Chapter 5

No time to waste: Lessons learned from waste management in the absence of public services

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Abstract

Development[1] within the Anthropocene can be described as a cradle-to-grave system. The linear economy uses non-renewable resources, built up over millennia to produce goods and services, many of which are used only once and then discarded. In this, waste becomes the anomaly of modernity's expectations of absolute efficiency, and therefore the generation of solid waste stands in contradiction to an efficient linear economy, threatening biodiversity, polluting, destroying habitats and contributing to global warming, when waste is burnt and when it is dormant on waste heaps, leaking greenhouse gases and heavy metals into the environment. Waste is especially

1 Editors' note: *Development* in the old meaning of the term, before sustainability was integrated into the concept.

problematic in low-income and informal communities that lack reliable waste management services. Although some residents collect recyclables for resale, the burning and public dumping of solid waste is common practice. These communal and personal dumping spaces are also regularly burned as a way of dealing with material accumulation, health risks and inconvenient smells. While some waste entrepreneurs collect recyclables for resale, the profit margins are extremely small, and they have limited access to the necessary transport and storage to recycle on a larger scale.

In this chapter, by using a collective case study approach, we consider the problem of waste in ten informal communities in the North West, Limpopo, and Mpumalanga provinces of South Africa by mapping illegal dumping sites throughout the communities. We also observe changes in these dump sites over time to determine how dynamic they are. We further investigate the characteristics of waste from 105 low-income households from five different low-income communities and how they relate to the waste that eventually ends up in informal dumping sites in these communities. Focus group discussions assist in understanding community members' perceptions of these waste management practices.

Lastly, the chapter describes Nova Institute's pilot alternative waste management interventions in two communities from the study. These pilot studies comprised three components: household waste separation at source; waste picker integration; and waste sorting facility establishment. Combined, these three components aimed to optimise material recovery for reuse, optimise recycling and composting, and reduce waste to landfill transfer or waste burning.

Keywords: burning, dumping, low-income communities, recycling, separation at source, waste, waste picker integration

1. Introduction: Waste in the Anthropocene

The modern linear economy is one of the most powerful factors that gave rise to the Anthropocene – the geological epoch in which human behaviour is the main driver of change

in the environment, including climate change, land use transformation, biodiversity loss and pollution (Eickhoff, 2024). One of the human activities with the largest impact on Earth is the production of waste (Riebeling, 2022; Vaverkova & Koda, 2023), to such a degree that the Anthropocene has been described as the "apotheosis of waste" (Hecht, 2018, p. 111) or the "age of waste" (Corvellec, 2018).

The modern economy is considered predominantly a linear economy or a cradle-to-grave system. Primary resources are extracted, processed, and made into products. These products, many of which are designed for single use, are eventually discarded and end up back in the natural environment as waste.

The accumulation of waste material in the natural environment is one of the most significant system failures of the modern economy, threatening biodiversity, destroying ecosystems, and contributing to climate change when heaps of waste not reacting to oxygen emit greenhouse gases or when waste is burnt (Rodseth et al., 2020). In addition, the modern economy will eventually face resource depletion and insecurity, and public health risks. This makes the movement to a more circular economy economically and environmentally imperative. Waste products can be mined for secondary resources that not only have economic value but also reduce environmental costs. This in itself has economic value (Van der Merwe et al., 2023).

Some examples exist of circular economy, such as designing products that can be easily repaired or refurbished and disassembled for reuse, or recycled, and using recycled materials in production (Kirchherr et al., 2017). However, these processes are still considered niche and not employed on a large scale.

For most domestic households in countries like South Africa, products are bought, used, discarded, and collected by municipal waste services and disposed of at landfills (Godfrey et al., 2017). Along the way, informal recyclers collect material for resale, but this is not a formalised process (Samson, 2020a).

In the 2023 StatsSA household survey report (StatsSA, 2023), only 60% of South African households receive waste

management services. Waste management services in townships and informal settlements in particular are not managed effectively (Haywood et al., 2021). Problems regarding waste are exacerbated when waste is infrequently or never collected. Low-income households, with limited resources, then need to manage their domestic waste on their own, which is not effective, since effective waste management can only be achieved with collaboration and cooperation amongst residents, companies, and authorities (Rodić & Wilson, 2017; Schenck et al., 2022; Kalina, 2020; 2021).

In the absence of public waste management, a household could pay for a private company to collect their domestic waste, but if other residents do not invest in private waste collection services and discard their waste in public, then the household that pays for private collection carries the cost of waste collection but does not have the benefits of a clean community. This leaves residents despondent about addressing waste, further exacerbating the situation, meaning that voluntary cooperation in waste management schemes is not feasible, since the negative effects of waste are not only felt by those who do not responsibly manage their personal waste but also by those who collaborate in voluntary waste management.

Furthermore, poor waste management not only affects the local communities but also ecosystems, waterways, and public health beyond the affected community. Poor waste management affects most of the Sustainable Development Goals (SDGs) set out by the United Nations (UN, 2015)[2]. Effective waste management needs to be centrally organised and preferably funded through channels such as taxes, government infrastructure support grants, urban development grants and public-private partnerships (Mokgabodi, 2013). This should also be conducted in low-income areas, with a lower contribution to taxes, since the benefits of efficiently managed waste would extend far beyond immediate community boundaries.

2 Editors' note: As well as the Planetary Well-being goals articulated in Chapter 1.

In this chapter, we consider waste management in the absence of frequent, reliable public waste collection services. We study eight low-income communities within Limpopo, Mpumalanga, and North West. Our main research question was: How do households manage their domestic waste in the absence of reliable waste collection and management services? We describe three possible strategies that households follow: burning, dumping, and recycling. We used a survey to document households' reported behaviour for burning waste on their private property, as well as dumping waste. We also recorded the location of all public waste heaps, which is an indication of dumping waste. We monitored a sample of the recorded waste heaps over time to determine if a typical waste heap grows, if it is ever cleared or burnt, or if it remains relatively unchanged over time, all of which can indicate public burning and dumping behaviour. In one community, we compared the composition of waste from households with the composition of waste from public waste heaps; this gives a preliminary indication of the type of waste that is more likely to accumulate on public waste heaps and is not collected for recycling. Lastly, we describe how the Nova team piloted the implementation of community-based strategies to manage waste in more responsible ways.

