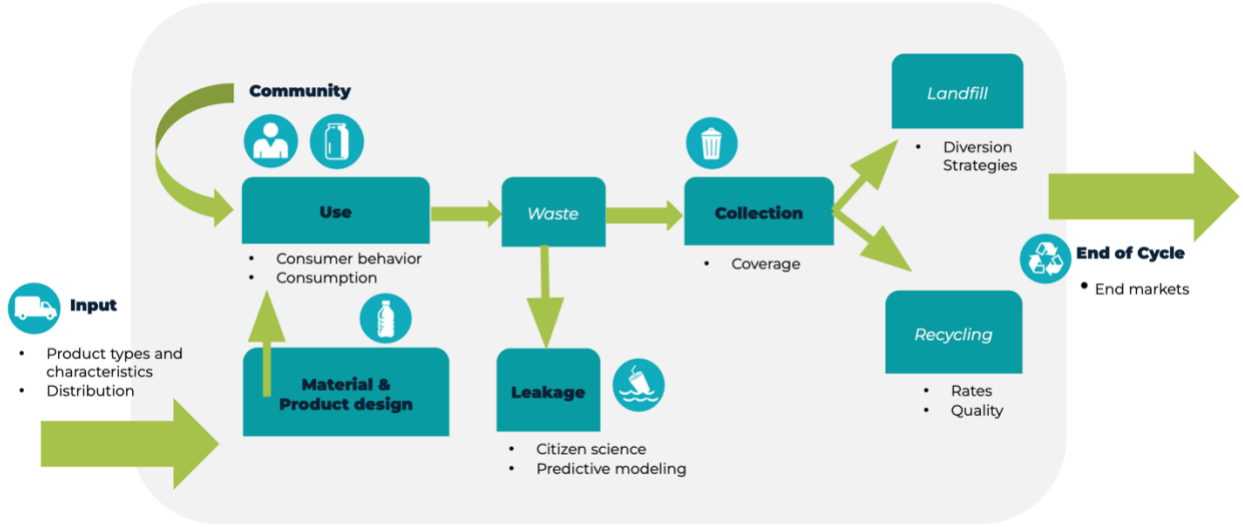
- "the value of materials in the economy is maximized and maintained for as long as possible;
- the input of materials and their consumption is minimized; and
- the generation of waste is prevented and negative environmental impacts reduced throughout the life cycle of materials."

Value of material is defined in the report as "understood to encompass the value for society as a whole, taking into account economic efficiency, environmental effectiveness and social equity" (UNECE, 2023). Thus, instead of materials being disposed of, because they are viewed of as having no value, efforts are made to ensure that materials have value and avoid being disposed of.

The idea of the CE is not new, especially in Africa. The Global Alliance for Incinerator Alternatives (GAIA) and Break Free From Plastic report, "Life Before Plastic, Demonstrating Traditional Practices of Reuse in Africa" highlights various local and cultural reusable practices in Africa (Naidoo et al., 2024). The report highlights traditional practices that valued the materials and the resources available and demonstrate that the notion of a CE or zero waste are not novel ideas but in fact were practiced before the invention of plastic. As Dar es Salaam's population grows and waste is continually generated efforts to understand the current solid waste management (SWM) are necessary to implement a CE system that is effective and works for Dar es Salaam.

The Circularity Assessment Protocol (CAP), the primary methodology used in this work was developed by the Circularity Informatics Lab (CIL) at the University of Georgia (UGA). It was designed as a quantitative and qualitative method used to quantify circularity in a city to support a city's decision-making. While this thesis will predominantly focus on plastic, CAP can be applied to different materials such as organic materials, metals, etc. CAPs can also help highlight any ongoing initiatives or products that increase circularity while also identifying opportunities for cities to increase circularity (Jambeck et al., 2024). CAP has been utilized in 50+ cities across 16 countries. CAP is made of 7 different spokes in which data is collected: input, community, product design, use, collection, end of cycle, and leakage. The spokes are shown in Figure 1.1 in a materials flow and represent how each the selected material for a project flows throughout a city. While the CAP provides city specific data regarding circularity, the uniform method allows makes it easily replicable and allows for comparison of the results between different cities. In Maddalene et al. (2023) paper 6 different "Urban Ocean" cities CAP results were compared and contrasted. Urban Ocean is a program implemented in 2019 by 12 cities in the Resilient Cities Network, Ocean Conservancy, and The Circulate initiative to end ocean plastic and build more resilient cities.

Figure 1.1 CAP Spokes Represented as Material Flow



Source: (CIL, 2025)

1.1.6 Prevented Ocean Plastics

Prevented Ocean Plastics (POPs), a recycled PET bottles (rPET) supplier, funded this study under Bantam Materials UK Ltd. In June 2023, POPs announced their goal of opening 25 collection centers by 2025 in Southeast Asia, South America, Sub-Saharan Africa, and the Mediterranean, regions historically lacking recycling infrastructure (POP, 2023). In April 2024 they announced that six of the collection sites have been opened in Indonesia and that the project is on its way towards completing its 25 collection centers by 2025 (POP, 2024). This thesis focuses on understanding the SWM process in Dar es Salaam through the circular economy lens. At the start of this project in Spring 2024, a collection center was under construction and opened in November 2024. This center is the first collection center opened in Tanzania, and the first in the African continent. The facility is located in the Exporting Processing Zone in Dar es Salaam

and processes blue or clear post-consumer PET bottles. The center expands collection of plastic for recycling in the city.

1.1.7 Local Implementation Partner: Nipe Fagio

An essential component of CAPs is that it is a collaboration with local city partners who provide their expertise and experience in the community. For this research project, Nipe Fagio, which in Swahili means “give me the broom”, was founded in 2013 and aims to improve waste management and reduce urban pollution through data gathering, policy advocacy, and action to achieve systemic change (Nipe Fagio, 2025a).

Since 2018, Nipe Fagio has participated in Break Free From Plastic’s (BFFP) global brand audits program, which was the audit’s inaugural year. The brand audit methodology was developed by Global Alliance for Incinerator Alternatives (GAIA), Mother Earth Foundation, Citizen consumer and civic Action Group (CAG), and Greenpeace Philippines in 2017. The training material is available for free in 15 different languages, along with an almost hour-long training video in 7 languages, which is also available on YouTube. The brand audits are cleanup events that are conducted at local sites, depending on which site the participating organization determines is most relevant to the community, such as beaches, mountains, rivers, local parks, etc., and all information is logged on the provided brand audit log sheets (#BreakFreeFromPlastic, 2025). The 2023 BFFP Brand Audit Report reported 250 brand audits from 41 countries and 25 audits from 9 African countries (#BreakFreeFromPlastic, 2024). Nipe Fagio has published the data they collected in 2018, 2019, 2020, and 2021 on their website and analyzed 350,000 units of waste. The analysis found that 64% of the waste audited over the four-

year period was plastic waste, and that in 2021, 76% of all waste collected was plastic. The common types of plastic found in the audits since 2018 are 33% Polyethylene terephthalate (PET), 31% Low-Density Polyethylene (LDPE), 5% High-Density Polyethylene, and the remaining 20% is made up of multi-layered, single-layered, polystyrene, and polypropylene. The brand audits have also found that 75% of the waste comes from local manufacturers and producers. The remaining 25% comes from foreign products (Nipe Fagio, 2025b).

Nipe Fagio has worked on promoting SUP Free policy and a Zero Waste Model in Tanzania and East Africa. Nipe Fagio is part of the Single-use Plastic Free East African Community (EAC) campaign, a joint initiative of GAIA members in East Africa advocating against SUPs. The EAC was reestablished in 2000 and comprises the Democratic Republic of Congo, the Republic of Burundi, the Republic of Kenya, the Republic of Rwanda, the Federal Republic of Somalia, the Republic of South Sudan, the Republic of Uganda, and the United Republic of Tanzania. The vision of the EAC is "to be prosperous, competitive, secure, stable, and politically united East Africa" (EAC, 2025). Nipe Fagio along with other GAIA member are advocating for the EAC to create policies that reduce the use of SUP which includes straws, cups, bags, and other major sources of plastic pollution. The campaign also aims at promoting alternatives to SUP instead, such as reusable bags, containers, and utensils. Their collaborative efforts also expand to the global stage (Ana Rocha, 2022). As members of GAIA, Nipe Fagio has also been present at the INC negotiations.

At a local level Nipe Fagio has been working on reshaping SWM in Dar es Salaam. In 2019, Nipe Fagio opened the first Zero Waste Cooperative in Tanzania. The cooperative is located in Bonyokwa and is managed by local waste pickers in the community. The goal of the

cooperative is to address the high cost of waste management and unreliability of waste services in Dar es Salaam and instead provide a decentralized and community-based solution that engages and educates the community. As a first of its kind solution in Tanzania, the cooperative and the surrounding area will also be a part of this projects research.

1.2 Research Goals

The goal of this research is to apply the CAP methodology for the first time in mainland Africa, specifically in Dar es Salaam, Tanzania. As waste generation on the continent is expected to increase and countries begin to look towards implementing sustainable solid waste infrastructure, this research will establish a benchmark for quantifying circularity in Tanzania and Africa. CAPs have also identified various circular initiatives that can inform stakeholders in other cities about possible circular systems that can be implemented in their respective context. This research will also add value to future CAPs by identifying more circular initiatives across the continents. The overall goals for this thesis are to:

1. Understand and provide opportunities to increase the circularity of plastic packaging and other materials in Dar es Salaam through the Circularity Assessment Protocol (CAP).
2. Identify Fast-Moving Consumer Goods (FMCG) entering Dar es Salaam, along with their manufacturers and parent companies
3. Highlight existing infrastructure that can promote and amplify the circular economy in Dar es Salaam

1.3 Research Objectives and Approach

The following objectives and approaches will support these main goals:

Objective 1: Establish the current state of SWM, plastic pollution research, and circular economy research in literature as related to Dar es Salaam

Approach: Conduct a thorough literature review of peer-reviewed articles and some global institutions' papers from 2000 to June 2024 focusing on SWM, plastic pollution, and circularity in Dar es Salaam. Analysis of the literature includes:

- identifying locations in Dar es Salaam where relevant research has been conducted,
- common data included in SWM papers such as waste generation and characterization,
- do papers connect poor SWM to plastic pollution,
- relevant SWM infrastructure and systems, and
- if any literature addressed the circular economy in Dar es Salaam.

Objective 2: Document baseline circularity of PET and other plastic beverage bottles in Dar es Salaam

Approach: Identify the lifecycle of a bottle in Dar es Salaam: How/why does the consumer use it, how is it collected, sent to a landfill or recycling plant, or does it leak into the environment? Are there efforts to minimize the use of plastic bottles? Data

collected from stores and restaurants will be used to establish what beverage bottles are available and who the manufacturers and parent companies of these products are. Desktop research and interviews from key stakeholders will identify the perception of bottles and alternatives available that promote reducing the usage of plastic bottles, how bottles are collected, and leakage data from the Marine Debris Tracker App will quantify bottle leakage into the environment.

Objective 3: Identify opportunities for optimizing circularity in Dar es Salaam

Approach: Identify ongoing initiatives in Dar es Salaam that promote circularity or waste reduction through desktop research, alternative availability, and interviews with key stakeholders. Analyze alternatives available in stores and restaurants or current systems for purchasing staple items that could transition to a circular economy. Assess the progress and implementation of the 2019 Ban on Plastic Bags. Identifying opportunities based on the results would be presented that would promote circularity.

1.4 Organization of the Thesis

Following the introduction, Chapter 2 will include a Literature Review that analyzes SWM and plastic pollution research in Dar es Salaam, while also identifying mention of the circular economy. Chapter 3 will detail the CAP methodology utilized to gather and analyze data in this research. Chapter 4 will present the results from this research for each of the seven CAP categories: Input, Community, Product Design, Use, Collection, End of Cycle, and Leakage. Chapter 5 will discuss the results and identify opportunities to support and optimize circularity in

Dar es Salaam. Lastly, Chapter 6 will summarize key findings, opportunities, and future directions. Overall, these chapters will be centered around establishing a baseline understanding of circularity in Dar es Salaam that will support identifying opportunities for promoting the circular economy.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Plastic pollution is one of the most pressing issues impacting our planet. In 2010, 275 million metric tons (Mt) of plastic waste were generated in 192 countries (Jambeck et al., 2015). That same year, it was estimated that 31.9 Mt of the 99.5 Mt of plastic waste generated within 50 km of the coastline in these countries was mismanaged, with 4.8 to 12.7 Mt entering the ocean (Jambeck et al., 2015). As the knowledge of plastic production and pollution was expanded, it was estimated that in 2015, 6,300 Mt of plastic waste had been cumulatively generated since 1950, of which 9% had been recycled, 12% incinerated, and 79% either accumulated in landfills or the natural environment (Geyer et al., 2017). If nothing is done to curb plastic waste, it is estimated that 12,000 Mt of plastic will end up in landfills or the environment by 2050 (Geyer et al., 2017). Countries and international bodies are now working towards tackling the issue of plastic pollution. Given the quantities of plastic waste generated and its durability and long life, it is a monumental challenge. In fact, Borrelle et al. (2020) found that efforts to reduce plastic emissions by 2050 would require a tremendous amount of work because simply increasing waste management capacity would not suffice. Society needs to begin valuing plastic instead of viewing it as waste, if they are unwilling to cease all production and use of plastic items completely (Borrelle et al., 2020).

Africa is rapidly growing, reaching 1.5 billion people in 2024 and is estimated to reach between 3.5 billion to 4.0 billion by 2100 (United Nations Population Division, 2024). Five of the eight countries expected to account for more than half of future population growth are in Africa: the Democratic Republic of Congo, Egypt, Ethiopia, Nigeria, and the United Republic of Tanzania (Sinha & Getachew, 2024). Not only is Africa's population growing, but it is also urbanizing. In 2023, the World Bank estimated that the urban population of Sub-Saharan Africa was 43% (World Bank Group, 2024c). Tanzania has an urban population of 37% (World Bank Group, 2024c). Urbanization is expected to grow in low elevation coastal zones, with 49 million more people living there by 2060 globally (Neumann et al., 2015). One of Tanzania's fastest growing cities is Dar es Salaam, located on the country's coast facing the Indian Ocean. The city is estimated to become a megacity with a population greater than 10 million by 2030 (United Nations, 2014). Based on the 2022 census, Dar es Salaam has a population of 5,383,729, accounting for 8.7% of the country's total population (Ministry of Finance and Planning, 2022). World Population Review estimates that Dar es Salaam's population in 2022 was 7.4 million and estimates its population in 2024 was 8.2 million based on the United Nations World Urbanization Prospects (World Population Review, 2025).

Population growth is a concern since increased population is related to increased waste generation (Mapunda et al., 2023). Increased waste generation does not always result in increased collection. Increased waste generation needs to be matched with increased collection or pollution from mismanaged waste, including plastics, increases. As such, there is a heavy emphasis on improving waste management in Africa and Dar es Salaam. In 2010, Africa mismanaged 4.4 million metric tons of plastic waste, which is expected to increase to 10.5

million metric tons in 2025 if nothing changes (Jambeck et al., 2018). Tanzania was estimated to have 100,000 metric tons of mismanaged plastic waste in 2010, estimated to increase to 500,000 metric tons by 2025 (Jambeck et al., 2018).

The government of Tanzania and Dar es Salaam have passed various laws regarding the safeguarding of the environment, individuals health, and proper methods for waste management. The 2018 National Solid Waste Management Strategy included fourteen different laws relevant to SWM in terms of land quality, pollution, health, workers, villages, industry, urban planning and energy. Table 2.1 identifies five of the fourteen laws mentioned in the National Strategy that are relevant to Dar es Salaam and includes the ban on plastic bags. Tanzania's Constitution provides an overarching precedence that individuals deserve to live in a healthy nonpolluted environment. Section 114 of the Environmental Management Act (EMA) requires that different containers be provided in order to ensure separation of waste. The EMA Solid Waste Regulations require that efforts be made towards waste minimization. Lastly, plastic bags regardless of thickness were banned in 2019 by the Tanzanian government and was amended in 2022 to include seals around plastic bottles. Overall, Tanzanian legislation requires that a safe clean environment be created and that efforts be made to minimize waste generation while also ensuring effective capture and disposal of waste.

Table 2.1: Tanzanian Legislation Regarding SWM

Constitution of the United Republic of Tanzania, 1977	Article 14: every person has the right to live and to the protection of his life by the society in accordance with the law Article 27 (1): every person has the duty to protect the natural resources of the United Republic

Environmental Management Act (EMA), 2004	Section 114: (1) For the purposes of ensuring minimization of the solid waste in their respective areas of jurisdiction, local government authorities shall prescribe: (a) for different types or kinds of waste or refuse or garbage to be separated at the source; (b) for standards to guide the type, size, shape, colour and other specifications for refuse containers used; and (c) for mechanisms to be put in place to involve the private sector and Non-Governmental Organisations on planning, raising awareness among producers, vendors, transporters, manufacturers and others on the need to have appropriate containers and enhance separation of waste at source. (2) The local government authorities shall, with respect to their areas of respective jurisdiction: (a) cause to be conducted appropriate Environmental Impact Assessment for all new major activities leading to proper management of solid waste; (b) manage solid waste generated in accordance with sustainable plans produced by respective local government authority; and (c) ensure the appropriate sorting of waste is made right at the source and in accordance with standards or specifications prescribed by the local government authority concerned. Section 119: The local government authorities shall in choosing the best method of solid waste disposal for their areas of jurisdiction consider the following matters: (a) climatic conditions; (b) economic ability; (c) interest of the community; (d) environmental, hygienic and social benefits; and (e) availability of tipping sites. Section 134: (1) Each local government authority shall, with respect to its area of jurisdiction, ensure that: (a) standards prescribed for the hazardous waste management are in place and operational at all the time; (b) premises producing hazardous wastes are adequately ventilated and are in compliance with prescribed standards; (c) waste effluents are treated or are so modified as to comply with prescribed standards before final disposal; and (d) hazardous liquid wastes are treated to conform with prescribed environmental standards at factory or on site before their discharge into public sewers or municipal oxidation ponds or in an open land or into receiving water bodies.
Land Act No. 4, 1999	The Ministry of Lands, Housing and Human Settlement Development is responsible for implementing the Act. The Land Act provides for: particular areas to be designated as “hazardous land”, the development of which is likely to pose a danger to life or lead to the degradation or destruction of the environment on a site or on land adjacent to the site. Hazardous land includes: mangrove swamps coral reefs wetlands

	offshore islands land designated or used for dumping of hazardous wastes land within 60 m of a riverbank, shoreline of an inland lake, beach or coast land on slopes with a gradient exceeding acceptable angle land specified by appropriate authority as fragile nature or of environmental significance the protection of hazardous land Landfill facility may not be constructed in sensitive sites
Public Private Partnership Act, 2010	The Act give effect to the public-private partnership policy; to provide for institutional frameworks for the implementation of public-private agreements between public sector and private sector entities; to set rules, guidelines and procedures governing public-private procurement, development and implementation of public private partnership and to provide for other related matters. Public Private Partnership Co-ordination Unit shall deal with promotion and co-ordination of all matters relating to public-private partnership projects undertaken within the Mainland Tanzania. (g) Environment and Waste Management (section 6 (3))
Environmental Impact Assessment and Audit Regulations, 2005 and 2018 amendments	First schedule on the projects category type A that are mandatory to undertake Environmental Impact Assessment (20). WASTE TREATMENT AND DISPOSAL: Toxic and Hazardous waste: Construction of Incineration plants; Construction of recovery plant; Construction of waste water treatment plant; Construction of secure landfills facility; and Construction of storage (temporary) facility. (b) municipal solid waste: construction of Municipal Solid Waste landfill facility (c) municipal sewage: construction of sewage sewer system
Environmental Management (Solid Waste) Regulations, 2009	The Regulations: detail the requirements and responsibilities for managing solid waste in Tanzania highlight waste minimization and cleaner production principles alongside the duty to safeguard the public health and the environment from adverse effects of solid waste detail permitting requirements (Part III), notably that any person dealing with solid waste as collector, transporter, waste depositor or manager of a transfer station will apply to the LGA for a permit. The local authority will also issue licences to individuals or companies qualified to operate solid waste disposal sites, i.e., a permit is required to operate a LGA waste disposal site.

Environmental Management (Prohibition of Plastic Carrier Bags and Plastic Bottle Cap Seals) Regulations 2022	Section 230 (2) (f) Part III: 5. All plastic carrier bags, regardless of their thickness are prohibited from being imported, exported, manufactured, sold, stored, supplied and used in Mainland Tanzania. 6. A person shall not import, export, manufacture, store, distribute, supply, sell or offer for sale beverages with plastic bottle cap seals. 7. A person shall not sell or offer for sale beverages or commodities wrapped in plastic unless the nature of such commodities requires wrappings by plastics. 8. Licensing authority shall not register or issue a license or permit to any person intending to import, export, manufacture, distribute or sell plastic carrier bags or beverages with plastic bottle cap seals that have been prohibited by these Regulations. Part V: 15. Local government authorities shall, in addition to their roles and functions on waste management provided for in the Act and in the Environmental (Solid Waste Management) Regulations- be responsible for ensuring compliance and enforcement of these Regulations; conduct public education and awareness programs on the implementation of these Regulations; and prepare and submit bi-annual report on implementation of these Regulations to the Director of Environment.

Modified from: (National Environment Management Council, 2022; URT, 2018)

2.2 Methods

2.2.1 Literature Selection

This literature review aims to understand the solid waste management (SWM) system in Dar es Salaam and its effect on plastic pollution. The Circular Assessment Protocol (CAP) methodology was utilized in this research. As such, the literature review also focused on identifying any mention of components of the circular economy in the literature related to Dar es Salaam. The circular economy is a system where materials never become waste through maintenance, reuse, refurbishment, remanufacture, recycling, and composting (Ellen MacArthur

Foundation). The following keywords were entered into both Google Scholar and the University of Georgia Library system:

- Africa Waste Management
- Africa Circularity
- Africa Plastic Pollution
- Tanzania Waste Management
- Tanzania Circularity
- Tanzania Zero Waste
- Tanzania Built Environment
- Tanzania Plastic Pollution
- Dar es Salaam Waste Management
- Dar es Salaam Circularity
- Dar es Salaam Zero Waste

Peer-review articles published between 2000 and June 2024 that mentioned or focused on Dar es Salaam or Tanzania in the title or abstract were selected for the literature review, no technical reports, thesis, or dissertations were included. Literature on Africa was included if it mentioned Dar es Salaam or Tanzania to establish SWM on the continent. Papers published by the United Nations, The World Bank, World Wide Fund for Nature (WWF), and International Union for Conservation of Nature (IUCN) were also included as they were repeatedly cited in the peer-reviewed articles. These sources establish an understanding of Tanzania and Dar es Salaam's impact on SWM and plastic pollution in the global context. Overall, 57 papers were identified through this process (Appendix A Table A.1).

The articles were sorted regionally in Africa, Tanzania, and Dar es Salaam based on the title or abstract. The articles were then organized into the following subcategories: Plastic Pollution, Microplastics, Solid Waste Management, Recycling and Organic Waste Management (Table 2.2). No articles selected for this review explicitly mentioned circularity or circular economy in the

title or abstract, and as such, no paper could be categorized under circular economy.

Table 2.2: Categorization of Papers

Regional Location	Categorization	Number of Papers
Africa (16)	Plastic Pollution	7
	Microplastics	3
	SWM	6
Tanzania (9)	Plastic Pollution	2
	Microplastics	1
	SWM	4
	Recycling	1
	Organic Waste Management	1
Dar es Salaam (32)	Microplastics	2
	SWM	24
	Recycling	5
	Organic Waste Management	2

It should be noted that four articles were identified that were published before the 2000s that mentioned SWM in Dar es Salaam but are not included in this literature review due to the rapidly changing nature of SWM (Halla & Majani, 1999; Kaseva & Gupta, 1996; Klundert & Muller, 1998; Yhdego, 1995). Also, six articles that studied plastic pollution, microplastics, or SWM in other cities in Tanzania were identified. However, they were not included in the overall review as they did not mention plastic pollution, microplastic, or SWM in Dar es Salaam. The papers included two papers that covered Arusha city (Onesmo et al., 2024; Richard, 2024), two covered Dodoma (Mushi, 2024; Nyampundu et al., 2020), one covered Zanzibar (Maione, 2021), two covered Kawagare (Krause & Rotter, 2018), and one covered rural areas in Tanzania (McClelland et al., 2022). While the literature published before 2000 or focused on other Tanzanian cities is not included in the overall review, it is worth noting that it does exist. It

highlights the importance of studying SWM or plastic pollution in Tanzania. The literature that covered other cities was published within the last six years, suggesting a growing awareness and interest in this issue. The growing interest is further emphasized by the fact that from the papers selected for this review, only four were published in the early 2000s, 23 were published in the 2010s, and 29 were published since 2020.

Forty-nine of the papers identified were featured in peer-reviewed journals; the other eight were from the organizations listed above. These papers were published in thirty-nine different journals. The most popular journal was Habitat International with five papers; Resources, Conservation and Recycling with three papers; Science of Total Environment, Marine Pollution Bulletin, International Journal of Environmental Research and Public Health, and Environmental Science and Pollution, each with two papers; followed by the remaining journals featuring one only. It should also be noted that three journals included Africa in the name, along with three other journals, including Tanzania.

