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Assessing the spatial distribution, human perception and pro–environmental behaviour towards plastic pollution in the Nkomazi Local Municipality, Mpumalanga Province, South Africa

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ABSTRACT

Plastic pollution has been a universal issue since the industrial revolution and the problem became to be noted by scientist in the late 1960s and early 1970s within aquatic environments. Plastic waste has a significant impact on the natural environment and humans. This study aims to assess the distribution, composition, human perception, and pro–environmental behaviour towards plastic pollution in the Nkomazi Local Municipality, Mpumalanga Province, South Africa. Specifically, the study intends to assess the (i) assess the spatial distribution, abundance, and composition plastic pollutants, and (ii) assess the respondent's understanding of the effects of improper plastic disposal on the environment and assess variables that affects respondents' choices for managing their plastic waste. The study was conducted in Nkomazi Local Municipality across three big towns (i.e., Komatipoort, Malelane, Hectorspruit), three small towns (i.e., Tonga, Kamhlushwa, Schoemansdal), and three villages (i.e., Phiva, Ntunda, Schulzendal). Firstly, a drive–by survey method was conducted to spatially locate illegal plastic dumping and enumerate the abundance and plastic composition. This was followed by 270 (30 per town/village) randomly selected household interview surveys to gather information on plastic pollution knowledge, perceptions, effects, and pro-environmental behaviours on local communities.

Results show that illegal dumping of plastics was common across both urban and rural areas but was more prevalent in low–income areas in big and small towns. Most illegal plastic dumpsites were categorised as large with most of these located in big and small towns than villages. Illegal plastic dumping was common along roadsides and vacant plots, and polypropylene (PP) and polyethylene terephthalate (PET) were the most common plastic identified across most dumpsites, being more visible in rural than urban areas. Interview results show that most respondents have knowledge about plastic pollution in urban areas (both big and small towns) compared to villages. Respondents were aware of both the health and environmental effects of plastic pollution, however, knowledge of pollution effects varied across the study towns and villages. Except for the pro–environmental behaviour linked to plastic disposal procedure, most of the respondents in both urban and rural areas are unaware of the pro–environmental behaviours linked to plastic management such as recycling, separation, reuse, and participation in pro–environmental campaigns. Both sociodemographic

variables (e.g., age and education level) as well as pro–environmental behaviours (e.g., reuse and sustainability) informed some of the respondents' positive perception regarding plastic pollution.

From a plastic pollution management standpoint, these results suggest (i) the need for financial investment by the municipalities towards plastic pollution reduction such as promoting reuse and recycling, (ii) measures to develop effective means of managing waste in the municipality are needed such as having waste facilities (bins) and effective waste collection time. In addition, (iii) strengthening pro–environmental attitudes and behaviour (awareness campaigns and citizen science) amongst residents of the municipality is needed to effectively manage waste pollution, and (iv) government financial and human resources investment in low–income areas because of the environmental justice mantra linked to plastic pollution. More studies are required on plastic pollution across different South African towns and cities to develop town/city specific waste management plans that are informed by human perceptions.

Keywords: Pro–environmental behaviour (PEB), plastic awareness and knowledge, Municipality, perception, plastic pollution, natural environment.

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CHAPTER ONE: GENERAL INTRODUCTION

1.1. Background of study

Plastic pollution on the natural environment is a major concern globally (Sivakumar, 2018). Plastic is a generic term which covers all different types of synthetic material used for packaging and manufacturing of various items (Dey et al., 2020). Plastics have been broadly utilised and have proven to be convenient for daily uses (Widayat et al., 2022). The amount of plastic production worldwide has been significantly increasing with great quantities of it being indirectly or directly disposed onto the natural environment (Geyer, 2020). Furthermore, despite being resistant to decomposition, old plastic packaging products greatly increase the likelihood of polluting the environment, including water, soil, and the ocean (Grebitus et al., 2020). Thus, local human community members are important actors and may contribute to the mitigation of plastic pollution problem by making different changes to their behavioural choices (McKinley, 2012).

It is important to assess the community's perception and pro–environmental behaviours (PEB) towards plastic pollution as they are major drivers. According to Hammami et al. (2017), community members persist to act in an environmentally unfriendly manner despite having a basic understanding of proper disposal of plastic waste. Consequently, it is intriguing to learn about the factors that affect how consumers react to the packaging of the products they use. Understanding consumers' purchasing and disposal decisions may contribute to solving the issue of plastics pollution. Thus, consumer behaviour in dealing with product packaging of waste can be used to understand how to solve the problem of environmental pollution caused by plastic waste. Rogayan and Elyionna (2019) observed a relationship between people's comprehension of ecological concerns and their behaviours in solving environmental issues. According to Sommer (2004), environmental sustainability is threatened by several environmental issues, including climate change, pollution, water scarcity, environmental noise, and biodiversity loss. Numerous of these issues have their origins on human behaviour and therefore manageable by changing the behaviour in question to lessen its detrimental impact on the natural environment (Manisalidis et al., 2020). For example, small changes with regards to recycling done by an individual could result in reductions in plastic waste dumping, which if done by multitude of people within a community trigger a significant change.