2. Low-income households' informal waste management practices

2.1 Context

The studies on informal waste management practices were conducted in four different municipalities in the provinces of Limpopo, North West, and Mpumalanga, each forming part of private sector air quality offset programmes. The studies were conducted to establish a baseline scenario on various socioeconomic and environmental aspects related to ambient air quality and 'quality of life' within these low-income contexts situated near private industry operations. Table 2 shows economic and geographical information for each of the communities, with data from StatsSA and the comprehensive household survey conducted by the Nova Institute. The

differences between the various contexts investigated here emphasise the message that waste technology must always be contextualised.

In the Govan Mbeki Local Municipality in Mpumalanga, we included the settlements of eMbalenhle and Lebohang. These two settlements are near the town of Secunda, which hosts one of the largest coal-to-oil refineries in the world. The two communities are about 30 km apart. The settlements of eMbalenhle and Lebohang have grown as the industry has given more economic opportunities. These two communities, especially eMbalenhle, are the largest of the communities considered in this study. eMbalenhle, which is closer to the refinery than Lebohang, has about five times as many people as Lebohang and is about 1.5 times more densely populated. However, the mean per capita income and monthly household income of the two communities are similar. Their access to services is also very similar; for example, in both communities, about three-quarters of people have access to electricity.

The two communities situated in Limpopo, Smashblock and Northam, are about 25 km apart and in the vicinity of a private-sector smelter. The communities have similar demographic characteristics in terms of population size and density. The community of Smashblock has a higher average per capita income, about 40% higher than the mean per capita income in Northam. However, Northam is a more established community, with most (88.7%) of the people using electricity, compared to Smashblock, which has no access to electricity. Similarly, a higher proportion of people in Northam live in structures made of concrete or brick (56.5%) compared to Smashblock (33.6%). There is, therefore, a high variation between the two selected communities in the Thabazimbi Local Municipality.

The three communities in the Rustenburg Local Municipality are at most 7 km apart. They are located in a semi-urban context similar to that of Northam. While the population density is like other communities in our study, a higher percentage of the space in the community is occupied.

While all three communities have high levels of electricity use, household structures are mostly informal, except for Bokamoso, where about 90% of participants said they live in a concrete or brick structure.

The communities of Sefikile and Mantserre are more rural and about 13 km apart, close to a private-sector smelter that forms part of the local mining industry. The communities are similar in size and population density, with electricity use ranging from 78% to 100%. However, a higher percentage of residents in Sefikile live in corrugated zinc structures (63.1%) compared to Mantserre (37.1%).

2.2 Methodology

Using a collective case study research design (Crowe et al., 2011; Yin, 2009) we used multiple methods to collect the necessary data, including focus group discussions, a comprehensive household survey, recording the location of illegal dumpsites, monitoring the dumpsites' changes over time, and analysing the composition of waste from households and dumpsites. Data collection occurred between 2020 and 2023. Each of the methods is described in this methodology section:

A **comprehensive household survey** was conducted on a randomly selected sample in each of the communities. Using secondary data and satellite imagery, the communities were divided into grids or polygons with approximately the same number of residents. Enumerators then systematically approached households to take part in the survey until the required sample size was reached.

Illegal dumping mapping: All waste heaps, exceeding 1 m^2 (Malinowski et al., 2015; Niyobuhungiro & Schenck, 2021) were regarded as illegal dumpsites and recorded. The National Waste Management Strategy for South Africa (RSA, 2011; 2020) uses the term 'illegal dumping' as dumping in public in South Africa is unlawful (RSA, 2011). Illegal dumpsites are often burnt by members of the community to reduce material build-up. Enumerators were given a specific route that covered the entire area multiple times, on which all dumpsites and other pollution

Table 2: Economics and geographical information on communities

Area	Total population	Area (km2)	Population density (per km2)	Mean household income (ZAR)	Households with electricity	Household structure made of 1) concrete or brick or 2) corrugated zinc or wood
Govan Mbeki Local Municipality (Mpumalanga)						
eMbalenhle	122,265	18.3	6,645	1,080	74.6%	No data
Lebohang	32,449	5.7	5,733	1,113	79.8%	No data
Thabazimbi Local Municipality (Limpopo)						
Smashblock	11,008	3.1	3,551	2,457	0%	1) 33.6% 2) 59.2%
Northam	12,006	2.1	1,921	1,775	88.7%	1) 56.5% 2) 42.7%
Rustenburg Local Municipality (North West)						
Ikemeleng	6,454	1.3	4,853	484	91.7%	1) 31.1% 2) 68.1%
Mfidikwe	4,992	1.0	5,094	-	100%	1) 18.1% 2) 80.4%
Bokamosso	2,983	1.3	2,386	-	100%	1) 89.1% 2) 10.9%
Moses Kotane Local Municipality (North West)						
Sefikile	5,050	4.3	1,172	-	78.0%	1) 36.9% 2) 63.1%
Mantserre	4,360	3.8	1,121	-	100%	1) 62.1% 2) 37.1%

Data on population size was taken from census data in 2011 (StatsSA, 2011) that listed populations per town and projected the average population growth rates of each municipality from 2011 to 2021. To estimate area size, the area was manually drawn on satellite images around each community. Mean household income, data on electricity, and house type from the Nova Institute Comprehensive Household Survey, conducted on a randomly selected representative sample in each community.

sources were logged. Although burning waste in private spaces was at times recorded when visible, this was not the primary focus of the enumerator and therefore all incidents were not recorded. Each community was mapped multiple times, from 20 days in the largest community to 10 days in the smallest community. We used the average number of heaps across all days and considered the average number of dumpsites recorded across all days.

After the illegal dumpsites were recorded, the communities were divided into blocks. A random sample of illegal dumpsites was selected for each block. According to the sizes of the communities, different numbers of dumpsites were selected; in Govan Mbeki Municipality, 30 dumpsites were selected; in eMbalenhle and 20 in Lebohang, during the summer and the winter and each site was visited at least 10 times. In Thabazimbi Local Municipality, 56 dumpsites were visited in Smashblock in winter. In Northam, 38 dumpsites were observed. Communities in Rustenburg Local Municipality and Moses Kotane Local Municipality were only visited in the winter. In Ikemeleng, 36 selected dumpsites were monitored, 14 in Mfidikwe, 36 in Bokamoso, 16 in Sefikile, and three in Mantserre. Every heap was visited every weekday for two weeks. Some selected sites were not monitored for the entire time frame because they were dumpsites that the fieldworkers were not able to identify again; this included 4 of the 16 selected dumpsites in Sefikile and 2 of the 14 selected dumpsites in Mfidikwe. With every visit, fieldworkers recorded what they observed by choosing whether (1) the site looks exactly the same; (2) there is new rubbish on the site; (3) the site burned since the last visit; (4) there is an active fire on the site; and (5) the site looks smaller (burned or some of the rubbish has been removed).