2.2.2 Analyzing the Literature

The literature was analyzed by manually searching for mention of the following key terms:

- Waste Generation or Rate
- Waste Composition or Characterization
- Informal Sector, Waste Pickers and Scavengers (an inappropriate term still used to describe waste pickers)
- Private or Formal Waste Management
- Refuse Collection Charge or Fee
- Source Separation or Segregation
- Recycle(ing) or Compost(ing)
- Organic Waste
- Circular Economy or Circularity
- Reduce or Reuse

- Pollution
- Plastic Pollution
- Health
- Informal or Unplanned Settlements
- Municipality and Ward

These terms were selected to help identify key information that identifies how much waste and what kind of waste is being generated, the formal and informal sectors' role in managing waste, identifying circular economy systems, and studies interested in the circular economy. These terms were also used to identify if papers connect mismanaged waste to pollution, which can harm people's health. The review also focused on identifying mention of plastic pollution, determining if connections have been made in general SWM papers, and which parts of Dar es Salaam have been studied. With a landmass of 1800 sq-km and 102 wards split between 5 different municipalities, understanding which areas have been studied and which are lacking.

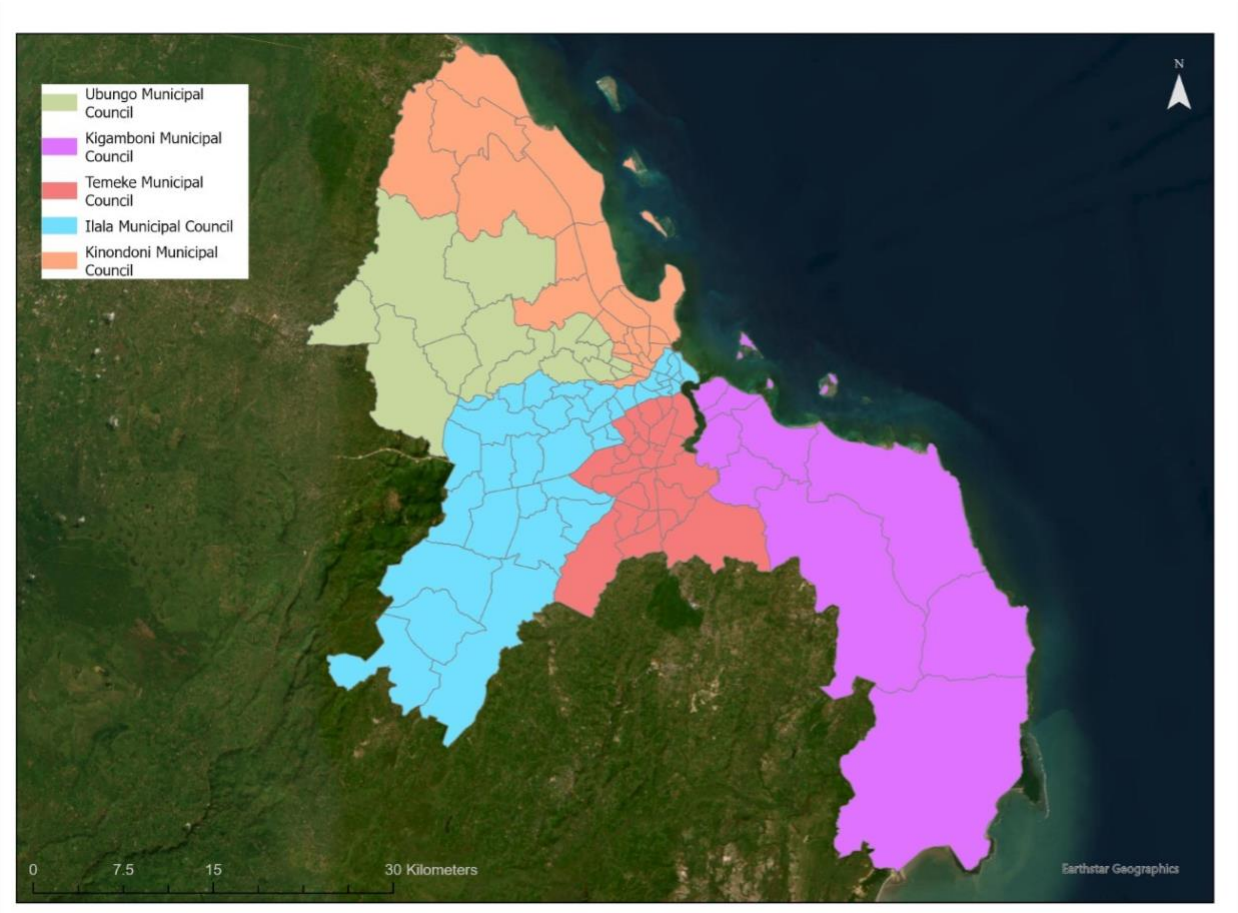
2.3 Results and Discussion

2.3.1 Study Areas in Dar es Salaam

Dar es Salaam is comprised of 102 different wards spread between 5 different municipalities. The municipalities are Temeke Municipal Council, Kinondoni Municipal Council, Ilala Municipal Council, Ubungo Municipal Council, and Kigamboni Municipal Council (Figure 2.1). Ubungo and Kigamboni are the most recent municipalities created and were syphoned off from Kinondoni and Temeke respectively. This occurred in 2016, as such papers, published before 2016 and even a few published later only referred to the original three municipalities. Kinondoni was the most studied municipality with 11 papers, Ilala was studied in 9 papers, and Temeke in 4.

The newest municipalities, Ubungo, was studied in 2 papers and was published within the last 2 years, and Kigamboni was studied in none. Seven papers have focused on the entirety of Dar es Salaam. Five papers only referenced the three original municipalities as they were published before or within 2 years of the change.

Figure 2.1: Dar es Salaam Municipalities



Unplanned or informal settlements account for more than 70% of all settlements in Dar es Salaam (Rasmussen, 2013). These settlements face challenges that make waste collection difficult. Informal settlements in Dar es Salaam were mentioned in 16 of the Dar es Salaam papers on SWM. These papers highlighted that the congestion of houses creates narrow passageways that make it difficult for the necessary collection vehicles to access the homes.

2.3.2 Waste Generation and Characterization in Dar es Salaam

Waste generation and characterization are important for cities in determining the necessary infrastructure to ensure proper waste management. Twenty-three of the Dar es Salaam papers included waste generation rates, and twelve included waste characterization for Dar es Salaam. Nine Africa and Tanzania papers included waste generation rates; only three were relevant to Dar es Salaam waste generation. The others were continental or country-wide waste generation rates. Three Africa and Tanzania papers include waste characterization. However, only two papers highlighted that organic waste is the predominant material in the waste and did not mention other materials.

Generation rates and characterization vary due to different data sources, methods utilized, or years of study. Eighteen of the Dar es Salaam included city-wide generation, and the rest only identified waste generation in the respective ward or municipality that the paper was focused on. The most recent waste generation rates in the literature ranged from 0.8 kg/cap/day to 1.05 kg/cap/day, which in 2024 Dar es Salaam waste generation ranged from 6,560 tons/day to 8,200 tons/day. Earlier papers cited waste generation rates of 0.4 kg/cap/day. Thus, this demonstrates

increased waste generation per person in Dar es Salaam. Waste generation and characterization can also vary by socioeconomic background. Senzige, Nkansah-Gyeke, et al. (2014) identified that waste generation in high socioeconomic households in Dar es Salaam was higher than waste generation in middle and low socioeconomic households. The study also identified that plastic waste generation is higher in the low socioeconomic households compared to high socioeconomic households by 12% (Table 2.3).

Table 2.3: Socioeconomic Waste Generation and Characterization

Waste Type	High socioeconomic category		Middle socioeconomic category		Low socioeconomic category	
	Kilogram	Percentage	Kilogram	Percentage	Kilogram	Percentage
Organic Waste	17,960	70.1	20,864	57.7	25,670	52.9
Paper and Cardboard	2,500	9.8	4,800	13.3	4,225	8.7
Plastics	2,114	8.3	5,200	14.4	9,872	20.3
Glass	1,500	5.9	3,190	8.8	5,900	12.2
Metals	575	2.2	720	2.0	1,952	4
E-Waste	460	1.8	800	1.2	607	1.3
Textiles	250	1.0	300	0.8	100	0.2
Other	254	1.0	309	0.9	500	0.4
Total	25,613	100	36,183	100	48,526	100
Generation rates (kg/cap/day)	1.31		0.94		0.90	

Source: (Senzige, Makinde, et al., 2014)

While these generation estimates do vary, they all reiterated that changes must be made to manage the waste as it will continue to grow as the city's population grows. In 2005, Dar es Salaam was estimated to generate 2,500 tons/day (Kassim & Ali, 2006). Estimated generation rates in 2024 are almost three times the 2005 rate.

Literature noted a lack of reliable data from the municipalities to estimate rates effectively. The lack of reliable data is problematic because the most recent solid waste collection rate in Dar es Salaam is 40% (URT, 2018). The remaining 60% is either illegally burned, buried, or dumped. Informal waste pickers help collect valuable materials from the dumped waste, but the data on how much is limited. Informal settlements also impact collection, Kamugisha et al. (2019) noted that a 1% increase in accessibility of the house would result in a 0.63% increase in solid waste management.

2.3.3 Refuse Collection Charges and Private Companies in Dar es Salaam

Part of the collection issue is the refuse collection charges (RCC). These charges were instituted when Dar es Salaam implemented the privatization of their SWM in 1995. A ward's income level determines RCCs, which results in low-income wards paying about 35% of what high-income wards pay (Kirama & Mayo, 2016). Lower revenue in these wards makes it challenging to implement technological advancements, which is made worse by low collection of RCCs. Fifteen papers from Dar es Salaam and two from Tanzania discussed refuse charges, it was not mentioned in the Africa papers. Twelve papers mention low collection of RCCs, which impacts the private companies' ability to make revenue. RCCs are not included in other utilities such as water or electricity; they are collected by hand at the end of each month via door-to-door collection (Omar, 2020a). This method creates challenges such as individuals not being home when RCC collection is conducted, failure to provide notice of price changes, and inadequate billing history (Omar, 2020a). Pellatt and Palfreman (2023) focused on using Smart-TRAC in

downtown Dar es Salaam to collect RCCs and found that it did increase collection and that users were interested in using it for other utilities.

Eighteen Dar es Salaam papers mentioned the private sector when discussing SWM. Two papers in the early 2000s appraised the private sector's impact on waste collection in Dar es Salaam. When private companies were introduced, collection in Dar es Salaam increased from 10% of 1400 tons/day in 1991 to 48% of 2,500 tons in 2005 (Kassim & Ali, 2006). The addition of the private was viewed positively due to the increase in collection. Today, it is estimated that only 40% of waste is collected in Dar es Salaam, and the remaining 60% is illegally dumped, buried, or burned (URT, 2018). Seven of the papers identified that the private sector faces challenges, which have impeded collection capabilities, including:

- Limited decision-making processes
- Little emphasis from local government on sustainable SWM practices
- Short contract duration
- Equipment has low collection capacity
- Limited personnel
- low RCC collection
- Inaccessible roads
- Low awareness from the community

Overall, RCC's and existing infrastructure can impact these companies' capabilities to hire people, invest in new technologies, and remain operational.

2.3.4 Recycling and Compositing

Forty-one papers mentioned recycling and discussed limited recycling in Dar es Salaam: twenty-four from Dar es Salaam, six from Tanzania, and eleven from Africa. Seventeen of the Dar es Salaam papers mentioned that source separation in the households is not practiced and

that expanding it would increase the value and recovery of recyclable materials. This means that most of the waste is collected for disposal in landfills. The informal sector collects the majority of recyclable materials. Fifteen papers discussed the role of the informal sector in the waste management process. It should be noted that four papers referred to waste pickers as scavengers, two in the 2000s and two in the 2010s. The term scavengers is a degrading way of referring to these individuals who play a vital role in managing solid waste in Dar es Salaam. Without them, much of the mismanaged waste and recyclables would remain in the environment or eventually be cleaned up during street sweeping and taken to the dumpsite. While waste pickers play an important role in collecting recyclable materials, the informality makes it challenging to gather data about collection. IUCN EA QUANTIS (2021) estimates that 4% of plastic is recycled. This number is lower due to the informal nature of recycling in Dar es Salaam.

Since organic waste makes up more than 50% of the solid waste in Dar es Salaam, fifteen papers from Dar es Salaam, three from Tanzania, and two from Africa mentioned the importance of composting the organic waste. Infrastructure to increase composting includes composting facilities, the most frequently mentioned, black soldier flies (BSF), and biogas generation. BSF uses organic waste as food for the larvae, which, when they reach maturation, are dried and used as animal feed. Fourteen of the Dar es Salaam papers mentioned compositing and recycling together. These papers highlighted that combining the two processes in Dar es Salaam would reduce the waste sent to the dumpsite. Senzige, Nkansah-Gyeke, et al. (2014) estimated that if 98% of Dar es Salaam's waste were collected for recycling and composting, only 2% would have to be sent to the landfill.

2.3.5 Disposal and End of Cycle in Dar es Salaam

Six papers focused on the end of life of SWM and used models to analyze how the system could be improved in Dar es Salaam. These studies identified that the current SWM infrastructure is insufficient and identified what costs and necessary infrastructure Dar es Salaam would need to invest in to proactively address SWM in the city. The models suggested separation facilities (e.g., material recovery facilities (MRFs)) for materials like plastic, metal, glass, and paper; composting facilities; landfills; processing and recycling facilities; and incineration. (Kazuva et al., 2021) focused on identifying a more suitable location for a landfill in Dar es Salaam. Pugu is currently more of a "dumpsite" than an engineered landfill where the waste in Dar es Salaam is disposed. The site was originally designated to be an engineered landfill but was not fully executed and has been an operational dumpsite since 2009. The site is also surrounded by houses with no fence or proper lining to prevent trash from moving or chemicals from leaking into the soil and water. All the above papers expressly stated that the current dumpsite/landfill needs to be updated to reduce the environmental and health consequences of waste disposal.

2.3.6 Plastic Pollution and Microplastics

Microplastics are small pieces of plastic less than five millimeters (NOAA, 2023). There are two sources of microplastics: Primary and Secondary. Primary microplastics are manufactured plastic pellets that create plastic or microbeads used in personal care products. Secondary microplastics come from larger plastic items such as plastic bottles or bags that have broken apart due to exposure to sun, heat, wind, and waves. Microfibers are another kind of

secondary microplastic that come from fabrics or furniture made from synthetic materials (NOAA, 2023).

All the literature was screened to identify the mention of pollution and plastic pollution resulting from improper SWM and the consequences of it on human health. The initial literature search found thirteen papers that included plastic pollution or microplastics in the title. The remaining literature was screened to identify mention of pollution or plastic pollution due to inadequate SWM. Eleven papers from Dar es Salaam explicitly used the term pollution when discussing SWM, but none used the term plastic pollution. Nine papers referred to plastic pollution as the consequence of poor SWM, these predominately came from the Africa and Tanzania papers. Majority came from the Africa papers that specifically studied plastic pollution, and none came from the SWM papers. Fourteen papers from Africa and Tanzania identified negative health consequences affiliated with improper waste management. The lack of connection in the SWM literature to discuss the implications of improper SWM on plastic pollution indicates a disconnect between these two areas of study, primarily from the SWM literature. This gap in understanding the effects of SWM shows that studies have focused on all solid waste, which is important. However, they have not addressed the long life of plastics, especially as plastic production and consumption continues to grow.

Waste Characterization mentioned in Section 2.3.3 did identify the amount of plastic generated in Dar es Salaam; however, it was not the central focus of those papers. Eight papers, six from Africa and two from Tanzania, included an estimated plastic generation rate for Tanzania. These papers were categorized under plastic pollution or microplastics. The IUCN Plastic's hot spotting report estimates that Tanzania generates 5.6 kg/capita/year, whereas Dar es

Salaam has a 30 kg/cap/year plastic generation rate (IUCN EA QUANTIS, 2021). The global average is 29 kg/cap/year; thus, Dar es Salaam's plastic generation exceeds the global and Tanzanian average (IUCN EA QUANTIS, 2021). Six of the eight papers identified the polymer type of plastic pollution and microplastics. Plastic polymers identified include PET, PP, LDPE, HDPE, synthetic rubber, and microfibers.

2.3.7 Circular Economy

Nine papers used the term "circular economy:" two from Dar es Salaam, two from Tanzania, and five from Africa. They mentioned that CE should be explored to address waste management issues in general. However, none of the papers explicitly aimed to analyze circularity or the CE in Dar es Salaam. Section 2.3.4 discusses papers that mention recycling and composting, which also play an important role in implementing the CE, by recovering valuable materials. Section 2.3.5 addressed papers that recommended the implementation of separation plants and composting in Dar es Salaam. These systems would add value to materials typically considered waste, specifically plastics or organic waste. It should be noted that two papers included incineration as a possible solution. Incineration destroys materials, and the by-product cannot be utilized and is landfilled. The recommendation of incineration plants in these papers does not promote a CE. The Bonyokwa Zero Waste Cooperative created by Nipe Fagio in 2019 was mentioned in Omar and Bullu (2022). Bonyokwa is in the western portion of Dar es Salaam in the Ilala Municipality. The goal of the cooperative is to provide a localized solution in an informal settlement of Dar es Salaam to implement Zero Waste in the city. The cooperative composts all organic waste and separates valuable recyclable material. Any residual waste is then

transported to the Pugu dumpsite. The cooperative is reducing transportation costs and minimizing waste sent to landfills. The cooperative is the first of its kind in Dar es Salaam and is the only infrastructure mentioned in the literature that is making steps towards implementing CE.

2.4 Knowledge Gap

This literature review focused on literature that evaluates plastic pollution and SWM in Dar es Salaam and aimed to identify existing literature on circular economy in Dar es Salaam. However, as mentioned in section 2.3.7, no study explicitly focused on circularity in Dar es Salaam. Section 2.3.6 discussed literature on plastic pollution and microplastics and found that no specific literature from Dar es Salaam discussed solid waste impact on plastic pollution. There is a knowledge gap in understanding circularity in Dar es Salaam and viewing the SWM system through the circular economy lens. This gap would be addressed by using the CAP methodology to analyze the SWM system and fast-moving consumer goods (FMCG) in Dar es Salaam. A portion of the CAP focuses on the product design, where these products are coming from, and any alternatives or systems that could aid in implementing a CE. As such, this research would increase awareness about what products and materials are available in Dar es Salaam that eventually end up in landfills, or illegally dumped, buried, and burned. This research will also identify infrastructure besides composting and recycling that can reduce waste generation and promote a circular economy, such as possible reuse or refill systems.

CHAPTER 3

METHODS, DATA COLLECTION, AND ANALYSIS

The primary methods used for this research are those of the Circularity Assessment Protocol (CAP), developed by the Circularity Informatics Lab at the University of Georgia and evolved from previous publications (Jambeck et al., 2024; Maddalene et al., 2023; Youngblood et al., 2022). Each CAP is different, though, with a specific focus on the context of each city where it is applied. This is the first CAP conducted on the African mainland.

Data collection and interviews were conducted from July 8th to August 30th, 2024. The local implementation partner (LIP) for this research project was Nipe Fagio. Nipe Fagio is a local nonprofit organization that has been active since 2013 working on collecting data regarding plastic pollution and actively engaging in regional, national, and global policy change. Nipe Fagio also established the first zero-ward cooperative in Dar es Salaam in Bonyokwa, to improve waste collection. I conducted field work in Dar es Salaam from July 8th to July 12th in addition to training Nipe Fagio Zero Waste Ambassadors for further data collection. Nipe Fagio continued the data collection and interviews after my departure from Tanzania. Data analysis was coordinated by me and conducted by myself with contributions from undergraduate research assistants from September to March 2025. Some of the data collection required collecting the cost of the product. The Tanzanian Shilling (TSH) and the United States Dollar (USD) are both included in this report. The TSH is converted to USD based on the July 2024 average exchange

rate for the month which was 2,641.83 TSH to 1 USD (Bank of Tanzania). Two additional interviews were conducted in March of 2025 after initial data analysis identified a reusable food ware system.

3.1 Survey Site Selection

The survey sites were randomly selected using ArcGIS Pro and data from LandScan Global 2022 from the Oak Ridge National Laboratory (https://landscan.ornl.gov) by UGA in June of 2024. LandScan Global combines geospatial science, remote sensing technology, and machine learning algorithms to create a 24-hour ambient population distribution movement per raster cell at 1 km spatial resolution (Sims et al., 2023). A 10x10km area is designated around the city center. The extracted LandScan data is broken into high, medium, and low ambient populations, as shown in Figure 3.1. Three 1x1 km sites are selected for each population level from the 100 km^2 area using the National Oceanographic and Atmospheric Administration (NOAA) Sampling Design Tool (https://coastalscience.noaa.gov/project/sampling-design-tool-arcgis/ Access Date: June 2024) for a total of 9 randomly selected sites in the 100 sq-km area. An additional 1 sq-km area in Bonyokwa Ward was added for this research. This site is the location of the first Nipe Fagio Zero Waste Cooperative. The NOAA Sampling Tool is used again to select 200x200sq-m sites from each of the 1sq-km sites for 30 randomly selected sites. The final sampling sites are shown in Figure 3.2 and encompass data from four of the five Municipalities of Dar es Salaam and thirteen different wards (Figure 3.3). All sites were confirmed by Nipe Fagio as being accessible and safe locations for data collection prior to the start of collection.

Figure 3.1: Ambient Population Activity of Dar es Salaam inside the 10x10km area plus 1x1km Bonyokwa area