Pro–environmental behaviour (PEB) refers to any actions or behaviours that individuals engage in to reduce their negative impact on the environment and promote sustainable living (Omarova and Jo, 2022). Individual values and beliefs play a key role in shaping PEB. For example, individuals who prioritize environmental sustainability may be more likely to engage in PEB than those who prioritize economic growth or other values (Steg and Vlek, 2009). Social norms also play a role in shaping pro–environmental behaviour, as individuals may be influenced by the behaviour of their peers and social networks (Keizer and Schultz, 2018). Economic incentives, such as subsidies for renewable energy or taxes on carbon emissions, can also motivate PEB by aligning economic incentives with environmental goals. Finally, policy interventions, such as environmental regulations and public education campaigns, can provide a framework for promoting PEB and creating a culture of environmental stewardship (Pelletier et al., 2008). Pro–environmental behaviour is an important concept in the context of addressing environmental issues such as climate change, deforestation, and pollution. By promoting sustainable living and reducing negative environmental impacts, PEB can help create a more sustainable and resilient future for both humans and the natural environment. For instance, Calculli et al. (2021) made remarks that, individuals who are aware of environmental problems are more inclined to take part in creating solutions to existing environmental problems.

Some of the studies (e.g., Al–Haziazlet et al., 2019; Si et al., 2019; Nazareth et al., 2019) have been conducted to assess local communities' awareness of their behaviour and perceptions in relation to plastic pollution. It is essential for researchers to continue to raise awareness in the context of community's perception concerning plastic pollution. Identified patterns would be used to assist in recognising potential mitigation measures. Assessing the perception and PEB towards plastic pollution among the community members depends on their participation and eagerness. Thus, the environmental knowledge and attitudes are key elements for changing human actions (Laabidi, and Charafi, 2023). However, the limitation on changing human attitude is mostly due to the lack of applicable and positive environmental attitudes by educators (Molstad et al., 2018; So et al., 2021).

In as much as the social aspects of understanding plastic pollution for management purposes is important, identification of illegal plastic waste disposal and the type of disposed plastic in communities is important. Landfills, dumpsites, and illegal dumping areas are some of the main areas where most plastic is disposed within communities (Su et al., 2021). Once disposed, most of the plastic gradually degrade the environment, with small particles ending up in river and

natural ecosystems (Khoaele et al., 2023). The negative effects associated with plastic disposal mostly affect poor communities that reside next to dumpsites. Plastic, particularly microplastic can affect plant performance leading to reduction in food yields which in the long run affects the poor (Okeke et al., 2022). Effects on humans and animals linked to plastic pollution have been widely reported (Okeke et al., 2022). All these effects are mostly felt by the poor who reside close to dumpsites and have limited financial safety net to buffer the effects. Therefore, the identification of dumpsites, the type of plastics at dumpsites, and sizes of dumpsites is important if effective methods of managing plastic pollution are to be developed, particularly from an environmental justice standpoint. Most plastic is deposited along vacant lands, road verges, and commonages due to proximity to houses and the fact that these are open access areas (Leitão et al., 2023). The type of plastic being illegally disposed tend to vary depending in communities, users within an area, and consumer behaviour. It is important to conduct studies on spatial distribution of illegal plastic waste dumping and well as composition if better management strategies are to be developed, especially in Africa were financial resources to manage plastic pollution are limited.

1.2. Problem statement

One of the most critical problems of modern times is plastic pollution: each year, 436.7 million tons of plastic were manufactured globally by 2023 (Dorigoni and Bonini, 2023; Houssini et al., 2025). The increased consumption of products packaged in plastic bottles and bags is causing severe environmental problems. For example, plastic pollution may result in a negative impact on ecosystems, thus, including the mortality of organisms through ingestion or entanglement (Li et al., 2016), the depletion of ecosystem health (e.g., loss of fish), the contamination of marine life with microplastics (Merrill et al., 2023), which has implications for food safety and human health, property damage, and an increased risk of flooding in urban areas (Jaikumar et al., 2022). The ignorance and lack of intervention to examine community's perception and PEB poses a significant impact on the environment. Therefore, studies on perceptions and PEB are required to improve the community's management of plastic waste.