An analysis of the composition of the illegal dumpsites was conducted in one of the communities, Ikemeleng in Rustenburg Local Municipality. Enumerators recorded the mass and volume of waste samples from illegal dumpsites over two weeks, dating to the end of October 2020. Two to four samples were drawn from each identified dumpsite by using 70 l plastic waste bins filled with materials from the dumpsites. Each

Table 3: Overview of available data

Municipality, province	Communities	Household Survey, sample size	Waste mapping	Waste heap monitoring	Public and household waste survey
Govan Mbeki Municipality, Mpumalanga	eMbalenhle	1,263	Jan– Feb 2023 and Jul 2023	S:-30 (March 2023) W:30 (July 2023)	No
Govan Mbeki Municipality, Mpumalanga	Lebohang	836	Jan– Feb 2023 and Jul 2023	S:20 (Feb–Mar 2023) W:20 (July 2023)	No
Thabazimbi Municipality, Limpopo	Smashblock	388	July–Aug 2021	S: N/A W: 56 (Aug 2021)	No
Thabazimbi Municipality, Limpopo	Northam	485	June 2021	S: N/A W: 38 (July 2021)	No
Moses Kotane Municipality, North West	Sefikile	236	June 2021	S: N/A W: 20 (July 2021)	No
Moses Kotane Municipality, North West	Mantserre	124	June 2021	S: N/A W: 3 (July 2021)	No

Municipality, province	Communities	Household Survey, sample size	Waste mapping	Waste heap monitoring	Public and household waste survey
Rustenburg Municipality, North West	Waterkloof	241	Jun–Jul 2021	S: N/A W: 36 (July 2021)	Yes
Rustenburg Municipality, North West	Mfidikwe	138	Jun–Jul 2021	S: N/A W: 14 (July 2021)	No
Rustenburg Municipality, North West	Bokamoso	147	Jun–Jul 2021	S: N/A W: 36 (July 2021)	No

An overview of the available data for each community is given. The sample size of the household survey refers to the number of people who were randomly approached to take part in the survey and gave their consent; participants were from randomly selected blocks in each community. The waste mapping dates show the months in which fieldworkers walked on preset routes to map each waste heap in the community. Waste monitoring heaps refers to the number of heaps that were selected to be further monitored for changes, the months in which this was performed are shown in brackets for the summer (S) and winter (W). The last column indicates in which community an analysis of the content of public waste heaps and household waste was performed. See Section 2.2 for more information.

sample was drawn at a separate point within the dumpsite to ensure that the samples were representative of the heap's contents. The samples were weighed and their content was sorted according to 13 waste categories, including plastic, paper, cardboard, glass, metal, e-waste, organic, sanitation, hazardous waste, construction waste and textiles, ash and dust, and other types.

A **waste composition analysis** was also conducted in Ikemeleng, which included the analysis of the composition of waste from 20 households. The household waste was sorted into the same 13 categories used in the public waste survey. Waste was collected once every week in each of the participating households. All the waste was then sorted into large collection bags and then sorted and weighed into each category.

Lastly, **focus group discussions** were held in each community forming part of the study. Here, members of households who participated in the household waste study were invited, as well as locally active waste pickers, to discuss their current waste practices and to conceive of possible solutions to the challenges that they faced related to their waste management.

3. Describing domestic waste behaviour

3.1 Waste collection services

The level of service delivery differs in each community. During a focus group discussion in Ikemeleng, one resident said: "(I) think service delivery will help in many things. If the municipality or government were rendering service here, the majority of problems would be minimised. Therefore, service delivery would be of great assistance."

Table 4 shows reported details of waste removal services, ranging from 80.3% waste removal services in the communities in Moses Kotane Local Municipality to only 29.5% of households with collection in Thabazimbi Local Municipality, which ranges from no collection in Smashblock to 55.9% of households with waste collection in Northam. Households with waste removal

Table 4: Household and domestic waste information

Region	Thabazimbi Municipality	Rustenburg Municipality	Govan Mbeki Municipality	Moses Kotane Municipality
Waste collection frequency:				
Once a week or more	29.5%	45.1%	66.9%	80.0%
Once every two weeks	0.1%	0.4%	1.1%	0.3%
Once a month	1.6%	0.8%	2.9%	0%
Less than once a month	0.1%	0%	0.3%	0%
Never/no services	68.7%	53.8%	28.9%	19.7%
Waste collection failure (only those with services)				
More than once per month	61.5%	28.8%	38.3%	2.8%
Once per month or less	1.5%	70.4%	12.2%	51.2%
Never or very rarely	26.4%	0.8%	49.7%	33.3%
How waste is disposed of (multiple answers possible)				
Dispose at a dump site	14.6%	10.5%	Data not available	0.6%
Dispose anywhere in public	3.0%	3.4%		0%
Recycle	0%	1.1%		3.9%
Burn waste	42.3%	55.0%		66.7%
Buried waste	1.3%	20.7%		0.3%
Composted or animal feed	0%	3.6%		0.3%
How often do you burn waste?				
Once a week or more	27.5%	38.5%	5.2%	28.6%
Once to twice per month	6.9%	13.1%	5.1%	28.6%
Less than once a month	7.9%	3.4%	1.5%	9.4%
Never	57.7%	45.0%	88.2%	33.3%

The data shown is from various household surveys done in the communities. See the methodology section for more information. The communities in Thabazimbi Local Municipality are Northam and Smashblock; the three communities in Rustenburg Local Municipality are Bokamoso, Mfidikwe, and Ikemeleng; the two communities in Govan Mbeki Local Municipality are eMbalenhle and Lebohang; and the two communities in the Moses Kotane Local Municipality are Sefikile (including the extension Ga Ramosidi) and Mantserre.

services do report some collection failures, ranging from 2.5% to 61.5% of participants who said that in the last three months, there have been more than one collection failure every month in the communities in the Moses Kotane and Thabazimbi Local Municipalities, respectively.