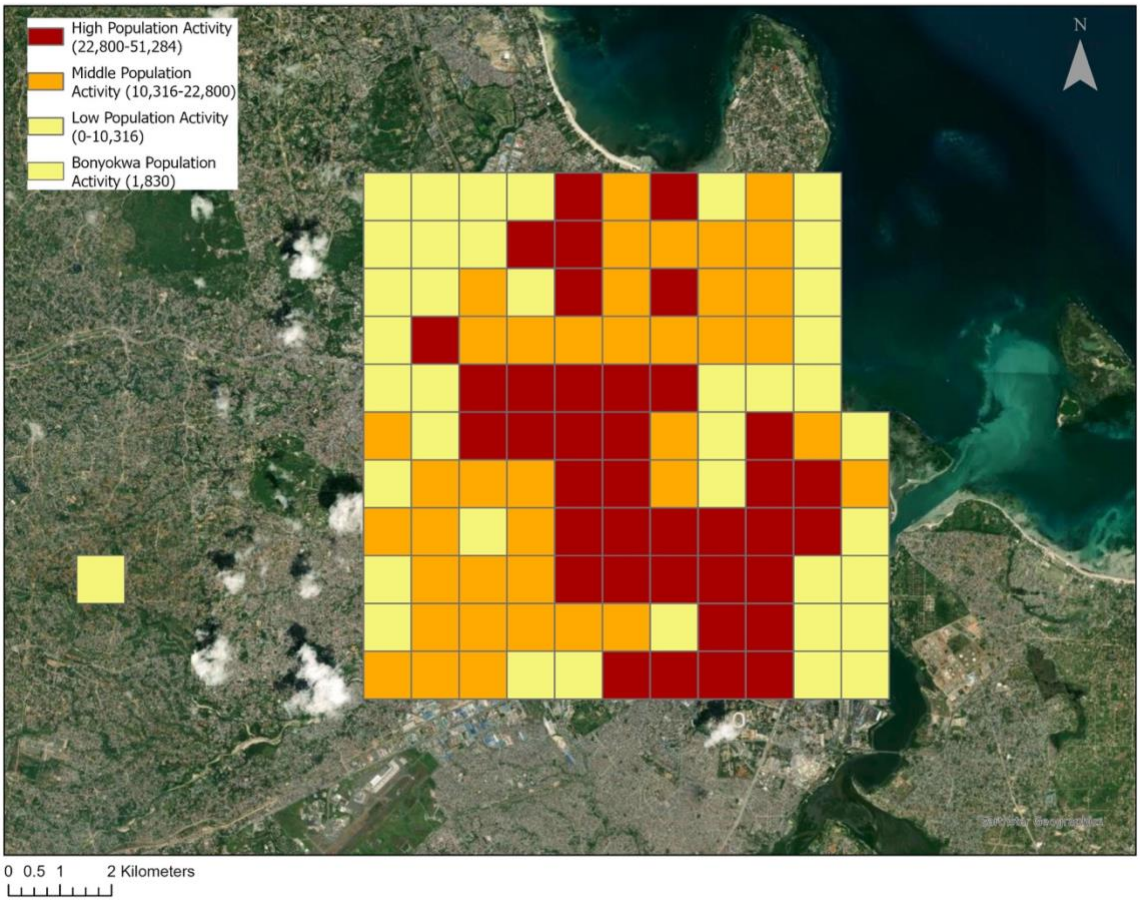


Figure 3.2: Final Dar es Salaam Sample Areas

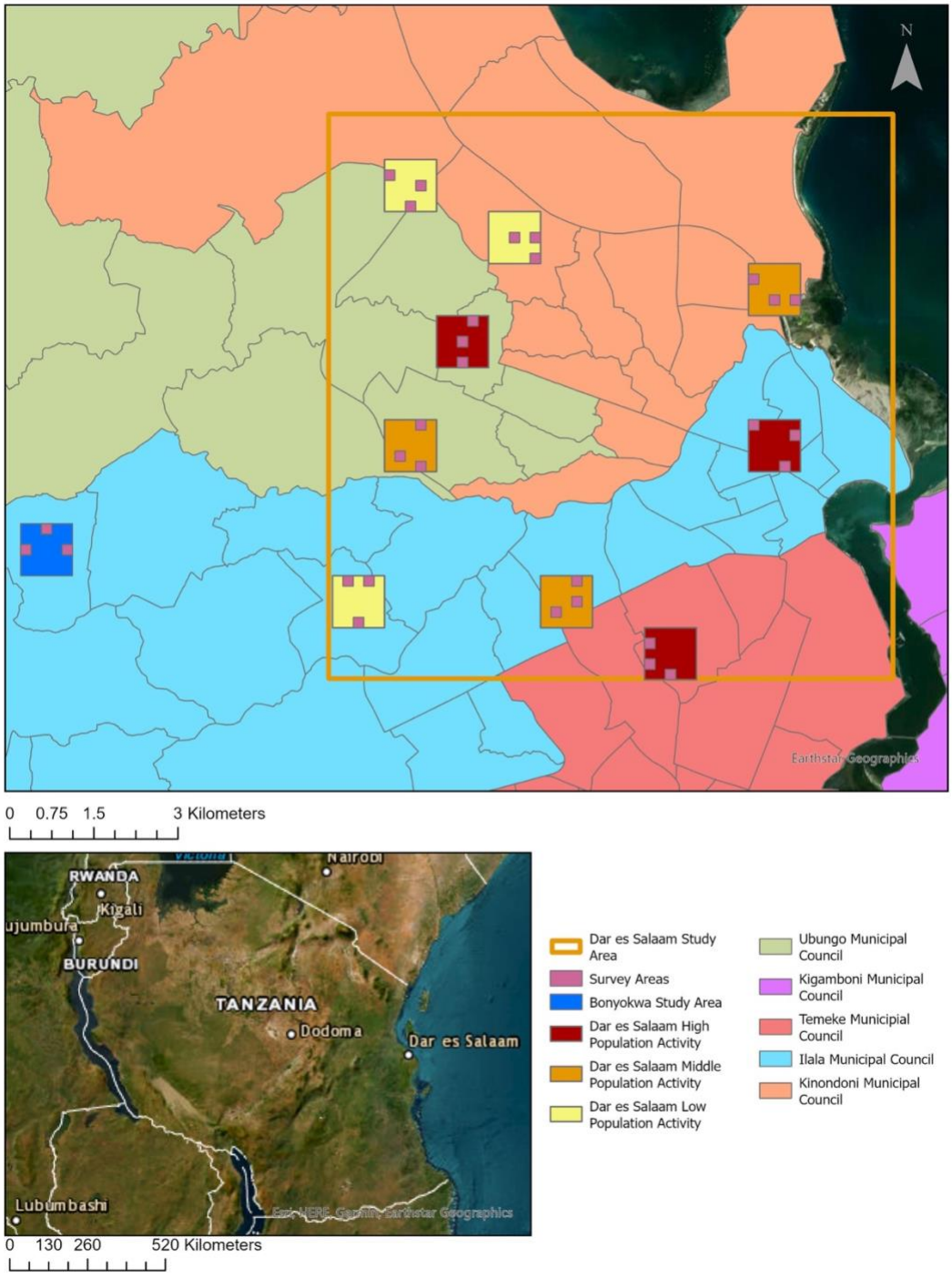
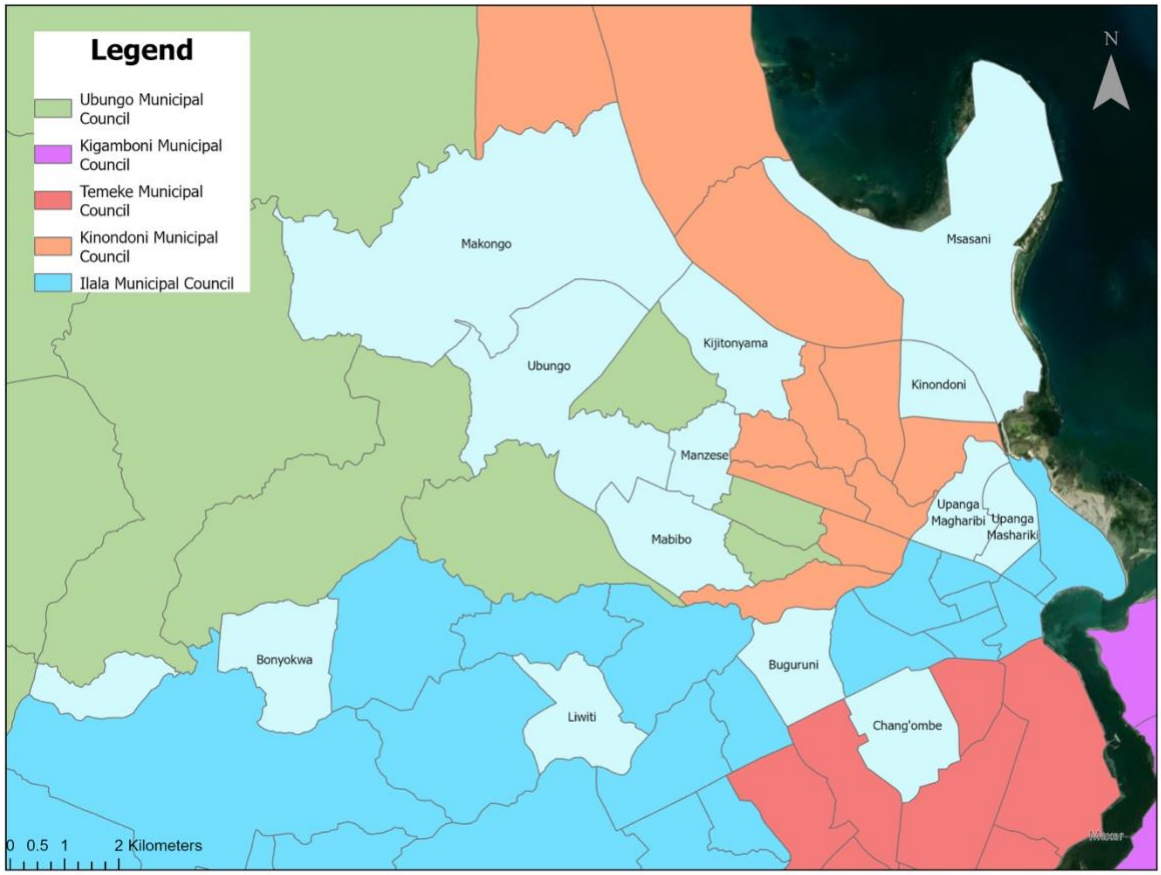


Figure 3.3: Wards and Municipalities included in the study area



3.2 Data Collection and Analysis

Data Collection began on July 8th, 2024, after a training session on July 7th. All data collection was completed by September 2024. Data Analysis began in September 2024 and was completed by February 2025. Majority of the data collection was conducted by Nipe Fagio's Zero Waste Ambassadors and all analysis was conducted by UGA undergraduate and graduate students.

In each of the 1 sq-km sample areas, data is collected from three stores and three restaurants. The stores range from convenience stores to major grocery stores. For restaurants, this includes any establishment offering to-go products, such as fast food, café, sit-down restaurants, etc. This data informs input, product design, and use spokes. In each 200x200 sq-m sample area, leakage data is collected using the Marine Debris Tracker App. Community data is collected through a series of semi-structured interviews with different stakeholders. Data was collected from 30 stores, restaurants, and leakage sites, and 26 interviews were conducted. The leakage sites are randomly selected as explained in Section 3.1. Stores and restaurants are selected for surveying based on if they are available within the 1x1 sq-km area. Surveyors must try to collect from different types of stores and restaurants from big franchise stores and restaurants to smaller stores and restaurants. If data is collected from franchise supermarkets or restaurants (ex. Walmart or KFC) then data is only collected from those locations once in one square even if they may be available in other squares.

Table 3. 1: Overview of All Data Collected

Collection Area	Data Collected

Store	• Input
	  ○ Popular Brand: Available in 50% of stores
	  ○ Manufacturing and Parent Company location
	• Product Design
	  ○ Weight of FMCG
	  ▪ Note: Plastic Packaging material
	  ○ Visual survey of all packaging material of FMCG and staples
	• Use

	○ Identified alternatives to SUP (ex. Reusable, refillable, compostable) ▪ Quantity, cost, and packaging of both the alternative and the SUP counterpart
Restaurant	• Product ○ Packaging material of to-go containers • Use ○ Identified alternative to SUP to-go containers (material and brand)
Leakage Sites	• Litter items collected using Marine Debris Tracker ○ Full list of items in Appendix A Table A.2

3.2.1 Input

The Input spoke documents the packaging of FMCG to identify the packaging material and its source by sampling products available in stores. FMCG are categorized as chips, candy beverages, and tobacco products. Common brands for chips, candy, beverages, and tobacco products were sampled, with brands found in more than 50% of the stores identified as popular products. The popular brands are purchased to establish the weight of packaging to product. Using a kitchen scale, plastic packaging for chips, candy, and beverages were weighed. Determining the weight of chips and candy packaging was challenging to weigh because they were lightweight, meaning they would weigh 0 g on the only scale accessible to Nipe Fagio. As such, for this report, only the weight of beverages was noted. Tobacco products are not purchased or weighed as masses of tobacco items are typically standard globally as established by CIL.

From the popular brands the packaging and manufacturing, distributor, or parent company information is noted from the label. If some information is not available, then desktop research was conducted. In the analysis process the distances between the manufacturing locations and parent companies and Dar es Salaam are calculated in ArcGIS Pro.

3.2.2 Community

The community spoke of the CAP involves semi-structure interviews with relevant stakeholders from convenience/grocery stores, private waste companies, informal waste sector, food vendors, local NGOs, academia, local plastic industry, and local companies. Best efforts are made to obtain at least three interviews from each stakeholder group to obtain 20 to 30 interviews. Questions were provided to Nipe Fagio and can be found in Appendix B. Interviews are anonymous, and quotes are cited using the above categories. Interviews were conducted in English or the local language. Interviews conducted in Swahili were translated into English using GoTranscript. Interviews were coded for thematic analysis into the following overarching categories:

- General SWM Challenges
- Waste Disposal/Waste Disposal Issues
- Waste Generation/Categorization
- Buy In From Community/Community Engagement
- Waste Collection/Collection Issues
- Community/Environmental Health
- Perception of Laws/Bans
- Perception on Plastic
- Education
- Current Community Initiatives
- Informal Sector
- Extended Producer Responsibility
- Opportunities/Strengths

- Other (Quotes that do not fall in any of the categories)

Subcategories that fall under the overarching category were also created throughout the thematic analysis.

3.2.3 Product Design

The product design spoke of the CAP documents packaging for FMCG and to-go containers from restaurants. As mentioned in the input spoke, the FMCG's brand, weight of product, and material information are noted and the popular brands are purchased for weighing. Additionally, visual surveys were conducted to get the overall packaging types for FMCG and staple items. Staple items surveyed in Dar es Salaam included rice, oil, laundry detergent, shampoo, flour, and tomato sauce. Standard CAP methodology surveys rice, oil, laundry detergent, shampoo, and flour. Staples and FMCG can include other items, as determined by the LIP to better centralize to data to the city. Tomato sauce was added as it is a very common ingredient in Tanzanian cooking. Nipe Fagio took photos of the shelf and assigned a percentage of how much shelf space each type of packaging form and material it encompasses. This included materials besides plastic packaging.

3.2.4 Use

The use section of the CAP examines the presence of alternatives to single use plastics (SUPs). This data is collected in the 30 stores and 30 restaurants. In stores, any alternative to SUP plastic is documented. For example, this can include items labeled as reusable, refillable, compostable, bulk, concentrated, or bring your own packaging. The alternative's material, brand,

cost, and quantity are noted, along with a similar SUP brand for comparison. The cost-effectiveness of other options is compared to SUP to examine if these products are economically accessible to the public expensive. In the restaurant survey, it was noted if a restaurant offered reusable items in-house or not. In each restaurant, the following to-go items were sampled: straws, utensils, cold cups, and food containers (for entrees). The material type and the brand were documented. The to-go items were also surveyed to identify if they were single-use, compostable, or reusable.

3.2.5 Collection and End-of-Cycle

Information about Dar es Salaam's solid waste management infrastructure was collected through literature review, interviews, desktop research and litter transects. The literature review focused on characterizing the formal and informal waste sectors and any previous plastic pollution research. Using the Marine Debris Tracker App, waste or recycling bins along the 100 m sample route are documented and it is noted whether the bins are empty or overflowing.

3.2.6 Leakage

The leakage section of the CAP examines what items are entering the environment. Data is collected in all 200 sq-m sites in 10 1 sq-km transect areas along roads or sidewalks. The route does not have to be straight but is continuous. A measuring wheel is used to measure 100 m that stays inside the 200 sq-m site. Pieces of litter greater than 2.5 cm are recorded in a width of 1 m. All data is recorded using the Site Assessment List on the Marine Debris Tracker App. The full list of items is included in Appendix A Table A.2. When collecting food-related packaging, the

item's brand is also added to the description category when it is visible. Items not included in the pre-populated list can be tagged as “other” with an added description. Analysis is conducted using ArcGIS Pro and Excel to quantify the litter density in each 100m x1m transect, which is then combined to represent the litter density in each 1km-by-1km area. The overall city litter density is quantified for the city, along with the top items, categories, and brands.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Input

Thirty convenience or grocery stores were surveyed in central Dar es Salaam and Bonyokwa, three in each 1 by 1km area. In this section, data collection focused on identifying the FMCG source of these products. Seventy-four unique FMCG brands were identified: 33 beverages, 22 candies, 10 chips, and 9 tobacco products (Table 4.1). The popularity of the brands was determined by whether the brands were available in more than 50% of the stores surveyed. Thirty-six brands were identified as being popular in Dar es Salaam, 15 beverages, 9 candies, 5 chips, and 7 tobacco products. Of these popular brands, 15 have parent companies in Tanzania. Beverages had the most brands local to Tanzania, with 11 having parent companies in Tanzania. The other four are products of The Coca-Cola Company or PepsiCo, brands headquartered in the United States.

Table 4.1: Top FMCG Brands

Beverages	**African Fruit** **Afya** **Azam Cola** **Azam Embe** **Azam Energy** Coca Cola Fanta

	Hill Water **Masafi** Mirinda **Mo Xtra** Pepsi **Sayona Tunda** **U fresh** **Uhai**
Candy	Big Boom BIG G **Boom** Dairy Milk **Ivori** Mabuyuz Painter Snickers Dairy Milk
Chips	**Chama** Dorito Lays **Sayona Boom** Simba
Tobacco Products	Camel Crescent & Star Embassy Marlboro Gold SM Sportsman Winston

Note: Products in bold have parent companies in Tanzania

The manufacturing and parent company information for all 74 brands were recorded from the packaging and desktop research, any information not identified from the packaging. The location of the manufacturing and headquarters of parent companies was key as this information was used to estimate the distance in kilometers between the products' origin and Dar es Salaam, shown in Table 4.2.

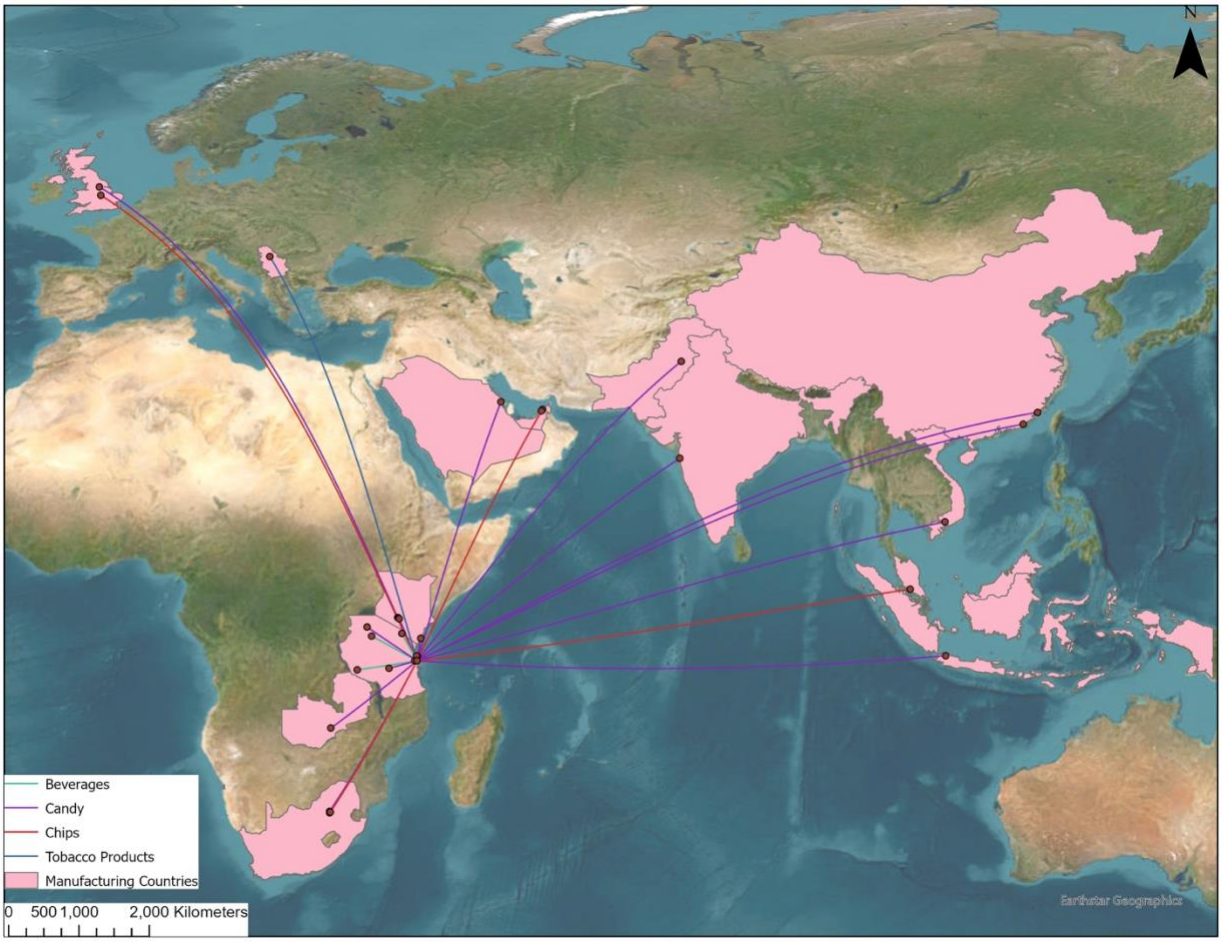
Table 4.2: Distances between Dar es Salaam and Manufacturers and Parent Company of Sampled Brands in Kilometers

	Length to Manufacturer (km)			Length to Parent Company (km)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Beverages	0	861	72	0	13,825	4,510
Candy	350	10,073	3,467	350	14,069	6,678
Chips	0	8,068	3,167	0	14,539	7,717
Tobacco Products	0	6,445	716	0	13,568	9,762

*Note: Distances were projected using an Azimuthal Equidistant projection, which can distort lengths at further distances. Manufacturer and parent company locations were approximated based on central coordinates for their city of residence. Values have been rounded to the nearest kilometer.

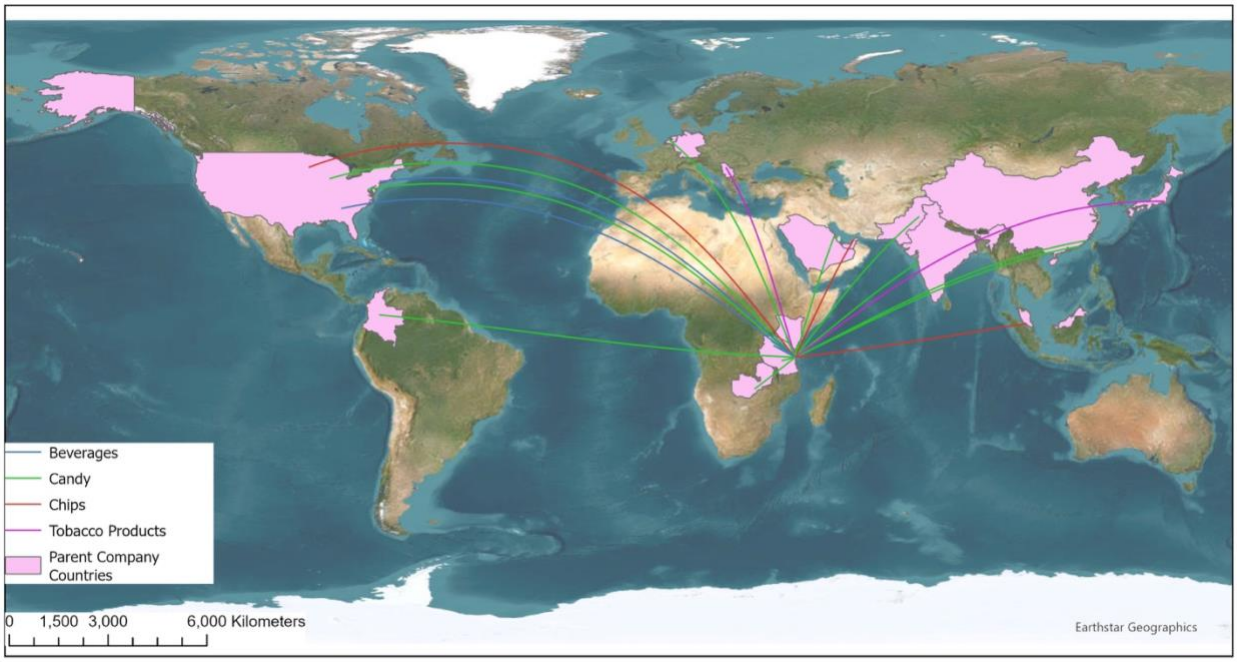
82% of the FMCG sampled are manufactured in Africa between Tanzania (62%), Kenya (12%), South Africa (7%), and Zambia (1%) (Figure 4.1). Of the products in Tanzania, 48% are manufactured in Dar es Salaam. The remaining products are manufactured in the United Kingdom, United Arab Emirates, Pakistan, India, China, Vietnam, Malaysia, Serbia, and Saudi Arabia. At least one product for beverages, chips, and tobacco products was manufactured in Dar es Salaam. Beverages travel the smallest distance compared to other products (Table 4.1), because 75% are manufactured in Dar es Salaam, and the remaining 25% is manufactured in Tanzania or Zanzibar. Having one category of FMCG that is completely manufactured in a country offers the Tanzanian government a unique opportunity to explore extended producer responsibility (EPR) legislation.

Figure 4.1: Manufacturing Locations for Products Surveyed



Only 46% of products are manufactured by parent companies based in Africa, compared to 82% manufactured there (Figures 4.1 and 4.2). About 39% of all brands' headquarters are based in Tanzania, with 76% of those located in Dar es Salaam. The United States is the headquarters for 28% of the products, with parent companies such as The Coca-Cola Company (Coca-Cola, Fanta, Sprite, Zenjy, Kilimanjaro, Schweppes, and Dasani), Pepsi Co (Pepsi, Mirinda, 7 Up, Mountain Dew, Sensation, Dorito, Lays, and Simba), Mars Inc. (BIG G, Juicy Fruit, PK, Snickers), Mondelez International (Dairy Milk), and General Mills Inc. (Bugles).

Figure 4.2: Parent Company Locations for Products Surveyed



4.2 Community

A total of 26 semi-structured interviews were conducted with seven different stakeholder groups to understand perceptions of plastic waste and solid waste management in Dar es Salaam. Interviewees include 7 Food Vendors, 1 Hotel, 4 Recyclers and Material Recovery Facility (MRF), 4 Private Waste Management, 4 Informal Waste Management, 3 Nonprofit Organizations, and 3 Government Officials (Table 4.3). The interviews were translated from Swahili to English and coded into the categories listed in Chapter 3. This spoke focuses on how community feels about plastic pollution and waste management. Not all quotes for the interviews are included in the spoke instead it's included in other CAP spokes when the information is pertinent.

Table 4.3: Summary of Interview Stakeholder List

Stakeholder Group	Number of Interviews
Food Vendors	7
Hotel	1
Recyclers and Material Recovery Facility	4
Private Waste Management	4
Informal Waste Management	4
Nonprofit Organizations	3
Government Officials	3

The consensus on plastic is that it is a significant problem in Dar es Salaam due to the harm it causes to the environment and living organisms. Plastic does not degrade; as such, it is ever-present in the environment, whether in its original form or as macro or microplastics. Its relentless presence in the environment raises concern among interviewees for soil and water health, as continual contamination can adversely affect humans. Interviews mentioned that plastic in the sewage system can become a breeding ground for mosquitoes that carry malaria and increase cholera. This is the result of plastic clogging drains that causes stagnant water. Plastic in drains can also eventually flow into the ocean. As a coastal city, plastic faces fewer barriers that could prevent it from reaching the sea. Plastic also poses safety risks, as dangerous sharp objects or chemicals can accumulate and injure an unsuspecting individual. Overall, interviewees were aware of plastic pollution in Dar es Salaam and its impact on the environment and the community's health and well-being.

> "… plastic pollution is a problem in our community because normally plastic, it takes time to decompose. Normally plastic affects not only human beings but all the living things which are living in the community and at the ocean." – NGO

When asked about policies, interviewees were most familiar with the nationwide ban on plastic bags that had passed in 2019. When discussing the ban, they specifically stated that banning plastic bags did away with black bags, but not all bags, as the law states. Some interviewees mentioned that due to the ban, different types of single-use bags are appearing now and are polluting the environment like the black bags once did. These new blue bags were mentioned to be used in markets for goods, such as rice, tomatoes, or meat. Like the black bags, the new blue bags are beginning to appear in the environment, raising concerns about their impact. Interviews did mention the availability of reusable bags and their positive impact on doing away with black bags, which is covered in more depth in Section 4.4.3.