Given the low coverage of domestic waste collection, as well as the higher failure rate, most households do not have regular waste collection. For example, on average, about a quarter of the households in the Northam and Smashblock (the two communities in the Thabazimbi Local Municipality) have waste collection services – but all of these households are located in the community of Northam, and none of the households in the community of Smashblock have waste collection services. In addition, 61.5% of households said that there was a failure in the weekly waste collection at least once per month in the last three months, which means that in these two communities, only 12% of people report weekly waste collection. The collection rates are better in Moses Kotane Local Municipality, with about 25% of households reporting regular weekly waste collection.

In the absence of public waste collection services or high failure of collection, households manage their own domestic waste. In the following section, we discuss three strategies that households commonly employ, namely, dumping, burning, and recycling waste.

3.2 Dumping and burning waste

The strategy most used to manage domestic waste is for households to dump or burn their domestic waste at public waste heaps within the community. We discuss these two strategies together in this section.

In the household survey conducted in the communities, most people said that they burn their waste or dispose of it at public waste heaps in the community. In the Thabazimbi and Rustenburg communities, 14.6% and 10.5% of participants said that they discard their domestic waste at public waste heaps in the community; in both communities, a further 3%

of participants said that they dump domestic waste anywhere in public.

During a focus group in eMbalenhle, a resident said: "(We burn) papers and old clothes that you do not need anymore, we throw them outside, light fire and burn them". Reportedly, the incidence of burning waste is very high, ranging from 42.3% in Thabazimbi to 66.7% of participants in Moses Kotane Local Municipality who said that they burn their domestic waste, either regularly or occasionally (see Table 4).

To understand the prevalence of illegal dumpsites and public burning in the community, fieldworkers walked routes covering the entire community and logged any instances of dumpsites, burning waste, and previously burnt waste. We found high levels of illegal dumping in the communities.

Figure 10 shows the number of dumpsites, burning waste, and previously burnt waste in each of the communities in our sample per square kilometre, differentiating, when data is available, between the winter and the summer. While Thabazimbi and Govan Mbeki local municipalities have the lowest density of dumpsites, consistent across the winter and summer, Rustenburg Local Municipality has the highest density of dumpsites, also with relative consistency between the seasons.

If we consider Figure 11, we see a more consistent trend across communities and seasons. Illegal dumpsites are the most common type of waste recorded in all communities and seasons, followed by previously burnt waste. All communities have more waste heaps, ranging from more than 80% in Moses Kotane in the summer to about 55% in Secunda in winter. All communities have a small percentage of actively burning waste, which is expected, since it is dependent on the exact time that the survey is conducted. In the cases where we have data for both seasons in a community, we see slightly more burnt waste in the winter than in the summer.

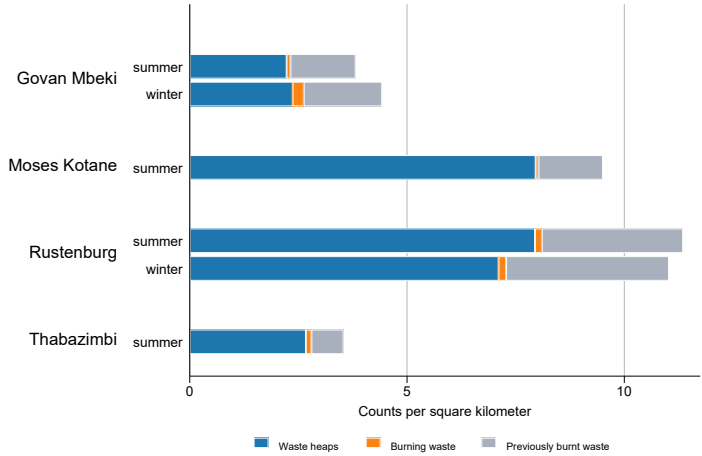

Figure 10: Illegal dumpsites, burning waste, and burnt waste in the communities in Northam (Mantserre, Sefikile), Rustenburg (Ikemeleng, Bokamoso, Mfidikwe), Secunda (eMbalenhle, Lebohang) and Thabazimbi (Smashblock, Northam) per square kilometre in the communities. Winter data was not collected in Thabazimbi, and summer data was not collected in Moses Kotane. See Section 2.2 for more information on the methodology.

Observing these recorded dumpsites over time also gives us an indication of how dynamic or static these dumpsites are. Meaning, are the dumpsites relatively stable over time, in that they do not become significantly larger or smaller over time, or do they change significantly over time? This could include frequent new deposits, frequent burning or removal of waste. To understand how dynamic or static the dumpsites are, enumerators visited a subsample of dumpsites in various seasons. They had to mark whether a dumpsite either looked the same, the site looked smaller (burned and some of the rubbish had been removed), or whether the site was burning or burned since the last visit or had new rubbish on the site. These dumpsites were observed over two weeks.

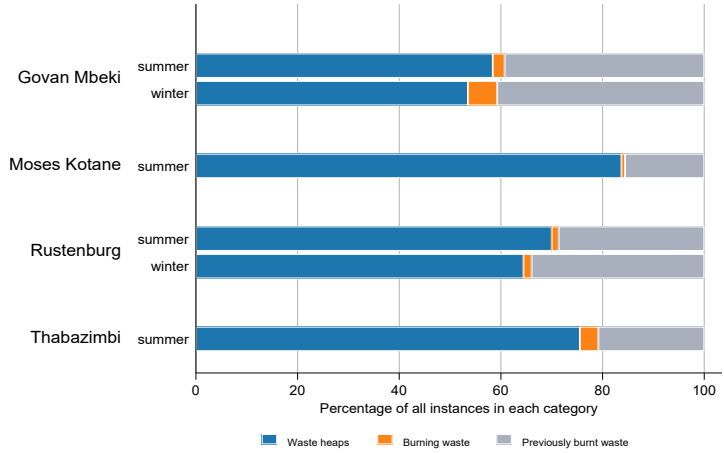

Figure 11: Waste heaps, burning waste, and burnt waste in the communities in Northam (Mantserre, Sefikile), Rustenburg (Waterkloof, Bokamoso, Mfidikwe), Secunda (eMbalenhle, Lebohang) and Thabazimbi (Smashblock) per square kilometre in the communities. Winter data was not collected in Northam. See Section 2.2 for more information on the methodology.

The observed changes in the dumped waste are shown in Figure 12 are place-dependent, with Rustenburg Local Municipality in the winter showing many new deposits and Moses Kotane and Thabazimbi local municipalities in the winter showing more dumpsites with no change. If we consider Goven Mbeki Local Municipality, with data for summer and winter, we can see that communities have similar dynamics across the seasons.

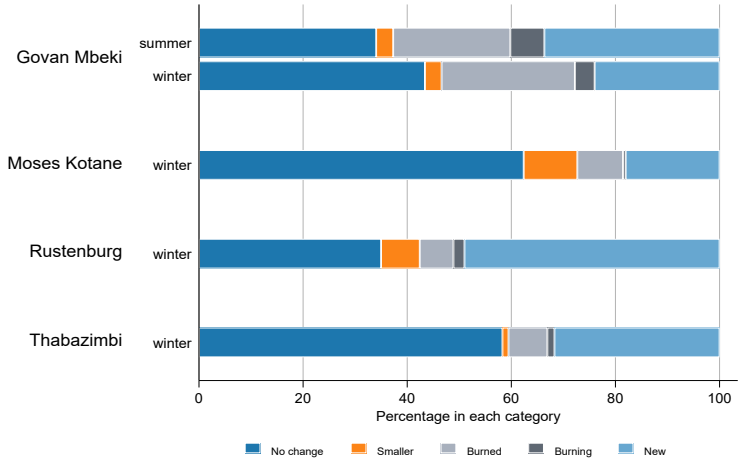

Figure 12: Changes in waste heaps over time. Blue shows waste heaps with no changes over time, orange shows heaps that decreased in size, light and dark grey show waste that was burned or is burning, respectively, and light blue shows heaps that grew with new waste deposits. No summer survey was conducted in Northam and Rustenburg.

3.3 Recycling waste

During a focus group in eMbalenhle, one resident mentioned the value of recycling: "You can see that the municipality is no longer interested in collecting our waste. So, we just must see what we do with the waste. What is helping us most is that we sell most waste, such as bottles, tins and even the papers too are weighed." In some cases, entrepreneurs or volunteers from the community also collect neighbours' waste, either to collect recyclable waste for resale or to merely help, usually by dumping the waste at informal dump sites in the community. During a focus group at eMbalenhle, one participant said that he and four other residents use a trolley to collect their neighbours' waste for free: "(G)oing around to other people and asking them if we can collect their waste and they give us the waste… Yes,

for free. We have sympathy for other people. It does not mean that we all want money."

In Ikemeleng, one of the communities in the Rustenburg Local Municipality, a household waste survey was conducted where the waste of a group of households was collected and analysed into different waste types. A public waste survey, where waste samples from public waste heaps were collected and analysed into the same waste categories, was also conducted in the same community. Comparing the composition of waste from households to the composition of waste from public waste heaps in the same communities could give an estimation of the type of waste that households discard and the type of waste that is more likely to be dormant on waste heaps, meaning not recycled or burnt.

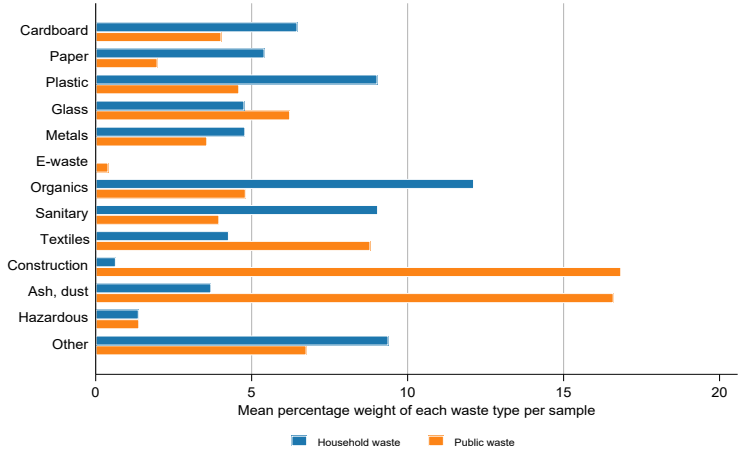

Figure 13: Household waste composition compared to composition of waste on public dump sites. Domestic waste from 20 households was categorised into 13 waste types (blue, household waste survey). Samples from multiple public waste heaps in the community were also drawn and divided into the same 13 categories (orange, public waste survey).

Figure 13 shows the weight of each waste type analysed from household waste (blue bar) and public waste (orange bar). We calculated the total weight of each sample and calculated the percentage of weight that each waste type contributed to the total. Figure 13 shows the mean of the percentage weight of each waste type per sample. Figure 13 should be used to compare the differences in the compositions from households and public waste heaps, i.e. comparing the length of the blue and orange lines for each waste type. Since we use the weight of the waste and not the volume, we could underestimate the presence of lightweight waste types, and the graph should not be used to compare the composition of waste across waste types.

From Figure 13, it is clear that certain waste types are more likely to stay dormant on public waste sites compared to others. This could be caused by multiple reasons, for example, certain waste types have a higher likelihood of being diverted from dump sites because of their recyclability, biodegradability, or can easily be burned. On the other hand, there could be a high accumulation of other waste types, because of the difficulty of disposing otherwise.

We do see that recyclable waste, specifically cardboard, paper, plastic, and metals, has a higher mean percentage per sample in household waste samples than in public waste heap samples, which could indicate that these items are intercepted for recycling after being discarded by the household. However, despite the important work performed by waste pickers to intercept recyclable waste for resale, there are still significant levels of recyclable waste on public waste heaps. Supporting informal waste pickers could increase the efficiency of their services.

We observe higher levels of biodegradable waste from household waste than from public waste heaps, which could be an indication that animals eat biodegradable waste on public waste heaps, or it follows the usual process of biodegradation. During a focus group in the same community, Ikemeleng, many participants mentioned animal activity related to public heaps; one participant said: "We do have a big problem with the pigs

… searching for food through the wastage, leaving the place upside down."