> "If I recall back in 2019, the government announced a ban on the use of plastic bags, these black ones. But right now, there is another wave of other types of plastic bags that many people are using. We see them going to the markets, buying something, and using them to carry those items." – Private Waste Management

> "The biggest issue is the packaging. Packaging have now become the carrier bags. Instead of packing products like rice, nuts, vegetables or seeds, we have seen that it is being used more by people to carry. When someone goes to the market, tomatoes or fish is packed in

> the bag, then when they go to the butcher, they also put meat inside. They have a certain blue color. These are also single use. The biggest problem is that they are used once. Once used, they go into our environment. We have already started seeing their effects. If you walk in different places, in the estates, you see them floating around because they have no use, and no one is responsible for collecting them." – NGO

Product design, not only of bags but of bottles, was cited in interviews as an issue during waste collection for recycling. Key issues were the colored bottles and smaller packaging. There is reportedly no market for colored bottles in Dar es Salaam, so they are rejected by recyclers when the bottles are brought to them. One item cited was the black Mo-Xtra bottles. Since these colored bottles aren't collected, they remain in the streets and pollute the environment. One NGO mentioned that these colored bottles are routinely found during beach clean-ups. Additionally, smaller packaging and the labels on bottles aren't recycled due to the difficulty. Larger bottles (1.5L) and non-colored plastic were the preferred packaging mentioned by recyclers.

> "If it is colored bottles and there is no appetite, even massive campaign cannot help, you must phase it out completely. There is no way. Then with the same PET, you find that they have a lot of labels which are not recycled. It's not like 100% it's recycled, so you need to remove all that." – Recyclers and MRF

When asked what changes interviewees desire to see, many highlighted the importance of education. Topics of education they felt should be emphasized included: source separation of waste, promotion of plastic alternatives, effects of plastics, environmental conservation, and income opportunities from waste management. One NGO interview highlighted green school projects, which aided in educating the students about waste separation. Source separation and income opportunities were mentioned together because they could provide employment opportunities for youth and income for families. In Dar es Salaam, residents pay a refuse charge for collecting waste. One Recycler & MRF interview mentioned that if families learned to separate their waste at the source, they would pay the families for the materials. This could aid in garbage collection as the government and the private waste management interviewees mentioned that the payment of refuse charges is an issue. When individuals do not pay the refuse charge, the waste is not collected, resulting in illegal dumping, burying or burning of waste.

> "To see how people get the education to separate their waste. People sometimes do not focus on waste separation because it does not give them any benefit. But if in the family you inform the family that you will separate the waste, we will come to collect this waste, we will pay you." – Recyclers & MRF

Since Dar es Salaam is a coastal city, beach clean-ups were mentioned as a very common way for the community to help remove plastic from the environment. NGOs mentioned conducting community cleanups about eight times a year and others at least once every month. The predominant material found during the beach clean-ups is plastic items such as plastic

bottles, foam pieces, food wrappers, flip-flops, plastic straws, nylon, glass bottles, plastic lids, plastic cups, and colored bottles. Engagement in these volunteer opportunities is noted as moderate, but people are taking away insight into how to reduce plastic pollution, which is viewed as a positive by the NGOs. One barrier to getting more volunteers is parents' concern for their children engaging in the beach cleanup due to dangerous materials such as syringes, which require more protective gear for the volunteers. Beach cleanups allow community members to actively engage in removing waste from the environment. Still, it was mentioned in one Private Waste Management that beach cleanups can't remove microplastics from the sea, which is an issue of grave concern.

> "We talk about beach cleanup, but we see that beach cleanup is still not enough for the safety of the sea because we feel that there is a lot of waste, especially micro plastic, that goes directly to the sea. You then have to use a lot of resources to remove that waste, especially micro plastic, from the sea, which I think is the biggest problem." – Private Waste Management

4.3 Product Design

4.3.1 Convenience Items

Sixty-one FMCG plastic packaging items were sampled in the 30 stores surveyed in Dar es Salaam, including 28 beverages, 23 candies, and 10 chips. Typically, in CAPs, the average weight of the packaging is measured; however, this proved challenging with candy and chip

brands whose smaller packaging would weigh in at zero on the scale. More than thirty CAPs have been conducted across cities in the United States (US), and the Circularity Informatics Lab at UGA has generated an expansive database of products' weight and packaging weight. To understand why the weights were repeatedly weighed in at zero, the results from the CAP in Dar es Salaam were compared to the product database at the Circularity Informatics Lab. It was found that the average product weight of US chip and candy products is much higher compared to Dar es Salaam. 350 different chip products have been sampled overall, and the average product weight is 83.0 g, with an average packaging weight of 5.06g. The ratio of chip product weight to packaging weight in the US is 16.3. The average chip product weight in Dar es Salaam is 20.6 g; thus, products in Dar es Salaam are 62.3 g less than products in the US. Also, the estimated average weight of chip packaging in Dar es Salaam based on the US ratio is 1.26 g. Similarly, 656 candy products have been sampled in the US, and the average product weight is 62.2 g, with an average packaging weight of 7.84 g. The ratio of product weight to packaging weight is 7.93. The average candy product weight in Dar es Salaam is 12.5, which would have an estimated average weight of 1.58 g. It should be noted that some candy brands in the US include toys and figurines or hard plastic for packaging, increasing the weight. Most candy packaging in Dar es Salaam is multi-layer film/film (Figure 4.3), a much lighter type of plastic, which means the actual weight of candy packaging in Dar es Salaam could be less than 1.58 g. Overall, Dar es Salaam offers smaller quantities of candy and chips than the US, resulting in smaller packaging. Examples of the packaging are shown in Figure 4.3. This smaller packaging means that to buy the same quantity, one must buy more items and collect more of the smaller packaging. To consume the same amount in the US, one would need to buy four chips or five candy packages.

This lighter packaging can also make it easier for these products to leak as they can blow off collection trucks or out of trash cans.

Only the weight of beverage packaging weight was surveyed for this CAP. The average weight of the beverage product is 718 mL, and the average weight of the packaging is 23.2 g. The ratio of product weight to packaging weight is 31.0.

Table 4.4: Average weight of plastic packaging for fast-moving consumer goods

	Country	Beverages	Candy	Chips
Number of Samples	US	424	656	350
	Tanzania	34	23	10
Average Weight of Packaging (g)	US	33.9	7.84	5.06
	Tanzania	23.2	Packaging too small to get weight	Packaging too small to get weight
Average Weight of Product (g or mL)	US	510	62.2	83.0
	Tanzania	718	12.5	20.6
Ratio of Product Weight to Packaging (# g or mL to 1 g)	US	15.0	7.93	16.3
	Tanzania	31.0	Packaging too small to get weight	Packaging too small to get weight

Note: Units rounded to three significant figures

Figure 4.3: Samples of Convenience items

(a) Chips

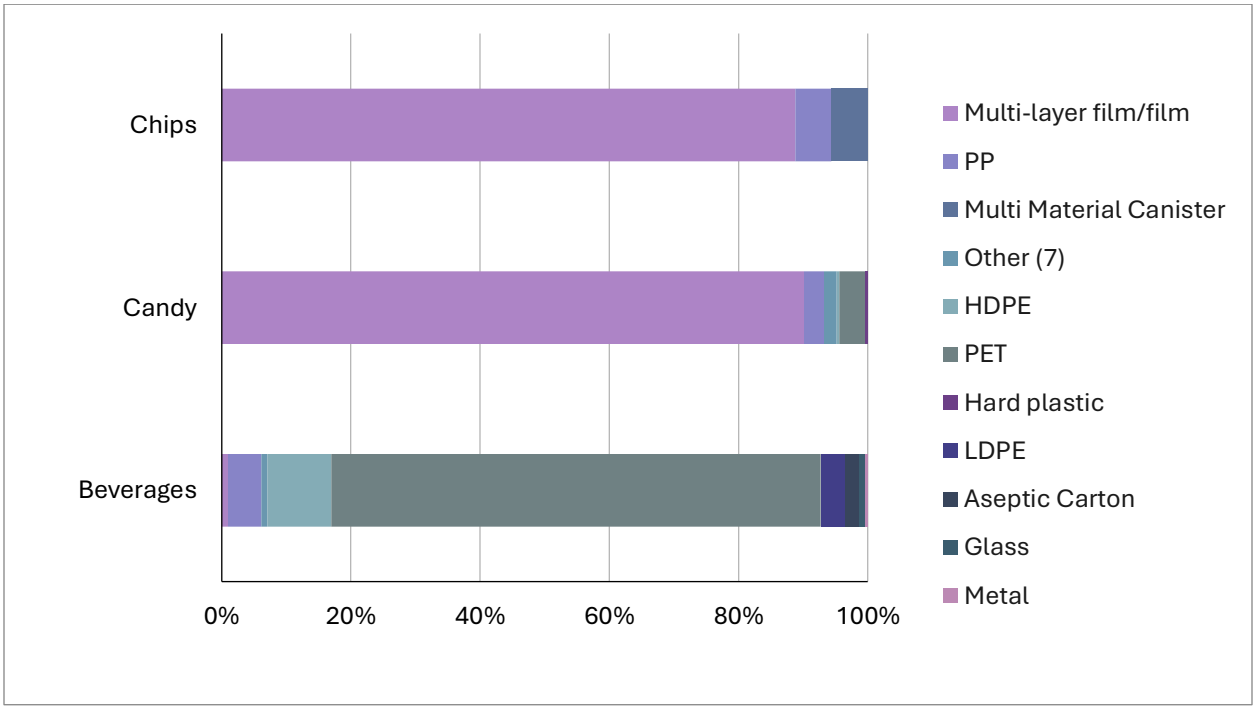
(b) Candy

(c) Beverages

Source: Survey

The packaging material of all FMCG and staple items is sampled through visual surveys and can include non-plastic products. The overall material in both Bonyokwa and the 10x10km Dar es Salaam central area is shown in Figure 4.4. The figure shows that the leading packaging material is multi-layer film/film (84.15% for chips and 85.59% for candy) and PET (76.6% for beverages). Non-plastic materials such as glass and aluminum make up a tiny percentage of the available material, 1%, and 0.33%, respectively. Thus, there is limited choice in packaging material for consumers in Dar es Salaam.

Figure 4.4: Overall Material Breakdown of Convenience Items in Dar es Salaam



Figures 4.5 and 4.6 represent the separate material breakdown of convenience items between central Dar es Salaam and Bonyokwa. Bonyokwa has a limited availability of items

compared to central Dar es Salaam. Additionally, no glass, aluminum, or aseptic cartons were surveyed in the three stores in Bonyokwa.

Figure 4.5: Dar es Salaam (10x10km) Material Breakdown of Convenience Items

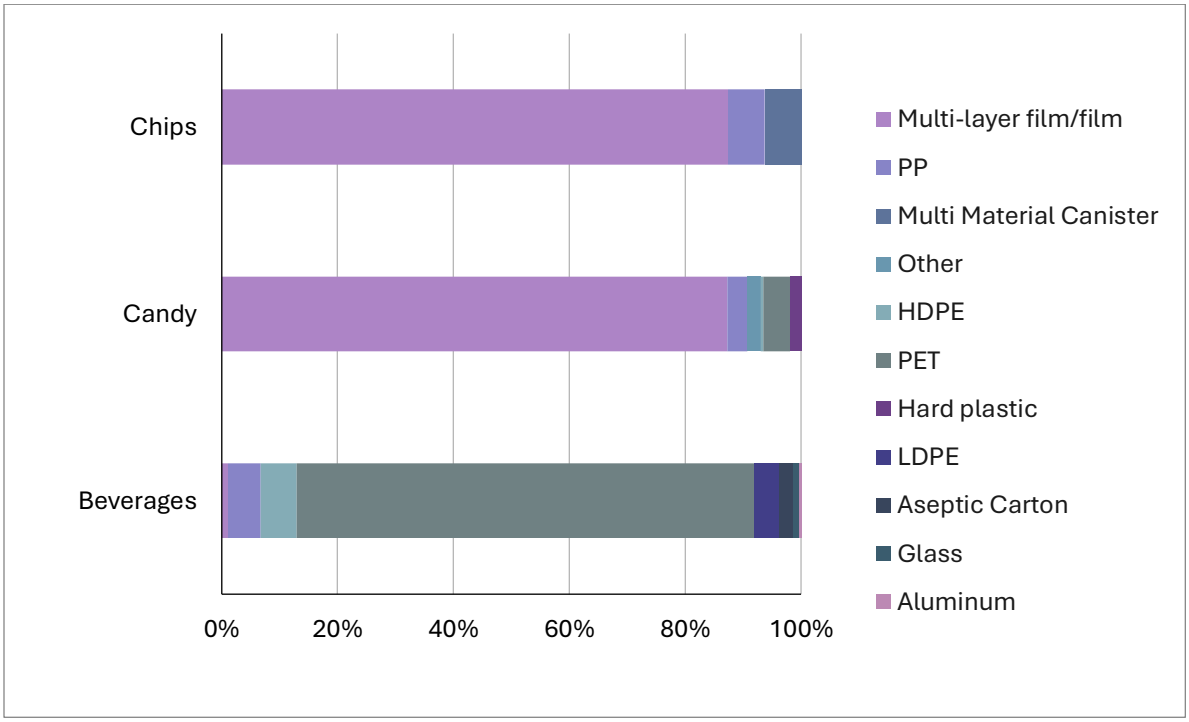
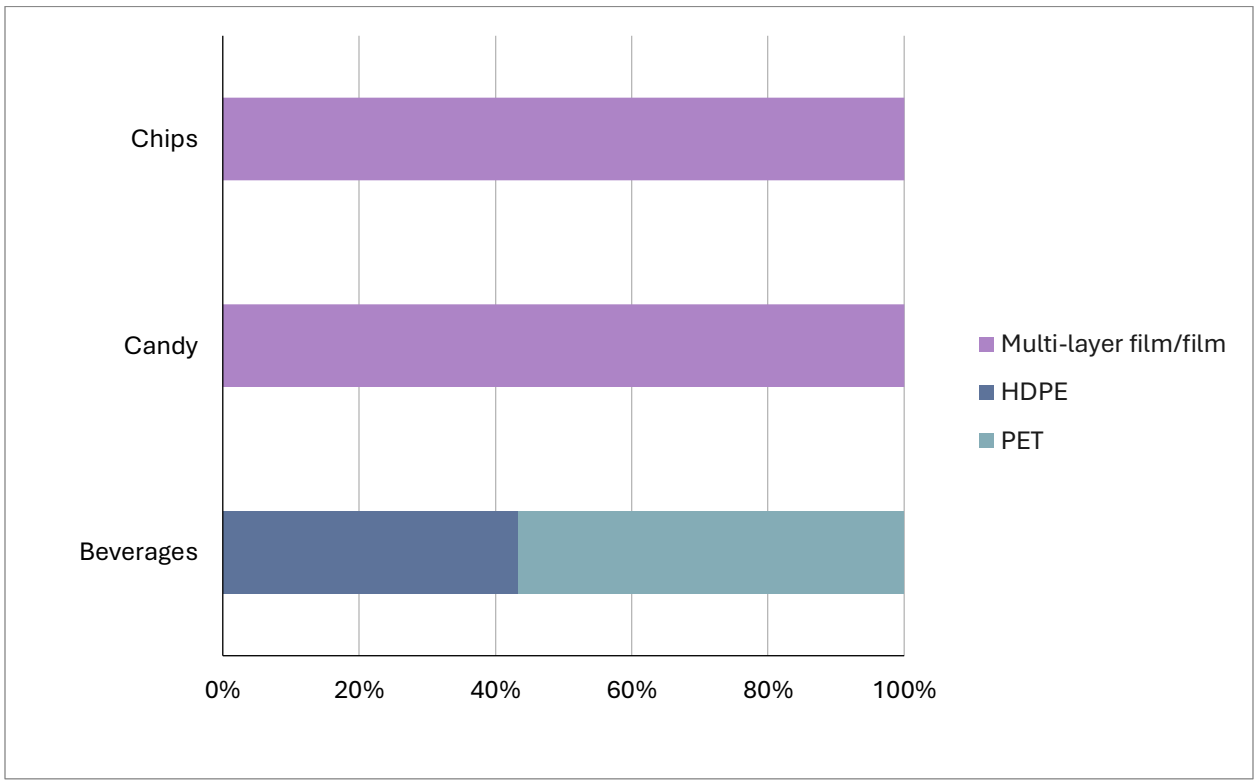


Figure 4.6: Bonyokwa Material Breakdown of Convenience Items



4.3.2 Staple Packaging

The packaging of staple items, specifically rice, oil, flour, laundry detergent, shampoo, and tomato sauce, was surveyed in the 30 stores. Figure 4.7 shows the overall material breakdown for all thirty stores surveyed (three in each 1 by 1 km area). Plastic packaging is the primary packaging material, with paper/paperboard being the only non-plastic packaging material observed at 1.39%.

Figure 4.7: Overall Material Breakdown of Staple Items in Dar es Salaam (10x10km) and Bonyokwa

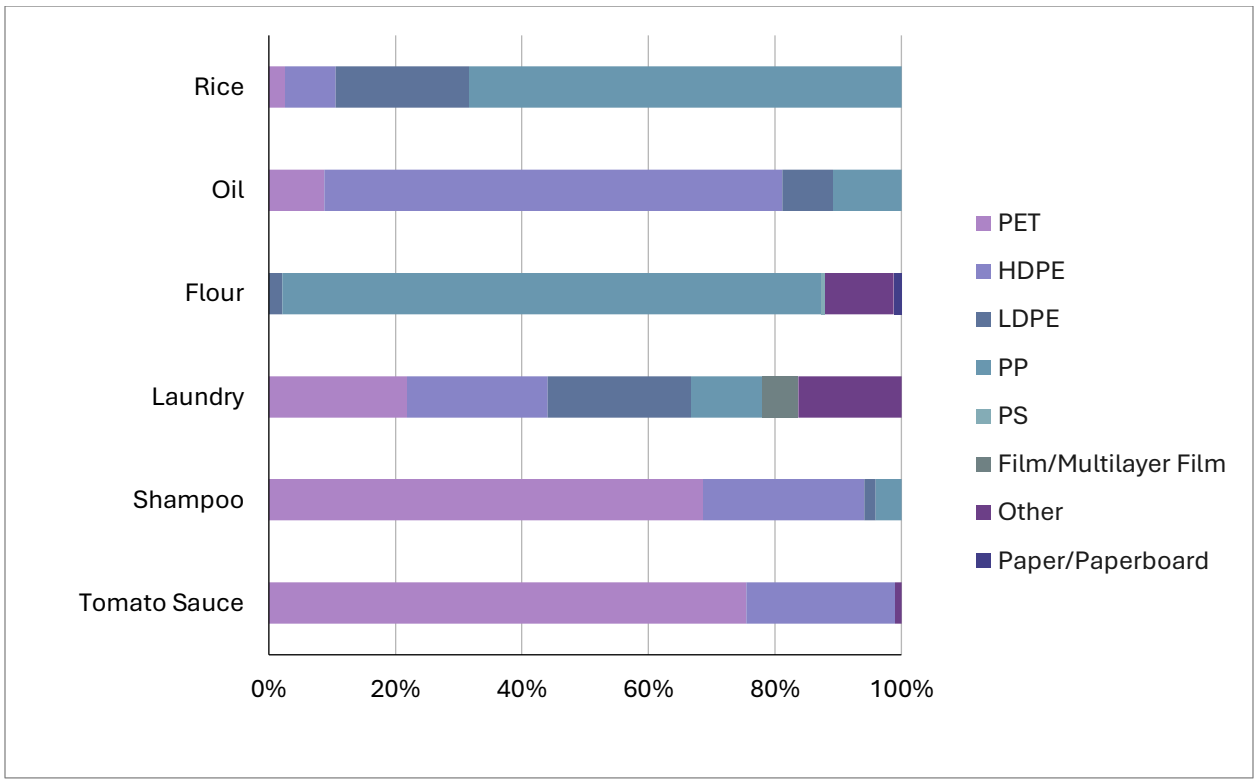


Figure 4.8: Dar es Salaam (10x10km) Material Breakdown of Staple Items

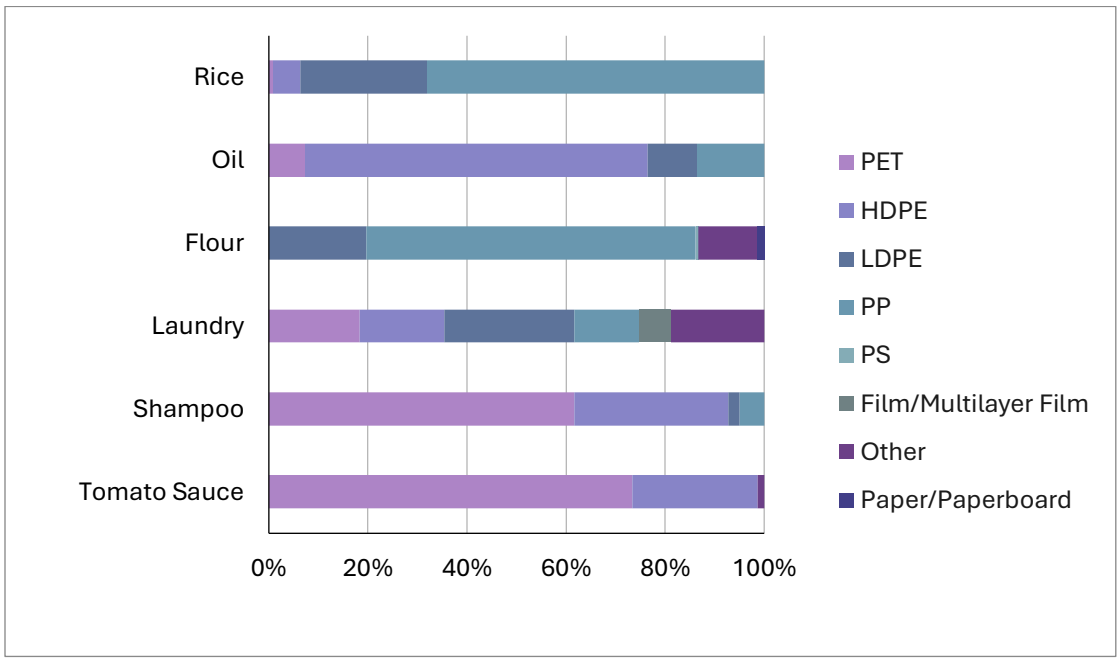
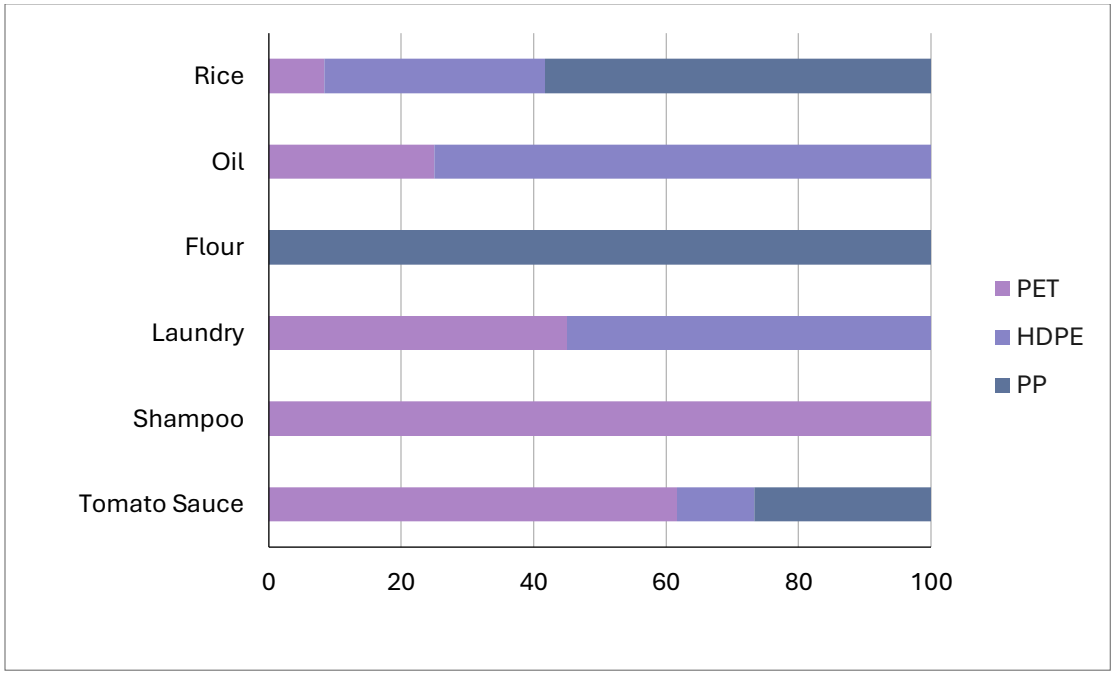


Figure 4.9: Bonyokwa Material Breakdown of Staple Items



4.3.4 Restaurant Packaging

All 30 stores between central Dar es Salaam and Bonyokwa were surveyed to identify the materials of to-go items, specifically utensils, straws, cold cups, and food containers. Restaurants were also surveyed to determine the availability of in-house reusable items. Twenty-nine out of 30 restaurants offered reusable utensils, plates, bowls, or cups (Figure 4.10). Cups were identified in 27 of the restaurants, and 25 were reusable. Plates or bowls were identified in 22 of 24 restaurants as reusable in-house. Straws were provided in 23 restaurants, but 22 were not reusable. Utensils were only identified in 6 of the restaurants. The limited availability of utensils may be because Tanzanians traditionally eat with their hands (Tanzanianspecialist.com, 2024).

Figure 4.10: In-House Tableware

Source: Survey

Table 4.5 lists all the materials for to-go items in the 30 restaurants. The table also identifies whether the material is single use or reusable. All items, except food containers, were single-use items. Only five to-go utensils were identified and were less available than the others. These items are also predominantly plastic, with one paper/paperboard cold cup. When possible, the to-go item's brand is noted. Straw brands and materials were identified because food vendors allowed surveyors access to the package in which the straws came in, which included the specific plastic type. Typically, this information is unavailable on the straw and is assumed to be unlabeled hard plastic. Common straw brands identified are Twiga Hygienic Drinking Straw (4), Imperial Packaging Ltd (11), Hotpack (2) and 4 Season (4). Twiga and Imperial are local companies, while Hotpack is made in the United Arab Emirates and 4 Season in China.

Table 4.5: Material of To-go Items

	Material	Single-Use	Reusable
Straw	PET	1	0
	PP	20	0
	PS	2	0
Utensils	Hard Plastic (unlabeled)	1	0
	PP	4	0
Cold Cups	Paper/paperboard	1	0
	PET	7	0
	PP	6	0
	PS	1	0
Food-container(s) for entrees including if (if applicable)	Aluminum	3	0
	HDPE	4	6
	Paper/paperboard	1	0
	PET	1	0
	PP	3	9

Source: Survey

CAPs typically survey whether compostable to-go containers are available, but Nipe Fagio quickly found that some restaurants offered a return option for reusable to-go containers and no compostable containers. Of the 30 restaurants surveyed, 15 offered a reusable to-go container, six made of HDPE, and nine made of PP (Figure 4.11). The availability of reusable food containers is a circular system, and users can return the containers to the vendor. Efforts were made to interview the owners of these restaurants to understand how the reusable to-go containers work; two restaurant owners agreed to be interviewed. Both interviews mentioned that the reusable containers were for regular customers who lived in the community, and they knew would return the container to them. Customers who didn't live in the community would be offered single-use containers. One interview mentioned that some customers even bring their own containers instead of the single use or reusable containers the restaurant offers. Lastly, one interview mentioned that the reusable containers come at a higher cost than the SUP containers. The interviewee did not elaborate on the reason why the containers may be charged more, but in typical reuse or deposit-return schemes customers are charged a higher upfront cost also known as deposit which is returned once the item is returned. This is most likely due to the higher replacement cost associated with these cases.

> "Regarding containers, as mentioned earlier, we use different utensils. There are strong plastic ones, and we also use metallic containers. Some plastic containers are reusable, and we specifically use these for our regular customers, especially those we are familiar with and deliver to, such as clients in nearby offices. We send the food in those containers, and they return them for reuse. However, other customers are just passing by,

what we call walk-in or one-time customers. For them, we use non-reusable containers. Once we give it to them, they take the food and continue their journey, marking the end of the container's use." – Food Vendor

Figure 4.11: Reusable To-Go Containers

Source: Survey

4.4 Use

4.4.1 Alternatives Available

During store surveys, alternatives to SUP packaging are observed. These items can include alternative materials, such as glass, metal, or compostable packaging, as well as items categorized as refillable, reusable, or bulk items. In central Dar es Salaam and Bonyokwa, 60% of the 30 stores surveyed had an alternative available, and 24 unique items were identified in

three product types: beverage bottles, hand soap, and laundry detergent (Table 4.6). In Bonyokwa, two stores surveyed were noted as having alternatives available.

Table 4.6: Alternatives Available in Dar es Salaam

	Beverage Bottles		**Hand Soap**	**Laundry Detergent**	
Use Type	Refillable		Refillable	Bulk	
Packaging Material	Glass	PET	HDPE	PET	PP
Products Observed	6	7	2	1	8
Average Alternative Quantity (g, ml, loads, or unit)	8,400	16,500	2,650	5,000	3,250
Average Alternative Price (TSH)	12,500	5,800	11,500	10,000	13,625
Average Alternative Price (USD)	4.73	2.20	4.35	3.79	5.16
Average SUP Quantity	600	3,100	375	250	360
Average SUP Price (TSH)	1,000	2,012	1,750	1,000	962.5
Average SUP Price (USD)	0.38	0.76	0.66	0.38	0.36
Average Cost Difference (- cheaper, + more expensive)	-64.29%	-391.54%	+16.67%	-50.00%	+346.81%

Conversion rate: 2,641.83 TSH to 1 USD

Source: Survey

The most readily available alternative was the beverage bottle. They were glass bottles and the large PET water bottles placed on top of dispensers (Figure 4.12). The glass bottles could be bought individually or in a plastic crate with 24 bottles for 12,000 to 13,000 TSH (4.54 or 4.92 USD). When the crate is returned with all bottles, a new crate can be purchased again at a discounted rate. These glass bottles are then sent back to be refilled. This refillable system creates a circular economy by disposing of SUP bottles. The average cost difference is based on the cost/unit of each item. The average cost difference for the glass bottles is 64.29% cheaper than the SUP bottles. Even though it is more affordable in the long run, the upfront cost of purchasing these bottles can be more complex than the upfront cost of the SUP bottle. Similarly, the refillable water containers are 391.54% cheaper. However, this does not include the cost of purchasing the water dispenser. When these containers are full, they can be very heavy, making them difficult to transport. The promotion of the larger drinking water jugs and reusable water bottles was mentioned during interviews as an alternative to the SUP bottles.

> "For example, once we use the alternative way of drinking water instead of using that of bottle, people they prefer more to use bottles but there are alternative of buying the large water and using glass to drink instead of using this bottle. This can be alternative, but the challenge is the people in the community to change it from using the small bottles to use the glass in drinking water." – Recyclers and MRF

Figure 4.12: Example Refillable Beverages

Source: Survey

Lastly, single-use plastic is a recent development in Africa, and previously it was customary to use reusable items. The Global Alliance for Incinerator Alternatives (GAIA) and Break Free From Plastic report, Life Before Plastic, Demonstrating Traditional Practices of Reuse in Africa highlights various local and cultural reusable practices in Africa (Naidoo et al., 2024). Five traditional alternatives and practices were identified in Tanzania:

1. Raffia, reed, sisal, and dried palm leaves to make baskets, mats, seats, beds, roofs, and umbrellas
2. Calabash and gourds used for liquid and food containers
3. Cloth and fabrics used to make reusable bags, diapers, and menstruation pads
4. Drying and fermenting vegetables and meats to extend shelf life

5. Wood and clay for kitchen utensils, décor and containers

Today, many of these traditional alternatives have been replaced by SUP. One interview highlighted the shift away from these traditional practices in favor of plastics that are more extractive and harmful to the environment.

> "However, managing it is challenging due to the recent surge in plastic usage. We can remember that in the past, the use of plastic was minimal, as people used to rely on one durable item. In the past, when you went to the store, you would carry a basket, pick your items, and come home. You used long-lasting items, and even if they wore out, they didn't have such a negative impact on the community. So now, plastic use has surged, creating problems due to its large-scale production and the numerous sources contributing to it. The solution to this is to stop the production of plastic from these sources and return to how things were in the past when everything was well-managed." – Recyclers and MRF

4.4.2 Repacking

Store surveys also look for repacking items from a larger bag into a smaller SUP packaging. 70% of the stores surveyed were found to repack in Dar es Salaam. A primary case of repacking in Dar es Salaam was weighing rice from large bags (Figure 4.13) into smaller LDPE bags (Figure 4.14 (a)). This system of large quantities of rice and weighing the exact amount of rice a customer requests provides a foundation for developing the circular economy in Dar es Salaam. If customers brought an existing container and used that instead, the need for the SUP repacking bags would be eliminated.

Figure 4.13: Bags of rice that are repackaged into smaller plastic bags

Source: Survey

4.4.3 Bags Available

Store surveys also look at the primary material of bags available, and if any alternatives to SUP bags are available. The most common material for a bag was LDPE, shown in Figure 4.14 (a), and cost 40 or 50 TSH (0.015 or 0.019 USD). Tanzania banned all plastic bags regardless of thickness; however, the survey found that SUP bags are still prevalent, as the LDPE bags were identified in all stores surveyed. All stores also offered reusable bag materials made of PP, as shown in Figure 4.14 (b), and cost 200 or 300 TSH (0.08 or 0.11 USD). Paper bags were also found in the surveys at no additional cost. The availability of alternative bags was mentioned during the interviews as an essential tool in implementing the 2019 ban on plastic bags, and many responded positively by actively reusing the bags. However, in two NGO interviews, the higher cost of the bag was cited as being difficult for people to afford, and as such, they will purchase the SUP LDPE bag.

Figure 4.14: Bags surveyed in Dar es Salaam

(a) Most Common Bag Material (b) Reusable Bag Material

Source: Survey

4.5 Collection and End-of-Cycle

Waste generation in Dar es Salaam ranges from 0.8 to 1.0 kg/cap/day (DCC, 2016). Based on the estimated 2024 population of 8.2 million, Dar es Salaam generates between 6,560 and 8,200 tons/day. In eight years, waste generation in Dar es Salaam has increased by 1,260 tons/day to 2,900 tons/day at a rate of 157.5 tons/day to 362.5 tons/day each year. This rate is higher than the estimated 80 tons/day a year from 2006 to 2017, which estimated that by 2031 Dar es Salaam would generate 6,400 tons/day (Kazuva & Zhang, 2019). Waste generation rates vary, but waste generation is increasing in Dar es Salaam, so infrastructure must keep up to manage the accelerating waste generation. In Dar es Salaam, waste collection is performed by the municipalities, the private sector, community-based organizations (CBOs), and the informal sector. Combined, these entities collect 40% of the waste in Dar es Salaam; the remaining 60% is

illegally dumped, buried, or burned (URT, 2018). Based on the estimated generation rate 3,936 to 5,166 tons/day of waste remains uncollected.

Tanzania and Dar es Salaam are making efforts to address the SWM challenges with the 2018 National Solid Waste Management Strategy and the Dar es Salaam City Master Plan 2016 to 2036. The last Dar es Salaam Master Plan was created in 1979. Since then, the city has undergone various changes that warrant a new Master Plan to address the city's evolution. In the new Master Plan SWM was identified as one of eight priority environmental issues along with informal settlements, urban renewal, traffic congestion, conflicts and air issues (DCC, 2016). The plan also addressed the need to increase recycling and composting to reduce the amount of waste transported to the Pugu dumpsite. The 2018 National Solid Waste Management Strategy aimed at promoting a sustainable and clean environment by 2025. The plan predominantly focused on Dar es Salaam but viewed the strategy and methods applicable to other cities in Tanzania since they faced similar issues. The strategy's main goals include waste minimization, maximizing the economic value of waste, promoting reuse and recycling, establishing proper disposal facilities, and maximizing waste collection (URT, 2018). A long-term goal of the strategy is to achieve 80% waste recovery by 2030, which includes reuse, recycling, composting, and energy recovery.

During litter data collection, the Marine Debris Tracker App is used to identify the availability of SWM infrastructure, such as waste and recycling bins. Only one waste bin was available in all 30 litter transects. This indicates a lack of access to waste disposal while people move around the city.

4.5.1 Collection: Private Companies

Before the establishment of public-private partnership (PPP) in 1995, waste was collected by the government. Today, waste is predominantly collected by the private sector, which includes private companies, NGOs, and community-based organizations (CBOs). The government still aids in collection, but at a smaller scale. The addition of private companies was to aid in increasing waste collection. In 1991, only 5% of the 1,400 tonnes of waste generated daily was collected, reportedly increasing to 48% of the 2,500 tonnes of waste generated in 2005 (Kassim & Ali, 2006). However, the most recent collection rate is 40%, indicating that while generation has increased, overall collection has not.

Dar es Salaam has five municipalities: Kinondoni, Temeke, Ubungo, Ilala, and Kigamboni. Each municipality is responsible for creating its own by-laws and refuse collection charges. Additionally, each ward can establish rules and select its provider for waste management. Before 2016, there were 73 wards, but with the addition of Kigamboni and Ubungo, it increased to 102. In 2010, the Dar es Salaam City Council identified that private companies serviced 44 out of the 73 wards (60%), and 23 private companies were registered. Some private companies will service more than one ward, hence the fewer companies than wards serviced. With 102 wards, if 60% are still covered, then 61 out of 102 wards have access to waste collection. Kirama and Mayo (2016) identified 49 private companies: 15 in Ilala, 23 in Temeke, and 11 in Kinondoni. A more up-to-date number of companies and the ward coverage area could not be determined from desktop research, literature, or interviews. As previously mentioned, more than 70% of Dar es Salaam settlements are unplanned, creating narrower passageways that make it difficult for companies to collect waste. That is why private companies prefer high-

income areas; they are planned resulting in more space for the necessary equipment to transport the waste (Kirama & Mayo, 2016).

Private companies operate based on contracts with a municipality or ward. These contracts last 1 to 2 years and must be renewed for companies to continue operating in their respective areas. Kirama and Mayo (2016) through interviews with 20 private sector companies, identified that 65% of the companies had one-year contracts. These shorter durations make it difficult for companies to finance their business through loans, credits, and bonds as there is the risk of the contract not being renewed. In addition to the short durations, these contracts are typically ambiguous and lack essential details including (Kirama & Mayo, 2016): excluded environmental requirements (enclosed truck bodies for the delivery of waste to the Pugu dumpsite); health and safety requirements (protective gear: gloves, respiratory protection, boots, and uniforms); and Refuse Collection Charge details not included (collection method, place, amount, timing, and sanctions against late or non-payment). Mpuya and Munishi (2024) conducted 41 interviews, 36 interviews with individuals from 16 private companies and informal groups, and five interviews with ward executives. Similar to Kirama and Mayo (2016), these interviews identified challenges with the contracts that create challenges for the private companies in implementing new technology to effectively manage the waste (Table 4.7).

Table 4.7: Current challenges for private companies in Dar es Salaam

Lack of Decision Making	• Lack of participation from all stakeholders in the decision-making process • Interview companies said communication from the government about when important decisions regarding SWM was discussed or clarified was improper • Government notifies via call and text messages and viewed lack of participation was due to unwillingness from the company • Results in continual status quo of sending all waste to the landfills, even though there is a high amount of recyclables in the waste
Limited emphasis on sorting, reuse, recycling, and recovery	• Disconnect between engagement strategies and these sustainable SWM practices • Local authorities priorities SW collection and transportation was reported by all 16 private sector entities
Inefficiencies in Solid Waste Management Contracts	• Contracts are limiting and prioritize collection and disposal ○ Do not mention recycling or waste recovery • Limited to one- or two-year renewable terms • Prevalence of short-term contracts hampers the private sector's ability to invest in the technology and infrastructure required for effective waste management

Source: (Mpuya & Munishi, 2024)

Overall, the short duration of the contracts, lack of involvement during the decision-making process, and more focus on disposal have limited the company's capabilities to invest in necessary technology or expand sustainable waste management practices.

The existing infrastructure determines the collection methods and equipment utilized by the companies. Common methods include door-to-door collection or a common collection point, which are more common in areas with narrower passageways. In a 2005 survey of 300 households across the three municipalities, 57% said collection is done door-to-door, 13% use a common collection point, and 30% did not receive any services (Kassim & Ali, 2006). Kirama

and Mayo (2016) found 80% of the service providers utilized door-to-door collection only. Collection and transportation of waste is typically done between 7:00 am to 8:00 pm. The Pugu dumpsite is 30 km from the city center and traffic congestion can impact the collection efficiency and transportation costs. That is why 30% of private companies identified that they collect waste daily, whereas 70% collect waste 2 to 4 times a week (Kassim & Ali, 2006).

Kamugisha et al. (2019) identified that in Kinondoni the equipment available for collection included 28 trucks, six tractors, three trailers, 69 pushcarts, and 127 wheelbarrows, which can collect 42.2% of the solid waste generated in Kinondoni. The 2018 National Solid Waste Management Strategy identified the required equipment to collect 3,000 tons (Table 4.8). The values were modified to include Kigamboni and Ubungo since the original table did not include these municipalities. Key assumptions include that any equipment that required 10 or less was kept the same and that the values above were modified based on the percentage of land that Kinondoni and Temeke lost when the new municipalities Ubungo and Kigamboni were established. The greater values were not assumed to be the same because the area served and the populations have changed. This will most likely result in a less accurate representation of what each municipality requires, but the aim was not to overestimate the necessary equipment. Also, the carrying capacity of each piece of equipment was not given. To estimate the new collection value, 3,000 tons/day was divided by the total original number of equipment, 918. It's estimated that the equipment listed in Table 4.8 could collect 3,300 tons/day. Which, based on the estimated 6,560 tons/day generated in 2024, would increase collection to 50%. This equipment does not account for pushcarts or wheelbarrows currently used to collect waste; instead, it

focuses on much larger equipment that will have difficulty collecting waste from the informal settlements.

Table 4.8: Modified Equipment Required from the National Solid Waste Management Strategy

	Dar es Salaam CC	**Ilala MC**	**Kinondoni MC**	**Temeke MC**	**Ubungo MC**	**Kigamboni MC**
Wheel Loader	1	1	1	1	1	1
Open Truck	5	10	10	10	10	10
Semi-Trailers	0	4	4	4	4	4
Skip Loaders	0	20	12	4	13	16
Skip Containers	0	230	125	45	125	175
Compactor Trucks	2	10	10	10	10	10
Street Sweepers	0	4	4	4	4	4

Cesspit Emptier	0	4	4	4	4	4
Gully emptying trucks	0	2	2	2	2	2
Water Boozers	1	2	2	2	2	2
Computer and accessories sets	0	3	3	3	3	3
Supervision car	1	3	3	3	3	3
Tractors	0	4	4	4	4	4
Excavator	1	0	0	0	0	0
Dump-Bulldozer	1	0	0	0	0	0

Modified from: (Bubegwa, 2012)

4.5.2 Collection: Refuse Collection Charges

In Dar es Salaam, refuse collection charges (RCC) were introduced alongside the privatization of waste management. Each household or business pays RCC's based on the municipalities and wards designated high-, middle-, or low-income levels. Wards can also

negotiate with the contracted companies for a lower rate. Table 4.9 identifies some RCC's reported in the literature. Desktop research was unable to identify RCC's from the municipalities or wards.

Table 4.9: Refuse Collection Charges

	Currency	(Kassim & Ali, 2006)			(Kirama & Mayo, 2016)			(Omar, 2020b)
		Low Income	Middle Income	High Income	Low Income	Middle Income	High Income	High Income
Ilala	TSH	700	1000	2000	500	1000-2000	NA	10,000 – 15,000
	USD	0.26	0.38	0.76	0.19	0.38 – 0.76	NA	3.79 – 5.68
Temeke	TSH	200 - 500	1000	NA	NA	NA	NA	NA
	USD	0.08 – 0.19	0.38	NA	NA	NA	NA	NA
Kinondoni	TSH	1000	2000	3000	5000	10,000	15,000	NA
	USD	0.38	0.76	1.14	1.89	3.79	5.68	NA
Ubungo	NA	NA	NA	NA	NA	NA	NA	NA
Kigamboni	NA	NA	NA	NA	NA	NA	NA	NA

Conversion rate: 2,641.83 TSH to 1 USD

Interviews stated that RCCs can start as low as 3,000 to 5,000 TSH (1.14 or 1.89 USD) for low-income areas and can go up to 10,000 to 15,000 TSH (3.79 or 5.68 USD) for high-income regions. Additionally, businesses will pay a different rate, as one interviewee mentioned restaurants paying 250,00 TSH (94.63 USD).

Inadequate collection of RCC's is a significant hindrance to private companies, resulting in higher expenditures than the revenue. In 2006, the collection in high-income areas was 80% while low-income areas were 50% (Kassim & Ali, 2006). In 2016, the overall collection of RCC in Dar es Salaam was 55% (Kirama & Mayo, 2016). Private companies must pay a percentage of

the RCC to the municipality, in Kinondoni it's 10-15% (Kirama & Mayo, 2016) and in Ilala it is 20% (Omar, 2020b). RCCs are not included in other utilities such as water or electricity; they are collected by hand at the end of each month via door-to-door collection (Omar, 2020a). This method creates challenges such as individuals not being home when RCC collection is conducted, failure to provide notice of price changes, and inadequate billing history (Omar, 2020a).

As mentioned in Section 4.5.2, private company contracts last 1-2 years. This limited time frame also limits companies from investing in necessary equipment. Pellatt and Palfreman (2023) worked with Green WastePro Ltd. in Mchafukoge and Kisutu wards, located in the downtown area of Dar es Salaam, to implement Smart-TRAC for RCC collection from 2019 to 2021. Implementation of Smart-TRAC saw an increase in RCC collection, but Green WastePro Ltd.'s contract was not renewed, and consequently, progress was lost. The promotion of RCC collection via technology would help address issues discussed in Omar (2020a).

Overall, RCCs finance waste collection in Dar es Salaam, but poor collection of these fees impacts private companies and the environment. Interviewees in Private Waste Management mentioned that it can be a challenge to collect the RCCs, and residents will resort to improper waste management. Omar (2020b) reported that some residents give the waste to an informal collector who disposes of it in unauthorized locations. One Private Waste Management interview indicated that it was still occurring.

> "You know when a citizen provides a service, at the end of the day they have to pay a waste fee. Now this is a difficult thing that we have been facing. Some say that they do

> not produce waste, and they do not have to pay a waste fee. But at the end of the day, the waste that they produce, they give to other people who we call-- some people collect waste from the streets, they give it to them, and then they go and throw it in places that they know." – Private Waste Management

4.5.3 Collection: Informal Waste Sector

Globally, 2 billion people earn their livelihood through the informal economy (ILO, 2018). In Dar es Salaam, the informal sector is crucial in collecting waste and recyclable materials not collected from the private sector. Waste pickers are often disrespected and devalued by the community, but they play a vital role in waste management. Waste pickers also put their health at risk by coming into contact with improperly managed waste every day. Their part in SWM in Dar es Salaam was included in the National Solid Waste Management Strategy, and their role in collecting recyclables was identified. The strategy also mentioned upscaling the informal sector to establish relationships with recyclers but didn't provide steps on how to do so. Nipe Fagio in collaboration with the Taka Ni Ajira Foundation has utilized the Zaidi App to register over 3,390 waste pickers in Dar es Salaam (Nipe Fagio, 2024a). Nipe Fagio also worked on establishing the Tanzania Waste Pickers Association (TAWAPA) which was announced in July 2024 during the Global Alliance for Incinerator Alternatives (GAIA) Annual International Zero Waste Cities Conference (Nipe Fagio, 2024b). The goal of TAWAPA is to advocate for waste pickers' rights and ensure that they are represented in local and national policy.

Waste pickers collect the majority of the recycling in Dar es Salaam. As mentioned in Section 4.5.1, private companies predominantly focus on collecting waste for disposal at the

Pugu landfill. In addition to the 3,390 waste pickers registered by Nipe Fagio there are an additional 450-600 waste pickers at the Pugu landfill collecting recyclable material (Yhdego, 2017). Waste pickers also collect recyclable material from the streets.

> "For now, community they did not pay anything for recycling. Those waste pickers, they collect it on the street and then they're going to sell to those formal industries. In a very small amount, they sell them to them. Of course, recycling is, you cannot compare recycling and dumping. You say dumping, because recycling, you use the waste. Waste becomes another product so you get the profit." - Government

Waste pickers see value in the materials they collect. As mentioned in Section 4.2, the black plastics were identified as having very low value compared to the colorless or clear plastics. Four interviews reported the price they pay waste pickers for the recyclable material they collect (Table 4.10). One kilo of the black plastic bottles pays a waste picker 50 TSH (0.019 USD) compared to clear plastic that pays 400 to 450 TSH (0.15 to 0.17 USD). Waste Pickers walk 10-15 kilometers daily over 8-12 hours while carrying 5-7 kilograms per trip in Dar es Salaam (Palfreman, 2015). All the material they recover is collected in a long plastic bag. If waste pickers only collected black plastic, they'd earn 250 to 350 TSH (0.09 to 0.13 USD) in one trip compared to 2,000 to 3,150 TSH (0.76 to 1.19 USD) that they'd earn collecting clear plastic bottles. Essentially, waste pickers would collect the same amount of product but be paid a lower price. In one trip, waste pickers would earn about 10x less if they had only collected black

plastic. The lower price difference of black plastics provides minimal incentive to collect these when the individual's livelihood and family's wellbeing are important.

Table 4.10: Reported cost of materials from Interviews

	What waste pickers get paid		What informal recycling transfer station sells it to recyclers for	
	TSH per kilo	USD per kilo	TSH per kilo	USD per kilo
Colorless Plastic Bottles	400 to 450	0.15 to 0.17	700 to 750	0.26 to 0.28
	450	0.17	600 to 700	0.23 to 0.26
Black Plastic bottles	50	0.019	150	0.06
Plastic	250	0.09	700	0.26
Cardboard boxes	NA	NA	200	0.08

Source: Interviews

> "Some consider them as people who are not aware of themselves. Others know their contribution to cleaning the environment. They know that they collect to earn an income and at the end of the day, to be able to afford living expenses. Because other women collect those bottles to sell, they earn an income, and at the end of the day, they even use the income to educate their children." – Private Waste Management

4.5.4 End of Cycle: Pugu Dumpsite

Since 1935 there have been nine operational dumpsites in Dar es Salaam, all of which were not zoned in the city's master plan (Table 4.11). These dumpsites were not selected based on technical or environmental suitability; they were chosen because they were close to collection areas. Four of the nine dumpsites were closed due to community action through the courts (Yhdego, 2017). Before Pugu became the current dumpsite, Kigogo was an unofficially utilized

by the city as preparations were underway for Pugu to become a sanitary landfill and ceased operation when Pugu became operational.