Even sanitary waste is eaten by animals, as one participant described: "The pigs, or even dogs, would bring the wasted diapers in the house. When you go outside the house in the morning, you see all these diapers brought by these animals all over the yard." This could be why we see a larger mean of sanitary waste from households' waste samples compared to public waste heap samples.

We also observed a remarkable amount of clothes on public waste heaps. This is significant, as one might expect low-income contexts to pass down or re-sell clothing, rather than dumping it on public heaps. This might be related to cultural values related to clothes, where owners would rather burn textiles than pass them on to others - an aspect to be further researched.

We see a much higher percentage of construction waste compared to household waste on public waste heaps, which could be attributable to various reasons. Construction waste cannot be burned and is difficult to dispose of; this means that over time, there will be a build-up of construction waste on public waste heaps. The same is true for ash, since ash builds up on the waste heaps every time public waste heaps are burnt to dispose of built-up material. In addition, people do not regularly dispose of construction waste, meaning that depending on the timing of when the waste of households is collected for analysis, there might not be any construction waste recorded from the household waste. It should be noted that construction waste is much heavier than other waste types, such as plastics, and since we consider the percentage weight of each waste type, this would overestimate the amount of construction waste on public waste heaps.

4. Possible solutions and interventions

Given the challenges faced by low-income households and the complexities related to their waste management practices, as illustrated in the case studies, the following section comprises

a consideration of possible solutions to these challenges by offering an account of two pilot projects that Nova implemented in Ikemeleng and Smashblock to address their waste management problems.

Improved waste management has the potential to increase jobs, reduce the impact on the environment, regain resources, and increase income through various income streams. The alternative waste management model designed by Nova, aimed at reducing waste burning and public dumping, does not comprise a distinct technology alternative, but rather a combination of technologies, materials, arrangements, and procedures. The configuration opted for in these projects is locally operated and relationship-driven, which is done by integrating waste pickers, employing local labour, and closely cooperating with residents. In addition, the project optimises recycling through separation at source (S@S) and establishing waste sorting facilities.

Project developers drew from three sources, namely:

1. The *Waste Picker Integration Guideline for South Africa*[3]
2. Waste Picker integration website; and
3. outcomes of Nova-waste picker interaction or co-creation during the baseline study.

The first two sources provided detailed procedures on waste picker integration into formal waste management structures, as well as offering background to the principles on which the national integration process is based. These principles include:

- **Separation at source (S@S):** separation at source is the separation of different types of consumer waste materials; firstly, at the point of generation and secondly, at a sorting facility once it has been discarded. S@S typically focuses on the separation of recyclables (and often further disaggregation into different types of recyclables), organic waste and solid waste. Selective collection of separated

3 DEFF/DSI 2020 Waste picker integration guideline for South Africa https://wasteroadmap.co.za/wp-content/uploads/2021/02/Waste-Picker-Integration-Guidelines.pdf.

materials ensures that they do not contaminate each other and that waste-to-landfill transfer is minimised.

- **Separation outside source:** the informal system created by waste pickers working in streets, open spaces and landfills to salvage recyclable and reusable materials mixed into the waste stream, and to separate, clean and transport them to either sell, use themselves, or make new products (Samson, 2020b).
- **Integrated separation at source:** separation at source that integrates waste pickers and their informal separation outside the source recycling system.
- **Waste picker integration:** the creation of a formally planned recycling system that values and improves the present role of waste pickers, builds on the strengths of their existing system for collecting and revaluing materials, and includes waste pickers – people who collect reusable and recyclable materials from residential and commercial waste bins, landfill sites and open spaces to revalue them and generate an income – as key partners in its design, implementation, evaluation, and revision. Waste picker integration requires changes in several spheres and includes the integration of waste pickers' work, as well as the political, economic, social, legal and environmental integration of waste pickers.
- **Recycling:** processing and manufacturing activities to convert previously used materials into new products or inputs.

4.1 Separation at Source at the household level

S@S encourages the recovery of recyclable resources and could generate an (albeit small) income in the reselling of recyclable waste. However, the implementation of S@S programmes without the integration of informal actors, such as waste pickers, risks them being cut off from their source of income and livelihood (Sekhwela & Samson, 2020; Wilson et al., 2006). It is therefore essential to align S@S initiatives with waste picker integration. Re-making products from recycled materials reduces the pressure on primary resources and reduces waste transference to landfills. Further, giving people the resources

to assist with separation at source could increase the recovery of nutrients from biodegradable waste and reduce the leaking of methane gases when biodegradable waste does not properly break down in anaerobic conditions. Additionally, it could increase the diversion of waste to the landfills.

S@S in these pilot projects consisted of sorting household waste into three waste streams consisting of recyclable, non-recyclable, and organic material, and for each of these categories, a waste bin was provided to households. The project included training households on how to separate their waste at home, provision of waste containers for each main waste stream and a weekly waste collection service performed by waste pickers. In addition, households received training and continuous evaluation to correctly execute waste separation. This aspect is of great importance and determines the level of successful household S@S, as also noted by other scholars (Babei et al., 2015; Matter et al., 2013). Household waste is collected weekly by waste pickers and sorted at a local sorting facility for recycling and local composting purposes before the remaining non-recyclable materials are transferred to a municipal landfill.

During the feasibility studies that Nova conducted, different sets of waste containers or bins were tested with households. The aim was to provide sets of bins to have storage options and capacity for recyclable, non-recyclable, and organic waste. For residential stands with three or fewer households, one set of three 70 l plastic bins with colour-coded lids was provided, and for residential stands with more than three households, two 120 l wheelie bins for recyclable and non-recyclable waste, and one 70 l bin for organic waste were issued.

The project personnel provided S@S training and support by recruiting local personnel to train households in the fundamentals of recycling and separating their waste into the correct bins. Instructive labels were placed on the bins to remind project participants of the correct bin in which to place each waste type. A stand evaluation officer was recruited and trained to visit each stand on at least a monthly basis to assess the stand compliance and offer follow-up training where

necessary. Lastly, a public information desk was created close to one of the waste sorting facilities, where queries could be received and resolved.

During the first month of waste collection from participating households, the stand evaluator had to conduct frequent follow-up visits to households, and conducted retraining, as the concept of waste separation took a few iterations before it was fully adopted. However, after this initial month, the follow-up frequency gradually decreased, and waste separation became a common household practice. The main challenge in this regard was experienced with stands which had multiple tenants or 'backyarders' renting from a landlord. These stands received one set of large bins that, therefore, were shared by all. For these stands, the evaluator had to arrange a day and time where all could be present to receive training together. This proved to be a successful method that allowed for convenient and effective material recovery from the collected household waste.