Table 4.11: Previous Dar es Salaam Dumpsites

Name	Years Operational	Life span	Size (hectares)	Characteristics
Mchikichini	1935 – 1954	19	NA	Open land in planned residential
Magomeni	1954 – 1964	10	NA	Open land closet to Jangwani river
Tabata	1964 – 1991	27	NA	Open land within industrial and residential area closet to Msimbazi river valley
Kunduchi and Mbagala	1991 – 1992	2	NA	Open land within unplanned residential area close to Indian Ocean
Vingunguti	1992 – 2001	8	6	Open land within unplanned residential area close to Msimbazi river valley
Mtoni	2001 – 2007	6	5	Degraded land within unplanned residential area close to Indian Ocean
Kigogo	2007 – 2009	2	7 – 18	Degraded land within unplanned residential area close to Msimbazi river valley
Pugu	2009 – present	16	65	Open land within unplanned residential area

Source: (Mapunda, 2007; Yhdego, 2017)

In the early to mid-2000s, the Dar es Salaam City Council was committed to developing the Pugu site into a sanitary landfill. It had budgeted funding for an Environmental Impact Assessment (EIA), especially since EIAs are mandatory for sanitary landfill projects. The EIA included an examination of all project phases and analysis of its potential impacts. Construction

at the Pugu site was planned for two years after the EIA was completed in 2004. Depending on the chosen scenario, the landfill would have had a 5- to 13-year lifespan and was designed to include:

1) Designed cell development
2) Full leachate management
3) Full landfill gas management
4) A daily soil cover, a final soil cover, and a compaction process
5) A fence with a gate
6) A daily record of the volume, type, and source of waste and a waste scavenging plan

Of the different scenarios, the one that least environmentally impactful and most cost-effective choice was designing a sanitary landfill at Pugu and a composting plant at Msimbazi. This option would also indirectly offer recycling benefits.

The Pugu location never became a sanitary landfill and has been used as a dumpsite since 2009. It is located 30 km from the center of Dar es Salaam (Figure 4.15). The Pugu dumpsite was revisited in 2016 to assess the ongoing operations. The visit found that the waste is not covered daily or monthly but is compacted by a bulldozer once it has been spread out. The only covering utilized at the site is to provide a route for vehicles to dump the waste. A weighbridge is located at the entrance of the dumpsite. Drivers provide information about where the waste is coming from so that it can be logged for the respective ward and municipality. The dumpsite receives 800 to 1,500 tons of waste daily from the municipalities (Yhdego, 2017). Thus, only 19% to 36% of the estimated 4,200 daily waste generation at the time was collected for disposal at Pugu. In 2016, there were reportedly 450 to 600 waste pickers at Pugu that would sort through

the waste for recyclable materials. The common materials recovered included plastic, clothes, glasses, metals, and boxes (Yhdego, 2017). In April 2017, construction on a fence began since much of the site was still open to people and animals. However, a 2023 news article reports no fencing at the site (Singh, 2023).

Figure 4.15: Location of Pugu Dumpsite

4.5.4 End of Cycle: Recycling

Less than 10% of materials in Dar es Salaam are recycled (URT, 2018). A survey of 639 households across the three original municipalities identified that paper and cardboard, plastics, glass and metals all materials account for 38% of the waste generated (Table 4.12). These materials are all recyclable. Plastics were the most predominant material, followed by paper and cardboard. An IUCN study based on 2018 data found that the plastic waste generation per capita in Dar es Salaam is 30 kg/cap/year (IUCN-EA-QUANTIS, 2020). This amount is much higher than Tanzania's average plastic waste generation per capita of 5.7 kg/cap/year. Based on the IUCN rate reported in 2024 Dar es Salam produced 674 tons of plastic daily. If efforts are not taken to minimize plastic consumption, then in 2030, with a population projected population of 10 million Dar es Salaam will generate 822 tons/day.

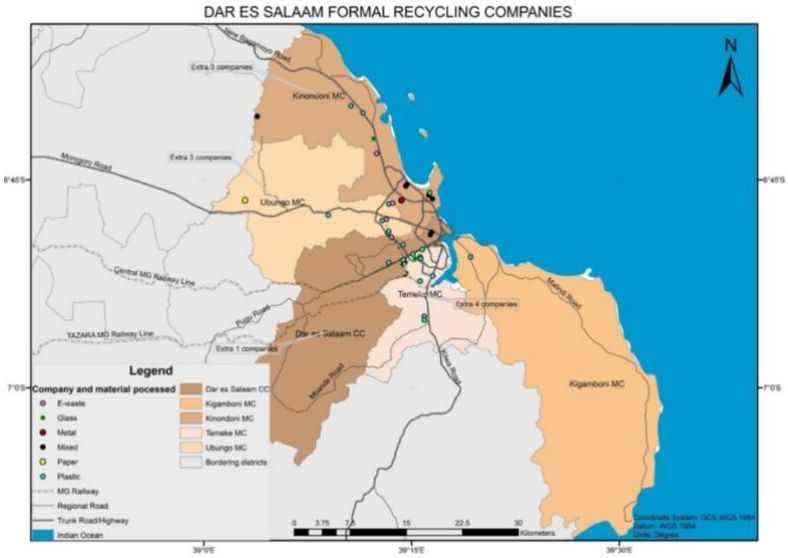
Table 4.12: Waste Characterization

Type of Waste	Weight (kg)	Percentage
Organic Waste	64,494	58%
Paper and Cardboards	11,525	10%
Plastics	17,364	16%
Glass	10,269	9%
Metals	3,090	3%
E-waste	1,867	2%
Textiles	850	1%
Others	1,063	1%
Total	1,105,22	100%

Source: (Senzige, Nkansah-Gyeke, et al., 2014)

As established in sections 4.5.1 and 4.5.3, materials are collected by private companies or informally by local waste pickers. Legislation in Tanzania requires that source separation happens at home in order to increase the collection of recyclables. Still, a survey of 450 found that 60% of respondents were unaware of waste separation and sorting for reuse and recycling (Monella & Leyaro, 2013). Since recycling operations in Dar es Salaam are largely informal Kirama and Mayo (2016) identified a few companies that were in the initial stages of recycling plastic and metal to minimize waste, and these companies included ECO limited, Mjimwema Environmental Care, and UMAWA. The Green Cities and Infrastructure Programme published a recent article on the Dar es Salaam Resilience Project (DURP) findings, identifying 47 formal recyclers in Dar es Salaam (Bella, 2025). These companies handle plastic, paper, cardboard, glass, metal, and electronic waste. 68% of the companies predominantly treat PET bottles. 84% of these companies have fewer than 100 staff and handle less than 1 tonne of waste yearly. The study found that some recycling companies faced unstable conditions, including regularly moving locations, changing operations, and stopping activities (Bella, 2025). The study also mapped the locations of the companies they identified (Figure 4.16). Most of the recycling is localized to the more central portion of Dar es Salaam and is limited in more rural and informally settled areas.

Figure 4.16: Location of Formal Recycling Companies in Dar es Salaam (Bella, 2025)



Source: (Bella, 2025)

Interviews identified a local recycler called Zaidi Recyclers. According to their website, they primarily focus on collecting paper but also collect plastics, glass bottles, and scrap metal. Zaidi recyclers utilize an app called the Zaidi App to connect with customers. This is the same app Nipe Fagio utilizes to register waste pickers. Waste pickers play an important role in the collection of recyclable materials because when a customer is ready to have their waste collected, the app will recommend waste pickers close by based on the customer's location (Zaida, 2024).

> "Zaidi Recyclers we collect almost 90% of sorted recyclables. Once we come at your offices, we tell you that they need to be sorted or segregate these wastes so that we can collect. If we collect plastic, it's a plastic. If a nylon is a nylon. We do it at the source, then

> of the 20% remaining- or almost 80%, they are done in the sites, but 20% we do it at our site because we have also programs for awareness called Reward for Recycling." – Recyclers and MRF

Another recycling company identified is The Recyclers. The Recyclers began operations in 2014 and reports that since then, they have recycled 13,108,890 kg and 10,480,855 plastic bottles, which has saved 4,884 cubic meters of space in the Pugu dumpsite (The Recyclers, 2024a). The Recyclers collects paper, cardboard, brown paper, newspaper, cans and tin, plastic bottles (soda, water, shampoo, and oil), glass bottles, soft plastic (bubble wrap and nylon), PVC, and PP bags. The Recyclers does not accept dirty paper or cardboard, foil, dirty or rusted cans, Styrofoam or yogurt containers, or colored plastic bags. They collect electronic waste and waste oil, but customers must receive confirmation from the company first due to costs and safety measures (The Recyclers, 2024b). The Recyclers offers two methods of collections. The Recyclers predominately works with commercial and retail businesses to manage their waste. If the business is large enough, they will place an employee who helps sort the waste into their respective categories before collecting it. For the general public they offer four collection points for common materials like glass, plastic, paper, and metal. They also offer collection of recyclables from 16 schools and offices located in downtown, Masaki, and Oysterbay.

Recyclable materials are available in Tanzania and efforts must be made in order to increase the collection of these materials. Recycling operations are increasing and the collaboration between formal companies like Zaidi and waste pickers is a collaboration that continually needs to be explored. As established in Section 4.5.3, waste pickers play an important

role in the collection. Source separation also requires continual promotion not only to increase collection of recyclables but also to increase composting opportunities in Dar es Salaam.

> "Also, recycling I think has become a very big initiative in this current period. Many people are collecting the plastic soda bottles for recycling. I see recycling, for this period, these recent years is happening on a very large scale, where it also helps us to reduce the amount of plastic waste." – Food Vendor-

4.5.5 End of Cycle: Compost

According to the National Strategy, organic waste comprises 50-70% of MSW, but only 2-3% of it is being composted (URT, 2018). Composting offers the opportunity to divert significant waste from the Pugu dumpsite and reduce methane emissions. According to the World Bank's Climate and Development report Tanzania contributed 0.31% of global greenhouse gas (GHG) emissions in 2019, making it the 46th largest global emitter of GHGs (World Bank Group, 2024a). From 2010 to 2020 emissions in the waste sector increased from 4.78 to 6.38 MtCO2e nationally. In Dar es Salaam, solid waste accounts for 55% of methane emissions and is expected to increase by 90% between 2024 and 2040. However, it can be reduced by 80% if technological mitigation efforts are implemented (World Bank Group, 2024b). Tanzania is one of 15 countries in the World Bank's global methane initiative to reduce methane emissions that will focus on reducing methane from agriculture and transportation nationally, and specifically in Dar es Salaam, it will focus on solid waste. Managing organic waste sustainably was also mentioned in the National Strategy. It proposed an 800-ton/day

composting plant in Dar es Salaam that would require an investment of $1 million USD. It also proposed that organic waste be utilized to generate biogas. The proposed plant would generate 2 MW of electricity and require an investment of $5 million USD.

Current projects are underway to implement composting in Dar es Salaam, including a composting plant in Mwagepegande and the Bonyokwa Zero Waste Co-Operative (discussed in Section 4.5.6). Composting businesses were also highlighted during the GAIA Zero Waste Cities Conference in July 2024 in Dar es Salaam, Tanzania: Chanzi and BioBuu. Both companies utilize black soldier fly (BSF) larvae that are local to Africa. They breed BSF and their larvae eat the organic waste. The larvae are dried and sold for chicken, pig, or fish feed. The larvae's feces can also be sold to farmers as a fertilizer, which can be up to 80% cheaper than synthetic fertilizer (Chanzi, 2025). BSF needs 1 kg of organic waste to produce 50 grams of protein (BioBuu, 2025). Compared to fishmeal or soy-based food used to feed animals, BSF produced 2,500 times more protein per acre per year while requiring less water (Chanzi, 2025). Overall, this process reduces methane generation of organic waste at the dumpsite and reduces the need for fishmeal or soy-based food for animals.

Chanzi began operations in 2019 in Tanzania and today operates in five cities across East Africa: Arusha, Tanzania; Dar es Salaam, Tanzania; Zanzibar, Tanzania; Nairobi, Kenya; and Mombasa, Kenya (Chanzi, 2025). Chanzi collaborates with local markets, farmers, and businesses to obtain spoiled food to feed the larvae. Chanzi reports collecting more than 10,000 tons of organic waste for all sites as of September 2024, or 2,000 tons per city (McGuckin & Sarma, 2024). Each site individually reduces methane emissions by 0.4 metric tonnes per day and 9.4 metric tonnes of CO2 per day (Chanzi, 2025).

BioBuu is a branch of The Recycler, a local recycling company in Dar es Salaam, that introduced BSF in 2015. Like Chanzi, they have at least one site in Tanzania and Kenya. During a BBC Smart Money segment in 2021, BioBuu reported that they processed 5 to 10 tons of organic waste a day or 1,825 to 3,650 tons a year. They produce 20 to 30 tons of fertilizer a month from the BSF larvae waste and 5 to 10 tons of larvae a month (BBC, 2021). Organic waste is collected via household compost bins offered by The Recycler. The Recyclers have also announced plans to open a bio-gas plant near Dar es Salaam that would handle 400 tons of organic waste a day and produce about 5 MW.

One compost plant exists in Dar es Salaam in Mwagepande, in the Kinondoni Municipality. The composting plant began operations in 2022 and accepts 179 tons of organic waste from Kinondoni (Kölsch & GmbH, 2024). The plant reports to reduce 18,000 tons/year of waste equivalent to 10,000 tons of CO_2 eq/year (Kölsch & GmbH, 2024). The organic waste is collected from two city markets and taken to a compost plant in Mwagepande, in the Kinondoni Municipality.

> "We also use like 25% of the waste to separate from the public places such as markets. We separate the waste and take the organic waste to our compost site in Mwagepande. We have a compost plant there which uses organic waste to produce compost." – Government Official

Food vendors also mentioned that their organic waste, primarily potato peels, is collected and used for livestock feed. Overall, there are three different ways in which organic waste can be

handled in Dar es Salaam. Offering opportunities to expand organic waste collection and treatment is a circular approach.

4.5.4 Bonyokwa Zero Waste Cooperative

This section will discuss the Zero Waste Cooperative established by Nipe Fagio in 2019 as it highlights ongoing efforts to increase collection. The Wakusanya Taka Bonyokwa Cooperative, Tanzania's first Zero Waste Cooperative to manage the only MRF in Bonyokwa and Dar es Salaam. The goal of the cooperative was to address the high waste management costs and unreliable services by implementing community-based source separation, cooperative-led collection, and decentralized waste management. The success of the cooperative has been replicated with its expansion in Zanzibar in 2024 and is in the implementation phase in Arusha. The goal is to expand this localized solution to other parts of Dar es Salaam and Tanzania.

The cooperative directly services the Bonyokwa area, which has a population of 12,000 from 2,998 households, and has had successful participation from 95% of the households and businesses. The cooperative supplies households with the necessary receptacles, to ensure source separation (Figure 4.17 a) and is collected daily via pulled wagons (Figure 4.17 b). All the collected waste is returned to the Bonyokwa MRF, where recyclables are sorted into their respective categories (Figure 4.18) and organic waste is composted or used for BSF farming (Figure 4.19). The compost produced also aids in local agriculture at the MRF (Figure 4.19). The cooperative income comes from waste collection fees and selling the recyclables, compost, BSF, and local produce grown next to the cooperative.

Figure 4.17:Waste Bins and Collection Waste

(a) Separate Waste Bins

(Nipe Fagio & gaia, 2024)

(b) Collection Wagons

(Source: Site Visit)

Figure 4.18: Sorted Recyclables at the Bonyokwa Material Recovery Facility

Source: Site Visit

Figure 4.19: Composting, Black Soldier Fly Maggot and Local Farming at the Bonyokwa Material Recovery Facility

Source: Site Visit

The estimated average waste generation per capita per day in Bonyokwa is 0.88 kg or 10.560 metric tonnes per day (Nipe Fagio & gaia, 2024). The reported annual average waste collected is 1,088.62 metric tonnes, comprised of 78% organic waste, 6.68% recyclable waste, 8.05% domestic hazardous waste, and 7.30% residual waste (Table 4.13). On average, 85% of the collected waste is either composted, recycled, or reused, which diverts waste from the Pugu dumpsite. This also reduces costs and emissions from transportation by providing a localized solution. The circularity of the system has resulted in the recovery of 16.4 metric tonnes of methane/year that would have been released if it had been sent to the landfill.

Table 4.13: Waste Collection from the Cooperative

	Collection Per Month (metric tonnes)	**Average Collection Per Year (metric tonnes)**
Organic waste	31.4	848.80
Recyclable	3.8	72.72
Domestic-Hazardous and Residual waste	6.45	167.10
Total	41.65	1,088.6

Source: (Nipe Fagio & gaia, 2024)

Lastly, the Bonyokwa MRF employees 35 individuals from the community. The cooperative provides waste pickers with established income and a vital role in the community. One interview reflected positively on the cooperative's impact on its employees.

> "We, the entire cooperative, and I have benefited from this system because we have become waste collectors. Unlike before, when we were waste pickers, we picked up and disposed of waste. Now, we are recognized as waste collectors with a system and acknowledged by the government. We even present our case to government bodies to ensure that waste management becomes sustainable." – Recyclers and MRF

4.6 Leakage

4.6.1 Overall Study Area

A total of 10,147 litter items were logged in the Marine Debris Tracker App in both the 9 sq-km area in central Dar es Salaam and the 1 sq-km area in Bonyokwa. Plastic categories comprise 65% of all the litter found, with food-related plastic at 49%, other plastic at 11%, and

plastic fragments at 5% (Figure 4.20). Plastic items continue to dominate the litter (Figure 4.21), with 8 of the 10 top items being items found under the food-related plastic packaging. It should be noted that cigarettes have a plastic film inside; thus, 9 of the 10 top items have some plastic. In comparative analysis of six cities (Pune, India; Panama City, Panama; Chennai, India; Can Tho, Vietnam; Semarang, Indonesia; and Melaka, Malaysia) where CAP has been previously done, cigarettes ranked in the Top 5 (Maddalene et al., 2023). In Dar es Salaam, they comprised only 4% of the overall litter (Figure 4.20) and were 2nd from the last of the top ten items. Plastic bottle caps and plastic bottles were the most prominent items found in the litter, accounting for 23% of the items found in litter transects. Compared to the five cities, plastic bottle caps ranked fourth in Chennai and fifth in Panama City (Maddalene et al., 2023). Metal bottle caps or tabs were also prominent in the litter. These were mainly tabs from the glass refillable bottles. As previously mentioned, consumers can purchase a crate with 16 bottles; however, these crates do not have anything for the caps to be placed in to be returned, and due to their small size, there is no monetary value for waste pickers to collect them.

Figure 4.20: Overall Litter Characterization by Count

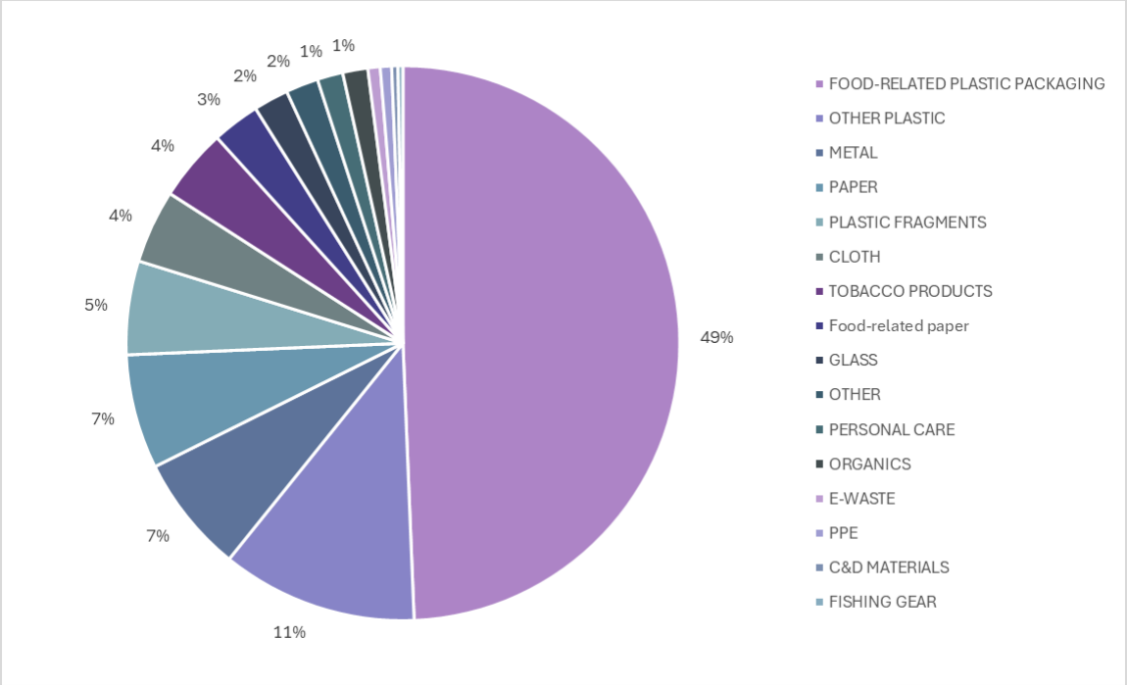
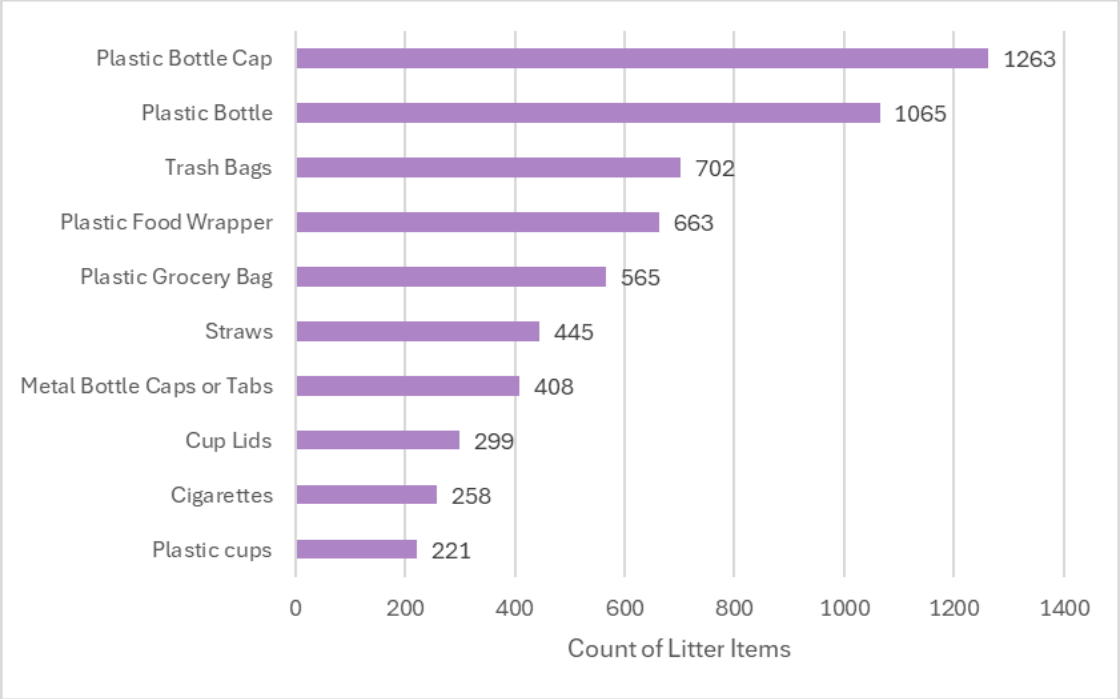