4.2 Waste collections and waste picker integration

Because of the lack of public waste management services, local entrepreneurs, or waste pickers, have seen the problem as an opportunity to secure a livelihood and improve the community. Supporting and integrating these informal waste pickers into an improved waste management system will keep income in the community and contribute to developing localised solutions for each community. It is therefore important to integrate the waste pickers and informal collectors into the new waste management project. However, it is important to note that integration should not be conceptualised in the absence of waste pickers but rather formed in consultation with them to ensure a shared understanding of this concept co-created and implemented (Sekhwela & Samson, 2020). During a focus group discussion at Waterval, one resident said: "There ought to be people hired from within the community to work specifically on the collection of waste. These people should be the ones looking around the community for full bins and call for collection according to sections". Utilising the informal

waste management systems rewards those entrepreneurs who have been contributing to waste management before, creates jobs in the community and increases the likelihood of creating location-specific solutions.

According to the waste picker integration guideline, the identification of waste pickers in itself serves multiple purposes, including leading to improved working conditions, ensuring access to social security benefits, integration into formal waste management systems, and promoting sustainable waste management practices.

For the pilot of this alternative waste management model, Nova engaged stakeholders who were actively involved with local waste processes. To assist in the identification and recruitment process, these stakeholders included waste picker representatives, local government authorities (ward councillors), waste management companies and NGOs. Such collaborations helped to ensure a comprehensive and inclusive approach to waste picker identification. Thus, a comprehensive list of waste pickers active within the community was drawn up as extensively as possible, and from this list, specific waste pickers who resided and operated in the pilot service block were recruited to participate.

Candidate waste pickers were required to produce official identification documentation. For South African citizens, this entailed their official identification document (ID), and Nova captured their ID number and filed a copy of this document as proof. For foreign nationals, a legitimate passport from their country of residence was required. Capturing this information will further enable participating waste pickers to take part in the national waste picker registration programme, which is a current national process forming part of the waste picker integration guideline. Furthermore, each waste picker was given a unique QR (quick response) code to assign them to a specific service block.

Waste pickers were required to provide their current residential address to indicate under which demarcated project service block they fell. This was performed to ensure that

recruited waste pickers service the same block where they are residing. Recruiting local waste pickers ensures a baseline familiarity with the working area and households living there.

To ensure the success of this project, it was necessary to establish that participating waste pickers already have experience in the practice of waste picking. This mainly entailed the collection, sorting and selling of recyclable waste materials, at least on a S@S basis. A survey was conducted in the recruitment phase to establish, firstly, that the individual was an established waste picker with collection, sorting and selling experience. Secondly, to estimate the current volume of materials that they collect. The latter is important to judge whether a waste picker has the physical ability and/or drive to collect waste on a full-time basis.

To perform the household waste collection, each waste picker was issued with a uniform, the necessary personal protective equipment and a trolley cart (see Figure 14), which mainly consists of a large plastic mould to limit the trolley weight and ensure ease of movement for the waste picker. The integration actions followed in these pilot projects worked effectively, as waste pickers typically spent half a day collecting and therefore had ample time to continue with their own waste practices as before. Waste pickers were remunerated for their collection by being paid R1,00 per kilogram. Scholars have noted the existing or potential tension between parallel running formal and informal waste management processes, specifically the competition to collect high-value recyclable materials (Godfrey et al., 2016; Sekhwela & Samson, 2020). In this sense, the pilot project integrates waste pickers to perform collection of all materials from households and thus eliminates the potential for competition with other formal actors.

Figure 14: Waste picker trolley

4.3 Waste sorting facility

The third component of the alternative waste management model comprised the establishment of a waste sorting facility, or a material recovery facility, as it is more commonly referred to within the waste sector. The main function of this facility is to further sort, weigh and process the waste material collected from the households, especially recovering materials for recycling and reuse. Locally processing waste, by sorting each waste type individually into different recycling waste streams, such as composting biodegradables and semi-processing waste, could reduce the transportation cost of waste, which comprises a significant cost in waste management. This does not, however, mean that a waste sorting facility drastically reduces the cost of transportation of materials; it only reduces the amount of waste transferred to landfills, and where materials can be sold or directly reused locally, the cost is eliminated, but the proximity of recovery facilities to large recycling companies

greatly determines the prices paid for it, therefore impacting the income of the waste pickers.

Figure 15: Local waste sorting facility

To perform these tasks, four individuals were trained and assigned to the roles of site officer (1) and waste sorters (3) for each waste sorting facility. These facilities consisted of three main infrastructural areas, namely a sorting area where recyclables are further categorised and weighed; three or four large 12 m shipping containers for material storage; and a composting area where organic waste is processed by applying the *bokashi* composting method . To achieve the goal of optimal waste-to-landfill diversion, recycling and composting processes had to be developed. For the recycling materials, which mostly consist of paper and packaging materials, categories were identified that are currently absorbed back into the local recycling economy, thus even though some waste types are potentially recyclable, the fact that a local economy has not been established for the waste type might render it non-recyclable.

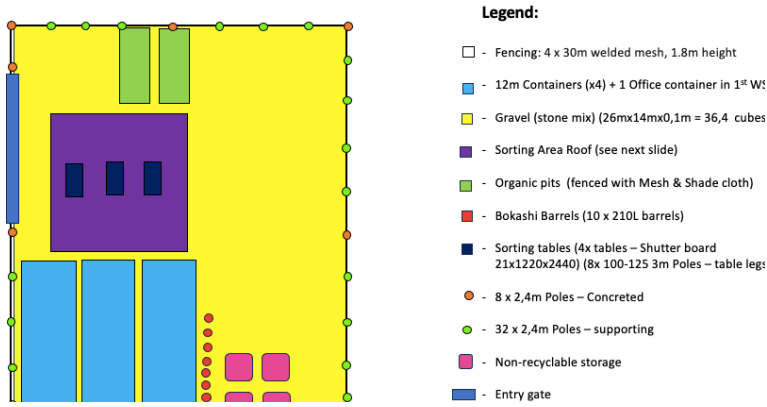

Figure 16: Plan of waste sorting facility

The recyclable materials are stored in 12 m shipping containers, and once maximum capacity is reached, these are sold to a local recycling buy-back centre. The income generated through this sale was paid out to waste pickers in addition to the R1,00/kg collection payment. We noted a significant difference in prices paid for materials between the project located in a rural context compared to the project situated in a semi-urban setting.