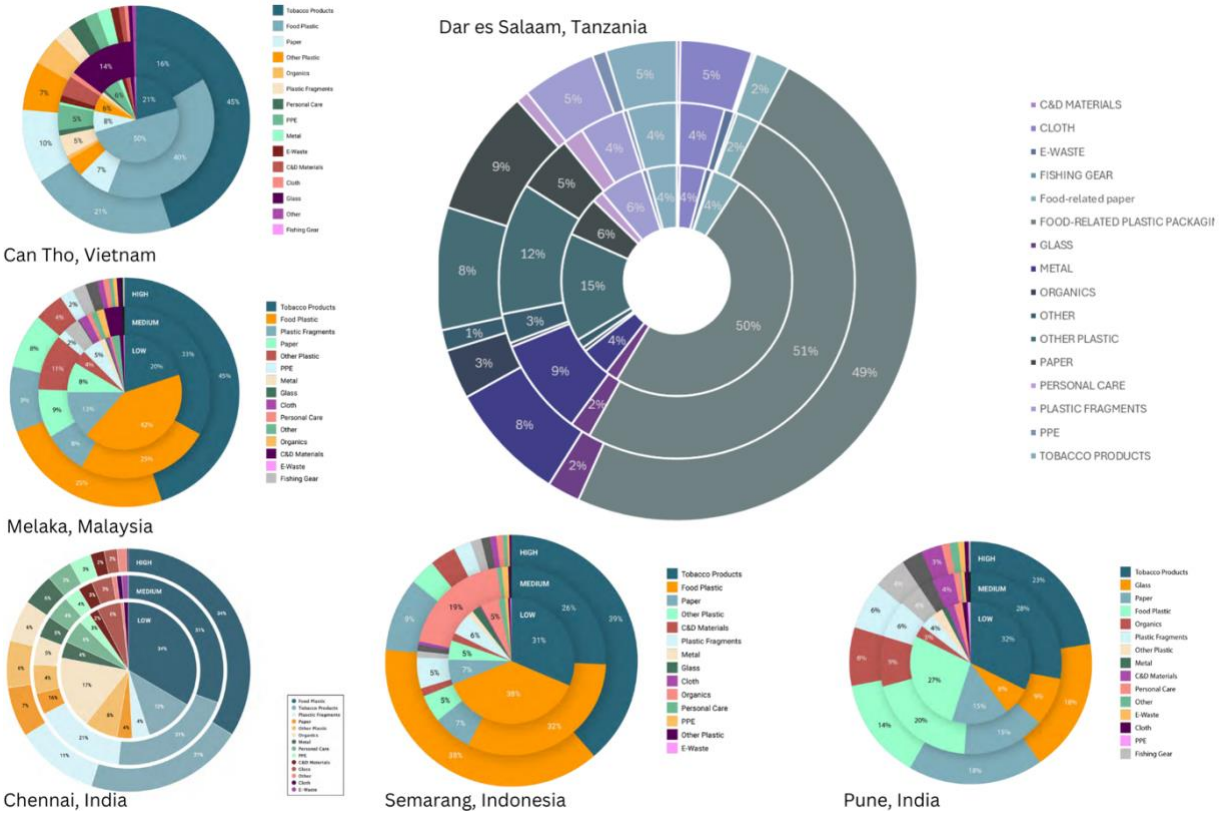
Figure 4.21: Overall Litter Top 10 Items



4.6.2 Site Characterization

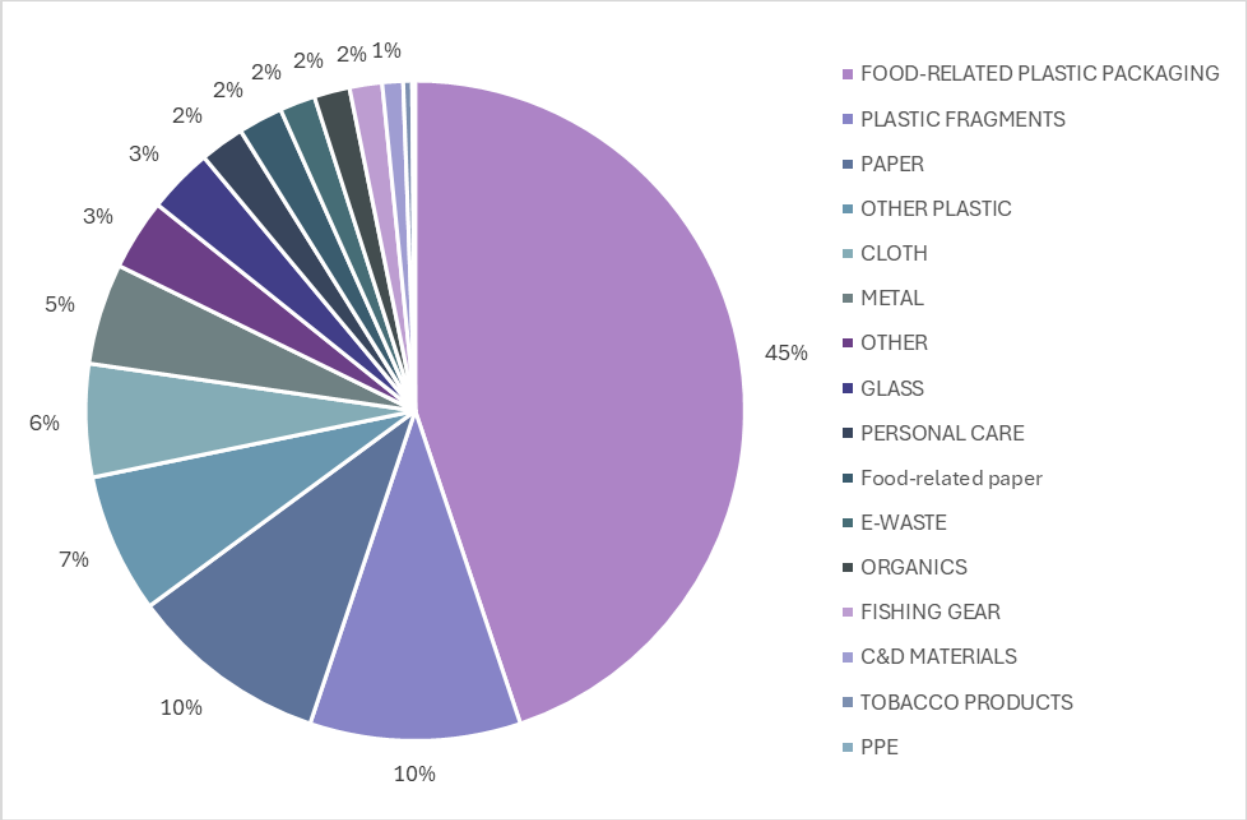
Figure 4.22 visualizes the different litter characterization among the three ambient populations in Dar es Salaam compared to five Urban Ocean cities: Can Tho, Vietnam; Melaka, Malaysia; Chennai, India; Semarang, Indonesia; and Pune, India. Food-related plastic packaging comprises around 50% of each population tertile, even in Bonyokwa (Figure 4.22). Previous CAPs have typically demonstrated variation in the makeup, but Dar es Salaam shows near uniformity across the populations. Compared to the five urban ocean cities Pune and Chennai, India, they have some uniformity but not to the same degree as Dar es Salaam (Figure 4.23).

Figure 4.22: Proportion of Litter Characterization in low (inner), mid (middle), and high (outer) population count areas in Dar es Salaam compared to Can Tho, Vietnam; Chennai, India; Melaka, Malaysia; and Pune, India



Source: (Circularity Informatics Lab, 2021a, 2021b, 2021c, 2021d, 2022)

Figure 4.23: Bonyokwa Litter Characterization



4.6.3 Litter Densities

The average litter density of 30 transects is 3.25 items per sq-m. This means that you will find 3.25 liters of items in every meter. Dar es Salaam is the second CAP conducted in Africa, and the first is in mainland Africa. The first CAP in Africa was conducted in Seychelles in 2019, with an average litter density of 0.97 (World Bank Group, 2019). Compared to the six Urban Ocean CAPs, Dar es Salaam has a slightly higher litter density than Pune, India.

Table 4.14: Litter Densities from Six Urban Ocean Conservancy CAPs

City	Population	Overall Average Litter Density (items/sq-m)
Can Tho, Vietnam	1,246,993	1.1
Chennai, India	4,328,063	1.1
Melaka, Malaysia	180,671	1.1
Semarang, Indonesia	1,653,524	1.1
Panama City, Panama	1,937,963	2.1
Pune, India	2,935,744	3.2

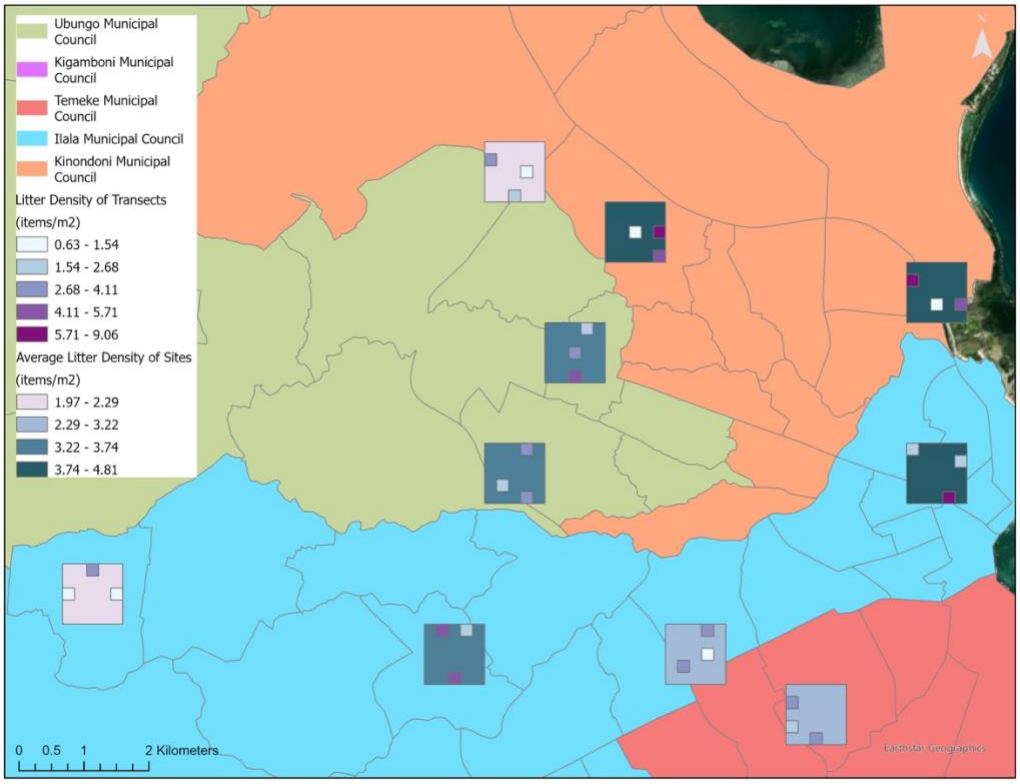
Source: (Maddalene et al., 2023)

The litter density in 200 by 200m transects ranges from a low of 0.63 to a high of 9.06 (Figure 4.24). The average litter density in the 1x1km transects in central Dar es Salaam ranges from 3.42 to 3.74, which are above the overall average litter density (Table 4.15). Additionally, Bonyokwa had a litter density of 2.29. A t-test and a non-parametric statistical test were conducted to identify if this was a statistically significant difference. It should be noted that the data is not normal but both tests indicated that Bonyokwa's lower litter density was not significantly different. Table 4.15 also identifies the top 5 items in each population transect. Plastic items almost accounted for all of the Top 5, except for the high population's metal bottle caps or tabs. Items such as plastic food wrappers, plastic bottle caps, straws, plastic grocery bags, and trash bags are lighter and more easily transported by wind or water.

Table 4.15: Dar es Salaam Litter Density and Top Litter Items for Each Area of Population Count

	Top Items	Average Litter Density (items/m2)
High (22,800 – 51,284 persons)	1) Plastic Food Wrappers 2) Plastic Bottle Cap 3) Plastic Grocery Bag 4) Metal Bottle Caps or Tabs 5) Trash Bags	3.58
Middle (10,316 – 22,800 persons)	1) Plastic Bottle 2) Plastic Bottle Cap 3) Plastic Grocery Bag 4) Trash Bags 5) Straws	3.42
Low (0 – 10,316 persons)	1) Plastic Bottle 2) Plastic Bottle Cap 3) Trash Bags 4) Straws 5) Plastic Grocery Bag	3.74
Bonyokwa (1,830 persons)	1) Plastic Grocery Bag 2) Plastic Bottle 3) Plastic Bottle Cap 4) Straws 5) Tags, tickets, and receipts	2.29

Figure 4.24: Litter densities in transects and sites surveyed in Dar es Salaam



4.6.4 Brands

Table 4.16 lists all brands identified in the 30 litter transects. 257 items out of the 10,147 items logged on Marine Debris Tracker App had identifiable brands (2.5% identified). Best efforts are made to determine the brands of litter items. However, exposure to the elements can remove identifying features from items, and smaller items can be even harder to identify. Figure 4.25 demonstrates some of the conditions of sites when collecting litter samples.

Figure 4.25: Conditions during data collection

Source: Survey

Quantity-wise, the most identifiable item was plastic bottles with 125 items. The most common brand was Mo-Xtra. It has been noted that Mo-Xtra bottles typically aren't collected due to their lower value, because of their color, black, compared to the clear bottles. This was also mentioned during interviews in section 4.2. As such, waste pickers often do not collect these bottles due to the effort and energy required to transport the bottles to the collection center. Items italicized in the plastic food wrapper row are labels from plastic bottles. Plastic bottles are typically identified by their film label or plastic bottle cap. If these identifying features are removed from the item by the elements or humans, it can be challenging to identify the brand on the bottle. As of July 3rd, 2024, the EU requires all beverage bottles under 3 liters to have a tethered cap to reduce the environmental impact of plastic bottle caps. The effect of the caps has still not been studied as it is a recent change. Still, a similar policy in Tanzania may be an avenue

for the government to follow to reduce the exposure of bottle caps in addition to legislation about colored plastic.

Figure 4.26: Photo of Mo-Xtra

Source: Survey

Table 4.16: Brands Identified in the Litter

Item	Brand	Amount Identified
Plastic Bottle 125 identified out of 1065 (11.7% identified)	Mo-Xtra	78
	Afiya	14
	Azam	13
	Uhai	3
	Pepsi	3
	Masafi	2
	U-fresh	2

	Tunda	1
	Kilimanjaro Drinking Water	1
	Jambo Embe Boribo	1
	Hill Water	1
	Dasani	1
Plastic Food Wrapper 26 identified out of 625 (4% identifiable) **italicized items are labels from plastic bottles*	*Mo-Xtra*	5
	Uhai	4
	Milkie milky	3
	Afiya	2
	Ukwaju ice lolly	1
	Ukwaju ice cream	1
	Ufresh mango	1
	Tiffany mintz	1
	Nice time ivory	1
	Mr Berry Big Boss	1
	Mabuyuz Chilli Balls	1
	Hide & Seek	1
	Green Label Tea	1
	Choco Chix	1
	Azam Ukwaju	1
	Azam Ballcon	1
Metal Bottle Caps or Tabs 35 identified out of 408 (8.6% identifiable)	Pepsi	28
	Mirinda	5
	7Up	2
Plastic Bottle Cap 21 identified out of 1235 (1.7% identifiable)	Uhai	14
	Afiya	4
	Mo-Xtra	1
	Jambo	1
	Azam juice	1
Plastic Cups 10 identified out of 221 (4.5% identifiable)	U-fresh	8
	Dar fresh Vanilla yogurt	1
	Asas Yogurt	1
Mini Alcohol Bottles 11 identified out of 84 (13% identifiable)	Smart Gin	3
	Kiwingu	3
	Kilimanjaro	2
	Windhock	2
	Double Kick	1
Aseptic Cartons 3 identified out of 67 (4.5% identifiable)	African Fruit	3
Glass Bottle 9 identified out of 55	Konyagi	4
	K-vant	2

(16% identifiable)	Flying fish	2
	Kilimanjaro	1
Feminine Care Product 14 identified out of 44 (31.8 % identifiable)	Softcare	14
Aluminum or Tin Cans 8 identified out of 41 (19.5% identifiable)	Fanta	4
	Coca Cola	2
	Azam Energy	2
Cigarette Packaging 9 identified out of 36 (25% identifiable)	Winston	5
	Master	2
	Crescent & Star	1
	Portsman	1

CHAPTER 5

KEY FINDINGS AND OPPORTUNIES

5.1 Input

5.1.1 Input Findings

Seventy-four FMCG were identified across 30 stores in Dar es Salaam. At least one item from beverages, candy, and tobacco was manufactured in Dar es Salaam, with candy still being manufactured in Tanzania. Thirty-three (33) beverages were sampled in Dar es Salaam, and 15 were identified as popular brands. Eleven of these brands have parent companies in Tanzania: African Fruit, Azam Cola, Azam Embe, Azam Energy, Hill Water, Masafi, Mo Xtra, Sayona Tunda, Ufresh, and Uhai. Also, 75% of all beverages are manufactured in Dar es Salaam, and the remaining 25% are manufactured in Tanzania or Africa. Overall, 82% of all brands are manufactured in Africa, and 46% have parent companies in Africa. Over one quarter (28%) of products have parent companies in the United States.

5.1.2 Input Opportunities

The relative closeness of manufacturers and parent companies provides opportunities for companies to implement circularity in Dar es Salaam. As mentioned in Section 4.4.1, refillable glass bottles for products like Coca-Cola, Sprite, and Pepsi can be purchased in crates with 24 glass bottles. Consumers can return the crate with all the bottles and buy the next crate at a

discount. However, these brands' SUP bottles are also available to the public. Extended producer responsibility (EPR) legislation and deposit return schemes (DRS) could allow these companies to improve plastic bottle collection.

5.2 Community

5.1.2 Community Findings

Twenty-four semi-structured stakeholder interviews were conducted with Vendors, Hotel, Recyclers and MRF, Private Waste Management, Informal Waste Management, NGOs, and Government officials. Interviews identified that improper collection of waste results in clogged sewers during the rainy season polluting the environment. There was also discussion that the bag ban is not being effectively implemented because bags are still available. Interviewees also discussed the fact that colored plastic bottles have no market, and as such, the products are not collected by waste pickers. Lastly, interviewees discussed wanting to improve education and specific topics included source separation of waste, promotion of plastic alternatives, effects of plastic, environmental conservation, and income opportunities from waste management. All these topics were deemed important in reducing waste generation and improving collection in Dar es Salaam.

5.1.3 Community Opportunities

Lack of source separation was identified as a hindrance to expanding recycling and composting operations. This is connected to a lack of awareness that it should be practiced. Expanding education around source separation and alternatives to plastic items is essential in

expanding recycling and composting in Dar es Salaam. Schools can play a vital role in increasing awareness. Lawson et al. (2019) found that children can impact educating their parents about climate change; thus, educating youth could positively impact increasing adults' understanding of these issues. Similarly, Hartley et al. (2021) analyzed how integrating intergenerational learning into K-12 based marine debris curriculum could create benefits for students, teachers, families, communities and the environment. Mazingira Plus is a community-based organization founded in 2019 that became a registered nonprofit in 2022 and operates in Dar es Salaam. Mazingira Plus advocates for waste diversion and zero-waste options. They offer two school programs, Zero Waste Model and Green School Program, focused on educating students about separation, composting, zero plastic to the ocean, and promoting sustainability and climate mitigation efforts (Mazingira Plus, 2025). They currently have 30 schools in Dar es Salaam involved in these programs and aim to create a Zero Waste Model school network.

5.3 Product Design

5.3.1 Product Design Findings

Sixty-one (61) convenience items and 68 to-go foodware items were sampled from 30 stores and restaurants in Dar es Salaam and Bonyokwa. Store surveys found that the weight of candy and chip products is 4 to 5 times less than that of US products, respectively, and as such, the packaging was lighter and could not be determined using the available scale. Plastic was the overall most common packaging material for all three convenience items. The primary materials for beverages were PET, chips, and candy, which were both predominantly packaged in film/multilayer film. Glass and metal in beverages made up 1% and 0.33%, respectively. The

most common packaging for staple products (rice, oil, flour, laundry detergent, shampoo, and tomato sauce) was primarily packaged in PET HDPE and PP. No alternative material besides paper/paperboard was identified, which was only observed in flour. The majority of restaurants offered reusable in-house. 50 of the 55 to-go items in-house were reusable. A survey of the restaurant to-go items found that 15 restaurants offered reusable to-go. The remaining to-go products are all single-use and predominately made of plastic. No compostable to-go items were identified.

5.3.2 Product Design Opportunities

Since most FMCG comes in plastic packaging, companies should target more recyclable packaging. Colored plastic packaging (e.g., colored PET) was noted as not being accepted because there is no recycling market. Changing all products to clear PET would increase the recyclability of products. Interviews established that there is very little to no demand for colored plastic in Dar es Salaam, and creating legislation that promotes the use of clear PET bottles would maximize the value of the bottles for brands that utilize colored plastic. Tanzania's government can also focus on addressing this issue by passing legislation that promotes clear PET bottles for beverages. This would expand ongoing efforts to reduce plastic pollution which were established by the passing of the plastic bag ban. EPR legislation, including ecomodulation specifically, could be an avenue to explore. Ecomodulation is a concept that penalizes the use of materials that are less circular and rewards producers whose packaging is more circular (e.g., more recyclable) (Lakhan, 2022). An example of its implementation would involve placing taxes on products that do not meet the requirements or providing subsidies to producers that

demonstrate their product is meeting standards to be more recyclable. Ecomodulation is part of a discussion to incentivize companies to minimize the environmental burdens of their products by making changes during the design process. In this instance the production or use of colored PET may be penalized with EPR fees prompting companies to redesign their packaging.

Reusable foodware in restaurants is a highlight of circularity in Dar es Salaam and should both continue and expand, if possible. A complete network of restaurants that offer reusable foodware could be compiled to identify the extent of this service in Dar es Salaam. Additionally, future work could focus on how to replicate the system in other businesses in Dar es Salaam. Fifteen restaurants were identified as offering reusable containers but only two agreed to be interviewed. There could be variations in the system that were not identified in this process. Various reusable containers were offered to local customers who could easily return the container. This system could be expanded by creating a uniform to-go container system that is used by a variety of different vendors. This type of deposit-return scheme for reusable foodware is currently being piloted by Perpetual in Ann Arbor, MI; Galveston, TX; Hilo, HI; and Savannah, GA (Perpetual, 2025). Customers pay a deposit on the container which is returned to them once they return the container. The goal of the system is to create a network where customers do not have to return to the original vendor, instead they can return the container at various drop off locations located around the city. These containers are then collected and cleaned in a sanitation facility and then returned to the vendors. A similar deposit-return scheme has already been established in Switzerland by reCIRCLE in 2015 and has expanded to Germany and France. Similar to the Perpetual process, customers are given a container and have seven days to return it free of charge. Containers are returned to drop-off locations established in the

city. reCIRCLE also has an app in which customers can locate participating restaurants and returned stations. Eight hundred (800) partners in Switzerland and 600 in Europe, reportedly reduce single-use to-go containers usage by 60,000 per day (reCIRCLE, 2025). Reusable foodware networks could expand access to the containers, as vendors would have a steady stream of container return and would not have to limit use to the localized immediate area. No compostable foodware was identified in Dar es Salaam, but if it is to be considered by restaurants, then city and private companies should make efforts to expand composting capacity in the city so that the products can be managed through composting.

5.4 Use

5.4.1 Use Findings

Sixty percent (60%) of stores surveyed had alternatives available, which included refillable beverages, bulk hand soap, and laundry detergent. The most cost-effective products identified were the beverages in large PET canisters, followed by the glass refillable bottles. Repacking was also identified in 70% of the stores; this included packaging rice or other staples. The bag survey found that SUP bags were available in all stores and cost between 40 to 50 TSH. The availability of these bags indicated that the ban on plastic bags is not being enforced. Reusable bags are available, but the SUP bags are cheaper and provide no incentive for customers to spend more on a reusable bag.

5.4.2 Use Opportunities

The availability of bulk staple items such as rice and beans allows businesses to promote customers' bringing reusable containers for their products. Vendors can provide an incentive, such as a discounted rate, for using a reusable container instead of a SUP bag. Promotional information regarding the use of reusable containers for purchases of staple items should be distributed to vendors to increase vendor awareness.

In terms of reuse and refill, there is one example of a case study from Chile. Algramo is a Chilean company that established a refill system in 2013 for detergent, dishwasher, floor cleaner, softener, and other cleaning products. In 2019 they established a mobile refill station that allowed them to transport the product to customers, allowing them to refill their container with the exact amount of product they require. Algramo has expanded to three more countries: the United States, United Kingdom, and Indonesia. Algramo reports in May 2025 to have used 758,596 reusable packaging, avoided 362,845 CO2 kg, and saved using 97,539 kg of plastic (Algramo, 2025).

SUP bags were identified in all stores, even though there is a ban on plastic bags. In addition, to increasing awareness regarding reusable containers, promotional material should also include information about the ban policy. The plastic bag ban policy also included fines on companies, so efforts could be made to identify the manufacturers and importers of the bags into Dar es Salaam.

5.5 Collection and End-of-Cycle

5.5.1 Collection and End-of-Cycle Findings

Dar es Salaam currently only has a dumpsite instead of a landfill. Limited collection of RCCs and limited contracts hinder private companies' ability to purchase technology needed to improve collection. Recycling and composting operations are limited, but companies and governmental initiatives are focusing on addressing the issue. Tanzania's National Solid Waste Management Plan addresses expanding recycling and composting services. The Bonyokwa Zero Waste Cooperative is a local solution that is successfully collecting waste and recycling from participating households. By engaging local waste pickers, they were able to provide job opportunities and a SWM plan that focuses on reducing waste sent to the landfill.

5.5.2 Collection and End-of-Cycle Opportunities

Source separation is key to supporting recycling and composting in Dar es Salaam. Legislation requires that households have separate bins, but it was identified that this is lacking. Local government and private companies could ensure that these bins are provided through the contract process. Legislation could also be expanded to provide waste pickers with necessary protection and rights, as they play a key role in the collection of recyclables. Additionally, Yhdego (2017), a technical report on creating a zero-waste ecosystem in Dar es Salaam, suggested that waste management infrastructure should reflect the Zero Waste Hierarchy that promotes rethink/redesign, reduce, reuse, recycle/compost, material recovery, residual management, and unacceptable (incineration).

As of November 2024, POP has opened their PET bottle collection center in Dar es Salaam Export Processing Zone. POP reports that currently up to 300 tonnes of PET bottles are collected from the center each month. The bottles are weighed and sorted based on color, the center only accepts blue or clear colored bottlers as these bottles reach their required material specification. If needed, caps and labels are removed by hand. The bottles are compacted into bales and exported to a recycling facility (Dar es Salaam does not have a recycling facility that meets international standards). POP is a recognizable organization that has established and met a variety of international guidelines in order to assure the viability and certification of their products from the materials. Colored plastic has been noted as a challenge to increasing the collection and recycling of plastic bottles in Dar es Salaam. POP combined with Nipe Fagio and other recycling companies could provide a united effort to reduce colored plastic beverage bottles distribution in Dar es Salaam.

5.6 Leakages

5.6.1 Leakage Findings

Over ten thousand (10,147) litter items were logged from all 30 transects. Plastic comprised 65% of all litter found, with food-related plastic packaging being the most predominantly identified item. Plastic bottle cap and plastic bottles were the top two items in the litter transects, comprising 23% of all litter items. The overall average litter density is 3.25 litter items/sq-m. Only 2.5% of brands from litter items were identified, 11.7% of plastic bottles were identified, and Mo-Xtra was the most identified. Only one waste bin was identified in all 30 transects, thus there is limited waste disposal options for residents.

5.6.2 Leakage Opportunities

The European Union requires that all bottles have tethered bottle caps to reduce bottle cap leakage. The Tanzanian government could consider similar legislation to reduce the amount of plastic bottle caps leaking into the environment. The government and beverage companies could also explore eliminating colored beverage bottles, as they have been identified as having no recycling value. The government could assess the installation of waste and recycling bins for commuters to provide necessary waste management infrastructure.

CHAPTER 6

CONCLUSION

The overall goal of this research was to apply the CAP in Dar es Salaam, Tanzania; the first CAP conducted on mainland Africa. The overarching objectives of this research was to identify existing research on the current state of SWM, plastic pollution and CE in Dar es Salaam; document baseline circularity of PET and other plastic bottles; and identify opportunities for increasing circularity in Dar es Salaam. A literature review of peer-reviewed articles on SWM, circularity, and plastic pollution found that only nine out of 54 papers mentioned CE. However, the CE was not the overall goal of the research. As such, this research is the first to center its analysis of plastic pollution and SWM around circularity through the use of the CAP methodology.

It's important to note that there are ongoing efforts at the community, private, and government levels that are promoting the CE in Dar es Salaam. The government of Tanzania and Dar es Salaam have addressed the importance of SWM and reducing plastic pollution in Tanzania and Dar es Salaam by the passage of the 2019 ban on plastic bags and the 2018 National Solid Waste Management Strategy. The primary objectives of the national strategy are to minimize waste, maximize the economic value of waste, promote reuse and recycling, and enhance waste collection and disposal facilities(!!! INVALID CITATION !!!). All these objectives align with components of the CE as defined by the UNECE (UNECE, 2023).

Overall, the application of the CAP in Dar es Salaam found that plastic comprised the majority of the litter found in the transects, but opportunities for product design and alternatives could reduce the consumption and leakage of plastic items. Colored plastics were noted as a material that has little value and, as such, is not collected, resulting in it being an item frequently identified in the litter streams and beach cleanups. POP, the sponsor of this research, as recently opened a collection center in Dar es Salaam. The center predominantly collects clear or blue plastic bottles. The Mo-Xtra bottles and other brands that utilize colored plastic would not be a viable product for POP's collection center. These sentiments were also shared by other recycling centers that reported paying 400 to 450 TSH per kg for colorless plastic bottles compared to 50 TSH per kg for black plastic bottles. In order to increase recyclability of bottles in Dar es Salaam, this research found that the most ideal material is clear plastic.

Store surveys found that single-use LDPE bags were available in all 30 stores surveyed, even though Tanzania's government implemented a Ban on Plastic Bags in 2019. While alternatives were available, they were at a much higher price. The ban demonstrates efforts to reduce plastic waste, but the lack of enforcement has led to the introduction of new a different type of plastic bag to the public. During store and restaurant surveys opportunities to reduce plastic consumption were found in the form of refill and reuse systems. Stores had large quantities of staple items, such as rice and beans, which was measured using a scale to the customers desired amount. This system allows for refill schemes that would ensure a container is being reused instead of a SUP bag, which was the packaging provided by the stores. Fifty percent of restaurants surveyed also provided reusable to-go containers to frequent customers, offering a zero-waste alternative to current to-go systems. Perpetual, in the US, and ReCircle, in

Europe, promote a city-wide reusable to-go container program by connecting restaurants to continual supply of reusable to-go containers and provide customers more drop of locations for the containers. The adoption of reusable to-go containers in 50% of the stores surveyed presents an opportunity for a ward or municipality scale program in hopes of achieving city wide implementation.

This research was conducted in collaboration with Nipe Fagio, a local nonprofit organization in Dar es Salaam. The CAP methodology or portions of the CAP can be conducted again by Nipe Fagio. As the city continues to grow and new recycling and composting initiatives begin the CAP can be reconducted to identify any changes in circularity in the CAPs various spokes. SWM has been addressed as a major issue not only for Dar es Salaam and the country as a whole. Reconducting the CAP in 5 years could be beneficial to help examine how the 2018 National Solid Waste Management Plan has impacted SWM. It would be notable to assess the plans aim to achieve 80% waste recovery by 2030 for the whole country, which includes reuse, recycling, composting, and energy recovery.

There is also the opportunity to conduct CAPs in other major cities including Arusha, Dodoma, and Zanzibar. These cities have started or announced plans to implement a Zero Waste Cooperative similar to the Bonyokwa Zero Waste Cooperative. Multiple city CAPs could provide valuable insight into circularity as a whole in the country and inform the development of the next National Solid Waste Management Plan. While CAPs are not the only method of determining progress, Nipe Fagio is already familiar with the methods now. They are also familiar with other tools from GAIA or other groups may also be used.

As Dar es Salaam moves towards becoming a megacity by 2030, a sustainable SWM system will be essential to ensuring a safe and healthy environment for the people in the city and the country. Additionally, reducing plastic consumption to reduce plastic leakage is crucial to addressing the ongoing plastic pollution crisis. Continual efforts towards a CE or zero-waste city can establish the city as a model for other rapidly growing cities in Africa and other continents.

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APPENDIX

Appendix A: Tables

Appendix Table A.1: Indetified Literature

Location	Category	Title	Citation
Africa	Plastic Pollution	Challenges and emerging solutions to the land-based plastic waste issue in Africa	(Jambeck et al., 2018)
		Plastic Pollution Hotspotting and Shaping Action	(Pucino et al., 2020)
		Plastic waste: Status, degradation and microbial management options for Africa	(Akan et al., 2021)
		Plastic pollution threat in Africa: current status and implications for aquatic ecosystem health	(Akindele & Alimba, 2021)
		National Guidance for Plastic Pollution Hotspotting and Shaping Action, Country Report for Tanzania	(IUCN EA QUANTIS, 2021)
		Plastic Pollution in Africa – Identifying Policy Gaps and Opportunities (WWF)	(Sadan & Kock, 2022)

		Quantifying Plastic Waste and Microplastic Contamination in African Aquation Systems: An Imperative for Sustainable Waste Management	(Oceng et al., 2023)
	Microplastics	A comprehensive review on micro-plastic pollution in African aquatic systems	(Mvovo, 2021)
		Macro problems from microplastics: Toward a sustainable policy framework for managing microplastic waste in Africa	(Deme et al., 2022)
		Proximity to coast and major rivers influence the density of floating microplastics and other litter in East African coastal waters	(Weideman et al., 2023)
	Solid Waste Management	Solid Waste Management in Africa: A Review	(Bello et al., 2016)
		Africa Waste Management Outlook	(UNEP, 2018a)
		Waste collection criticality index in African cities	(Loukil & Rouached, 2020)

		Current situation of solid waste management in East African countries and the proposal for sustainable management	(Ntagisanimana et al., 2021)
		Waste management in Africa: a review of cities' experiences	(Kumar et al., 2022)
		The paradox of solid waste management: A regulatory discourse from Sub-Saharan Africa	(Muheirwe et al., 2022)
Tanzania	Plastic Pollution	Status Updates on Plastics Pollution in Aquatic Environment of Tanzania: Data Availability, Current Challenges and Future Research Needs	(Shilla, 2019)
	Microplastics	Microplastics in beach sediments and cockles (Anadara antiquata) along the Tanzanian coastline	(Mayoma et al., 2020)
	Solid Waste Management	Status of Waste Management in East African Cities: Understanding the Drivers of Waste Generation, Collection and Disposal and Their Impacts on Kampala City's Sustainability	(Aryampa et al., 2019)
		Analyzing the Compliance of the National Solid Waste Management Related Legislations in Selected Local Government Authorities in Tanzania	(Omar & Bullu, 2021)

		Assessment of solid waste management practices in Tanzanian cities	(Omar & Bullu, 2022)
		Tanzania – An Assessment of the Solid-Waste-Management Ecosystem	(Singh, 2021)
	Recycling	Sustainable recycling model: A comparative analysis between India and Tanzania	(Uiterkamp et al., 2011)
	Organic Waste	Food industry waste – An opportunity for black soldier fly larvae protein production in Tanzania	(Isibika et al., 2023)
Dar es Salaam	Microplastics	Microplastics in marine beach and seabed sediments along the coasts of Dar es Salaam and Zanzibar in Tanzania	(Nchimbi et al., 2022)
		Seasonal difference in marine litter along the coast of Dar es Salaam, Tanzania	(Peter & Rocha, 2024)
	Solid Waste Management	Appraisal of solid waste collection following private sector involvement in Dar es Salaam, Tanzania	(Kaseva & Mbuligwe, 2005)

		Solid Waste Collection by the private sector: Households' perspective – Findings from a study in Dar es Salaam city, Tanzania	(Kassim & Ali, 2006)
		Environmental Exposure and Public Health Concerns of Municipal Solid Waste Disposal in Dar es Salaam, Tanzania	(Kihampa, 2013)
		Assessment of Community Participation in Privatized Domestic Solid Waste Management in Tanzania: A Case of Kinondoni Municipal Residents	(Kibonde, 2014)
		Factors influencing solid waste generation and composition in urban areas of Tanzania: The case of Dar es Salaam	(Senzige, Makinde, et al., 2014)
		Who should take the garbage out? Public opinion on waste management in Dar es Salaam, Tanzania	(Cheng & Urpelainen, 2015)
		Challenges and prospects of private sector participation in solid waste management in Dar es Salaam City, Tanzania	(Kirama & Mayo, 2016)

		Multi-objective Optimization Model Formulation for Solid Waste Management in Dar es Salaam, Tanzania	(Lyeme et al., 2016)
		Determinants of Individuals' Willingness to use Economic Instruments for Solid Waste Management in Dar es Salaam: The case of Mwananyamala and Mikocheni wards	(Kazuva, 2017)
		Implementation of a goal programming model for solid waste management: a case study of Dar es Salaam – Tanzania	(Lyeme et al., 2017)
		The DPSIR Model for Environmental Risk Assessment of Municipal Solid Waste in Dar es Salaam City, Tanzania	(Kazuva et al., 2018)
		Benchmarking performance of solid waste management and recycling systems in East Africa: Comparing Kigali Rwanda with other major cities	(Kabera et al., 2019)
		Public private partnerships for successful solid waste management and prospects for reducing public health risks in Kinondoni Municipality-Dar es Salaam, Tanzania	(Kamugisha et al., 2019)

		Analyzing Municipal Solid Waste Treatment Scenarios in Rapidly Urbanizing Cities in Developing Countries: The Case of Dar es Salaam, Tanzania	(Kazuva & Zhang, 2019)
		Repercussions of Improved Municipal Solid Waste Management on Flood Risk Reduction: The Case of Dar es Salaam, Tanzania	(Sakijege, 2019)
		Assessment of the Refuse Collection Charges in Covering Waste Management Cost: The Case of Ilala Municipality – Dar es Salaam, Tanzania	(Omar, 2020a)
		Implication of Refuse Collection Charges Practices on Waste Collection Service in Selected Urban Areas in Tanzania	(Omar, 2020b)
		GIS- and MCD-based suitability assessment for optimized location of solid waste landfills in Dar es Salaam, Tanzania	(Kazuva et al., 2021)
		Income and Value Chain Activities in Informal Solid Waste Collection in Tandale, Dar es Salaam, Tanzania	(Mushi et al., 2022)

		Impact of Population Dynamics on Solid Waste Generation Trends in Dar es Salaam Metropolitan	(Mapunda et al., 2023)
		Smart technology solution for a cleaner city: a case study of Dar es Salaam, Tanzania	(Pellatt & Palfreman, 2023)
		Transport Mobility Analysis for Informal Settlements in Dar es Salaam, Tanzania	(Mohamed et al., 2024)
		Private Sector Challenges in Sustainable Solid Waste Management, Dar es Salaam City, Tanzania	(Mpuya & Munishi, 2024)
	Recycling	Recycling inorganic domestic solid wastes: results from a pilot study in Dar es Salaam City, Tanzania	(Kaseva et al., 2002)
		The potential for solid waste recycling in Urban Area of Tanzania: The case of Dar es Salaam	(Senzige, Nkansah-Gyeke, et al., 2014)
		Determinants of Households Willingness to Participate in Solid Waste Separation for Reduce, Reuse, and Recycle: The Case of Dar es Salaam	(Monella & Leyaro, 2013)

		Sustainability of Social Enterprises Involved in Waste Collection and Recycling Activities: Lessons from Tanzania	(Charles, 2019)
		Waste segregation and potential for recycling – A case study for Dar es Salaam City, Tanzania	(Kihila et al., 2021)
	Organic Waste	Potential and constraints of composting domestic solid waste in developing countries: findings from a pilot study in Dar es Salaam, Tanzania	(Mbuligwe et al., 2002)
		Urban biowaste for solid fuel production: Waste suitability assessment and experimental carbonization in Dar es Salaam, Tanzania	(Lohri et al., 2015)

Appendix Table A.2: Full List of Debris Litter Items and Associated Material Categories

Material	Items
C&D Materials	Aggregate & Brick Bolts, Nails, and Screws Building Materials Lumber Other C&D
Cloth	Clothing Towels or rags Fabric Pieces Other Cloth
E-Waste	Batteries E-Waste Fragments Wire Other E-Waste
Fishing Gear	Buoys and Floats Fishing Line Other Fishing Gear Plastic Net or Net Pieces Plastic Rope
Glass	Glass Bottle Glass or Ceramic Fragments Other Glass
Metal	Aluminum Foil Aluminum or Tin Cans Foil to-go container Metal Bottle Caps or Tabs Metal Fragments Other Metal
Organic Waste	Food Waste Other Organic Waste
Other	Other Popsicle or lollipop Stick
Other Plastic Products	Bulk Bags Flip Flops or shoes Plastic String, Tape, or Packing Straps Rubber Bands Trash bag Tires Balloons Plastic toys or balls Car Parts

	Hard plastic jugs or containers Other Plastic
Food-related paper	Paper cups Paper food box or container Paper plates or bowls Compostable paper cups Paper food wrapper Compostable food box or container Napkins Other Food-Related paper
Paper	Office paper and newspaper Tags, tickets, and receipts Corrugated Cardboard Paper fragments Other Paper
Personal Care Products	Blister Pack or other pill packaging Cotton Buds Ear plugs Personal Care Product Sachet or packet Toothbrushes Toothpaste or Other Product Tube Flossers Feminine products Needles and syringes Other Personal Care Products
Food-related plastic	Foam cups Plastic cups Compostable plastic cups Cup Lids Plastic Bottle Aseptic cartons Mini alcohol bottles Plastic Bottle Cap Plastic Food Wrapper Condiment packet or container Plastic Grocery Bag Sandwich or snack bags Plastic Utensils Straws Foam to-go container or clamshell Plastic to-go container or clamshell Compostable plastic container or clamshell Other Food-Related Plastic
Plastic Fragments	Film Fragments

	Foam Fragments Hard Plastic Fragments Rubber/ tire fragments Other Fragments
PPE	Disinfectant Wipes Disposable Gloves Face Masks Other PPE
Tobacco Products	Cigarette Packaging Cigarettes Tobacco Sachets or packets E-cigarettes and vaping Plastic cigar/cigarillo tips Lighters Cannabis-related waste Other Tobacco Product

Appendix Table A. 3: Overview of Site Litter Density

Ambient Population	Population Average Density	Average 1x1km Density	Site	Density (items/sq-m)
High	3.58	3.22	1 A	3.26
			1 B	2.38
			1 C	4.03
		4.02	2 A	7.18
			2 B	2.68
			2 C	2.21
		3.51	3 A	5.71
			3 B	2.91
			3 C	1.9
Middle	3.42	2.79	4 A	3.23
			4 B	1.45
			4 C	3.68
		3.48	5 A	4.11
			5 B	2.59
			5 C	3.72
		4.01	6 A	4.52
			6 B	1.01
			6 C	6.49
Low	3.74	3.74	7 A	4.58
			7 B	1.76
			7 C	4.87
		4.81	8 A	4.67
			8 B	9.06
			8 C	0.71

		1.97	9 A	1.87
			9 B	0.63
			9 C	3.4
Bonyokwa	2.29	2.29	Bon 1	1.54
			Bon 2	1.47
			Bon 3	3.86

Appendix B: Semi-Structured Interview Questions

Core Questions

This question set can be used as a starting place in most key influencer interviews and should be adapted based on additional community concerns.

- Tell me more about your organization's work and your role.
- Do you feel plastic pollution is a problem for your community?
    - If yes, how does it affect your community?
    - If not, why not?
- Do you know about any efforts in your community to provide alternatives to plastic? [You can provide examples to clarify if needed. Examples may include reusable bags, reusable food ware, compostable products, or others observed in store survey.]
    - If so, how have you seen the community respond to these alternatives?
    - If not, are there alternatives you would like to see offered in your community? Why do you think it difficult for your community to use that now?
- What do you feel the level of awareness is around plastic pollution in your community?
- Are there local policies on product packaging or waste management in your community or for your business? [If this information is already known from background research, you can skip to the questions below.]
    - [If policies don't exist,] are there policies you think should exist in your community?

    - [If policies do exist,] would you say this policy is enforced for businesses/residents in your community?
- If you could wave a magic wand and change the way plastic is used or waste is managed in your community, what would you do?

Additional Questions for Government Officials

Some answers to these questions may already be known through background research. Where possible, it is helpful to clarify information obtained online with a local official. To shorten the process, you could summarize your current understanding of the system and ask for confirmation and clarification rather than following the questions below in a step-by-step way.

- How and where is your waste managed? (e.g., landfill, recycling, etc. by % if possible)
- Describe the current waste management system in your community or for your business.
    - Who collects waste in your community for households? What is the frequency of collection?
    - How is it collected (door to door, community dumpster, etc.)?
    - Does everyone in your community have access to waste collection? If not, what are the biggest obstacles to reaching 100% collection?
    - How is waste collection paid for in your community? If there is a cost to households, what is that cost? Is this cost prohibitive to members of your community receiving waste services?
    - What does waste collection look like for multi-family housing units? (Is it collected by private haulers? Is adequate collection capacity provided?)

  - What does waste collection look like for businesses and commercial properties? Is it collected by private haulers?

- Is there recycling in your community? If so, describe this system. What percentage of waste is recycled in your community?
  - What items are accepted for recycling in your community?
  - Is your recycling single stream or source separated? If recycling is separated, what categories is it separated into?
  - Do you have challenges with contamination in your recycling streams? What are typical contamination levels?
  - Are there recycling education efforts in your community? Which groups are promoting recycling education? Are there any particular messages you have found very effective or not effective at all?
  - Who collects recycling in your community? Is there informal sector involvement?
  - How are recyclables collected in your community (door to door, community recycling bin, drop off centers, etc.)?
  - Do households need to sign up to access recycling services or is it automatic? What does the enrollment process look like?
  - What is the frequency of collection?
  - Does everyone in your community have access to recycling collection? If not, what are the biggest obstacles to reaching 100% collection?

- How is recycling paid for in your community? If there is a cost to households, what is that cost? Is this cost prohibitive to members of your community receiving recycling services?
- Is recycling more costly than landfilling in your community? Are you able to profit from the sale of recyclables?
- If there is informal sector involvement, describe this system. How does your community view the informal sector? How do you view the role of the informal sector?
- Do commercial properties like businesses and multi-family units participate in recycling? Is recycling required for commercial properties? If businesses do not participate in recycling, what do you think the obstacles to recycling are?
- Where are recyclables taken after collection? Is industrial composting available in your community?
    - If yes, how are organics collected and processed? Are biodegradable plastics accepted in this stream? Do you have challenges with contamination in the organics stream?
    - If not, what are the biggest challenges with composting in your community?
- What is the biggest source of waste in your community? (industry, tourism, households, etc.)
- Does your community face challenges with illegal dumping? If yes, where does this typically occur? What types of materials are being illegally dumped?

- Does street sweeping or gutter cleaning occur in your community? How often does this occur?
- Do you have current data on waste generation per capita and waste characteristics in your community? If so, can you provide this to us?

Additional Questions for Environmental Non-Profits

This question set is specifically adapted for groups conducting cleanups and environmental awareness activities. There may be other non-profits that are key influencers in your community, and these questions may need to be adjusted accordingly.

- How often do you organize cleanups in your community? What do participation levels in these cleanups typically look like? What age groups and types of people typically volunteer?
- What types of debris do you most commonly find during cleanups?
- Do you collect data during your cleanups? Could you share that data with us?
- Are there environmental education messages that have resonated particularly well in your community or messages that have not worked?

Additional Questions for Waste Management Companies

- What is the biggest source of waste in your community? (industry, tourism, households, etc.)
- How do you haul waste? What type of vehicles do you use to haul waste?

    - Who pays for waste hauling services? (Sometimes it is cities or private residences or businesses.)
- Where is waste taken after collection? (transfer station to landfill, waste to energy facility, etc.) [Landfill or dumpsite] Is waste taken to a designed landfill? Does it have environmental controls like a liner, leachate treatment system, and methane gas flares?
    - Who manages this landfill (private company or municipality)?
    - What is the tipping fee to dump waste (cost of dumping per amount)?
    - Is the waste compacted and covered? If so, how often?
    - On average, how much waste is this dump site receiving per week (or per day or per month, etc.)?
    - Does this landfill receive waste from outside your community as well?
    - When was this site opened?
    - How many more years is this site estimated to last for your community?
    - Do you know where waste will be put once this dump site is full?
- Are there waste pickers who work on this dump site? If so, how many? What are they collecting?
    - How does your community view the informal sector? How do you view the role of the informal sector?
- Are there other landfills in your area? (i.e. for hazardous waste or construction & demolition waste)
- What is the biggest difficulty with managing waste in your community?

Additional Questions for Recycling Centers or Materials Recovery Facilities

- What items are accepted for recycling in your community?
    - What does the process of sorting recyclables look like once they arrive at your facility?
    - How many tons are you processing a day? What are the approximate percentages of each material?
    - What are the end markets for each category of recyclables?
- Do you have challenges with contamination in your recycling streams? What are typical contamination levels?
- Do you have the capacity to accept more recyclables if the community collects more?
- Have you noticed any major changes in prices or contamination in recent years?

Additional Questions for the Informal Recycling Sector:

- How long have you been in this business? How did you get started in this business?
- What are the common/most valuable materials you work with?
    - What price do you pay for each material?
    - What price do you sell each material for?
    - Can you estimate the quantity of each material?
- How many waste pickers sell to you?
    - Where are they primarily collecting the waste?
    - Are they primary collectors or secondary aggregators?
    - Do the same waste pickers sell to you every day?

    - Do you pay daily advances to waste collectors for selling to you? How much?
    - Do you have a contract with waste collectors who are selling to you? (often a larger advance given at the beginning of employment that must be paid back at the end)
- Do you have to do any processing to materials that come into the shop? (i.e. taking labels and caps off PET bottles, sorting, etc.)
    - How many employees work for you doing this?
    - Can you tell us what you pay your employees?
    - What are their hours? How many days a week do they work?
- Where do you sell your material to? Do you know what happens to it after that?
- Have you noticed any major changes in prices in recent years?
- Do you sell to multiple aggregators or one fixed aggregator? Are you paid in advance?
    - If you sell to multiple aggregators, how do you choose which one to sell to?
- What is your average monthly profit?
- Do you own your shop or pay rent? How much?
- If you could collect more plastic, would you? What are your biggest obstacles to collecting more?

<u>Additional Questions for Hotels</u>

- Who are your guests? How many guests do you have on a typical night? In high season? Low season?
- What plastic items do you provide to guests? (breakfast items, shampoo bottles, etc.)

- Was there a time when you did not provide products in plastic? How have you seen things change?
- How do you deal with waste produced in your business? Do you recycle or compost? If yes, are there challenges with recycling or compost? If not, why not?
- Do you use any alternatives to plastic?
    - If so, why did you switch? How have your guests responded?
    - If not, do you have ideas for alternatives you could use? Why is it difficult for you to use that?
    - Do you feel environmental issues are a priority for your guests?
    - Can you provide estimates of waste generation (how often you empty your dumpster and dumpster capacity)?

Additional Questions for Stores and Restaurants

- Who are your customers? How many customers do you have on a typical day? In high season? Low season?
- What is the main source of waste generated in your business?
- How do you deal with waste produced in your business? Do you recycle or compost? If yes, are there challenges with recycling or compost? If not, why not?
- Do you use or sell any alternatives to plastic?
    - If so, why did you switch? How have your customers responded?
    - If not, do you have ideas for alternatives you could use? Why is it difficult for you to use that?

- Do you feel environmental issues are a priority for your customers?
- Can you provide estimates of waste generation (how often you empty your dumpster and dumpster capacity)?