Organic waste was the only waste type for which Nova developed its own recovery or reuse process. By utilising the *bokashi* composting method, organic waste is mixed with *bokashi* bran, placed in 210 l plastic barrels, and sealed off from oxygen to ensure anaerobic fermentation. The organic materials remain in these barrels for two weeks to allow the anaerobic decomposition process. Hereafter, it is buried in soil for further breakdown and to be turned into valuable compost. This process has added significant value to the waste management model, since the analysis of the composition of the household waste showed that a significant portion of household waste is organic (see Figure 13).

The two pilot projects established by Nova indicated that by adding infrastructural devices such as a waste sorting facility, a significant amount of waste materials can be recovered for reuse and recycling that would, in the absence of

the project, be burned or landfilled. In summary, each of the three components forming the alternative waste management model was implemented with relative success. The introduction of household S@S to the pilot project's participants was adopted with less effort from Nova staff than was initially anticipated. Training and equipping households to practice S@S is one aspect of the process, but there are no guarantees that participants would be willing to change their behaviour. However, as mentioned above, S@S was successfully adopted by the majority of participants. Secondly, the form of waste picker integration applied by these pilot projects allowed for effective household waste collection. On average, waste pickers collected from 15 households per day, which required about two hours of their time. This number could be doubled, at least, which would then also increase their income. Lastly, the sorting, weighing, storage and composting activities related to the waste sorting facility were conducted with relative ease. The high-value recyclable materials were easy to sell; however, materials such as glass proved to be a challenge in the rural pilot project. Nova has yet to establish whether a need exists within these communities for garden compost. The processing of organic waste into compost was effective, but the uptake of this material into the communities still needs to be tested.

5. Conclusion

The linear economy is unsustainable, using limited primary resources to produce goods and services, which are only used once and discarded. The build-up of waste is a limitation of the modern economy (Kirchherr et al., 2017). This is most evident in informal communities that do not have reliable public waste services. Residents then resort to managing their own waste (dumping, burning, and burying), forming local recycling and waste collection practices. However, it is difficult to develop effective private service or a voluntary community approach to waste collection, since the benefits of effective waste management, including a clean community and reduced public health risks, are enjoyed by everyone in the society, irrespective of whether they contributed to these successes. This makes it

very difficult to address waste concerns without public policy, regulations, and collective efforts (Haywood et al., 2021; Viljoen et al., 2021)

We see some significant variation in the communities which we studied in this chapter; some communities have no public waste collection services, and others have up to 80% coverage of the community. For those communities with waste collection services, we do see varying levels of service failure. In the absence of waste collection or with high service failure, people need to manage their own domestic waste, which is mostly conducted through dumping in informal dumping sites in the community or burning, in private and public spaces: such as what was found by Haywood et al. (2021), Viljoen et al. (2021), Niyobuhungiro and Schenck (2021) and Schenck et al. (2022). This results in high levels of unmanaged waste throughout the community, as was also recorded in the study when illegal dumping sites were mapped and monitored. We do see some consistency across seasons for the two communities where we have data on illegal dumpsites for the winter and summer seasons. However, observing these dumpsites over time shows variations across communities; while communities in Thabazimbi and Moses Kotane local municipalities have relatively static dumpsites (with little growth or reduction), communities in Govan Mbeki and Rustenburg local municipalities have more dynamic heaps, with more deposits and more burning.

We also find more waste that is difficult to dispose of (such as construction waste, textiles, dust and ash) compared to household waste, on dumpsites. In addition, we find less waste that is easily recycled, such as plastics and paper, which indicates interception by informal recyclers. However, some recycling materials such as glass are not collected by the same ratio, and are more prevalent on dumpsites. Glass constitutes a heavy recyclable material and the value thereof is quite low (typically around R0.50c/kg) compared to other recyclables. This might explain its prominence on illegal dumpsites. Similar trends were found in the studies by Schenck et al. (2022).

Supporting the practices of informal waste pickers could increase the efficiency of their services and increase recycling rates even further. For example, while many entrepreneurs collect recyclables for resale, the profit margin is small and on a small scale. They face high fixed costs. Informal recyclers do not have access to the necessary transportation and storage to scale up their operations and increase their income. A possible solution is to integrate the informal solutions, including recycling and waste picking, into a centralised system. Giving households the necessary resources to separate at source will increase nutrient recovery from biodegradable waste, increase collection of recyclables, reduce waste to landfill, and reduce pollution from burning domestic waste. Building on established informal waste practices will ensure that the solutions are fit for each community and increase income and job creation in that community.

Given the limitations of informal community initiatives, it is therefore important to assist communities with centralised waste management interventions. Improved waste management increases well-being in the communities by reducing unsanitary conditions and toxic smoke from waste burning, which constitutes a public health concern (Kalina, 2020; 2021). Improved waste management also increases general life satisfaction and could also have secondary advantages, such as increased investments in the communities (Haywood et al., 2021; Fadhullah et al., 2022; Perkumienė et al., 2023).

We studied a pilot waste intervention that integrated local waste pickers to collect waste from households that was separated at the source into organic waste, recyclable waste, and non-recyclable waste. Here, waste pickers transfer all collected household waste to a local waste sorting and processing facility, that discarded non-recyclable waste to a municipal landfill, recyclable waste to buy-back centres and composted organic waste on-site. The outcomes from the two pilot projects discussed strongly indicated the potential for an alternative waste management model consisting of three components (household S@S; waste picker integration; local waste sorting facility) to maximise recovery of recyclable and reusable

materials, and to optimise waste to landfill diversion. From these findings, we conclude that the operational design of this intervention shows the potential to effectively address public waste dumping and burning in the absence of formal waste management processes. However, these pilot studies discussed form part of a private-sector air-quality offset programme and are funded in this way. This programme does not necessarily offer a sustainable financial model for the suggested waste management process, and perhaps a private–public partnership could be considered to financially sustain such a waste model once the offset compliance is completed.

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