Very few studies (e.g., Dumbili and Henderson, 2020), have been conducted on human perceptions and PEB towards plastic pollution on natural environment within the African context, as well as South Africa, particularly in Mpumalanga province (e.g., Dalu et al. 2023). According to Dumbili and Henderson (2020), inadequate waste management and recycling infrastructure, a workforce that is underqualified or inadequate for collecting waste, lack of

awareness of the ecological and possible adverse health effects of plastic pollution, poor resource allocation, and late litter collection could all contribute to the plastic pollution problem's growth. In the local context, understanding pro-environmental behaviour and how to promote it is critical when it comes to plastic pollution, where there is widespread agreement that human behaviour is the primary cause (Dalu et al., 2023). O'Brien and Thondhlana (2019) investigated perceptions, practices, and potential intervention measures of plastic bag use in South Africa, and the findings revealed that while many participants believed there is a plastic issue around the country, they still used plastic bags as they considered them to be efficient. The link between PEB and ecological awareness was examined by Rampedi and Ifegbesan (2022), who showed that PEB and other environmental factors, such as environmental concern, knowledge, intention to make sacrifices, vary significantly by respondents' education level, location of residence, cultural identification, and region of residence. In Europe, a study by Soares et al. (2021) on public perceptions of plastic pollution revealed that understanding public perceptions regarding plastic pollution could be a helpful resource for engaging society in solutions to minimize its environmental impact. The study's participants regarded the bio–ecological effects of plastics as a greater concern than the socioeconomic impact. Therefore, there is a need for more PEB research on plastic pollution if the problem of plastic pollution is to be effectively managed.

Few studies have been undertaken to assess individuals' perceptions and PEB in category B municipalities (non–metropolitan municipalities) such as Nkomazi Local Municipality, located in Mpumalanga province of South Africa. Category B municipalities are towns and rural areas that are governed by a district municipality. While many studies on waste management studies in South Africa has concentrated on metropolitan municipalities (Rasmeni, and Madyira, 2019), and little is known about how people perceive and respond to plastic pollution in rural settings. Therefore, investigating community's perceptions of plastic pollution and PEB in both urban and rural areas is needed to develop effects ways to handle and disposal plastic waste.

Plastic pollution is frequent and apparent in developing countries, due to waste removal services which are ineffective or limited (Ferronato and Torretta, 2019). This is exacerbated by the illegal and improper disposal of plastic, with individuals resorting to incineration, causing other environmental degradation such as air quality. Furthermore, plastics might build up in neighbouring watercourses resulting in severe impacts to river ecosystem, which then subsequently affect ecosystem services. Knowledge on spatial location of plastic dumpsites

and the type of plastics being dumped becomes key in developing management measures. For example, municipalities need to know the spatial location of existing dumpsites if clean–up campaigns are to be conducted. This therefore requires studies on spatial location to be conducted. Such information can assist in locating the dumping, developing measures to address the dumping, and engaging stakeholders like plastic producers on how to manage waste if managers are aware of the type of plastic being dumped. Overall, spatial location of plastic dumping could address waste management challenges that municipalities face and help in resource allocation for waste management, e.g., more resources are areas with more dumps. Information from this study would be useful for raising awareness and enhance better management of plastic waste and lead to the better conservation of the natural environment within South Africa and the world at large.

1.3. The significance and justification of the study area

Plastics are low–cost, lightweight, and long–lasting materials that can easily be moulded into a wide range of objects for use in a variety of applications (Hopewell et al., 2009). Plastics have vast range of uses, people have found plastics to be advantageous and have become an essential component for human conveniency (Seyyedi et al., 2023). Despite this, there is rapid identification of plastic waste accumulating in landfill sites and the natural environment, with the likelihood of disastrous impacts for natural environment. According to Jambeck et al. (2018), plastic pollution in African nations is not just an environmental problem but also a significant societal and economic challenge that has an impact on the natural environment and infrastructures. Analysing how members of the community perceive plastic pollution risks and how such risk perceptions affect the environment provides an understanding and mitigation measures that will influence PEB and future behavioural changes. Given that people are intimately involved in the manufacturing and consumption of plastic products, Pahl and Wyles (2017) observed that social and behavioural research methods, such as qualitative methods, are required to assess people's perceptions and behaviour related to the impact of pollution on the environment. Previous research has found that, although people are aware of environmental challenges such as climate change and pollution, perceptions are that businesses and governments should have a greater share of the responsibility (Vince and Hardesty, 2017).

There is a need to understand plastic pollution, therefore results of this study will fill knowledge gaps and improve the improper plastic waste management and that exist within the Nkomazi local municipality. Although plastic pollution is a global issue, the implementation of local

plastic management policies and a local municipality's waste legal framework will aid in combating plastic pollution in the area. There is a continuing need to expand the municipality's field–data bases on perceptions and PEB around plastic pollution. This study will be utilized by industries such as produce packaging, built environment and construction, textiles, transportation and automotive, electrical appliances, and industrial machinery to understand and expand knowledge of plastic waste generation and disposal, as well as to improve PEB and contribute to the reduction of plastics in the environment. Although Soares et al. (2021), suggested that there is a general understanding that plastic materials degrade the natural environment, this study will provide in–depth knowledge of how individuals perceive plastic pollution, its impact on public health and the environment, and the development of innovative solutions meant to manage within the municipality (town specific solutions). Perceptions and PEB towards plastic pollution is an underexplored research topic in environmental psychology. There is a dire need to understand the fundamental reasons of individuals' choice of improper disposal of plastics after use. South Africa is working to address the issue of plastic pollution and its effects on human health and the environment. The information acquired will assist policymakers in better understanding which strategies may be most appropriate for Nkomazi Local Municipality to prevent plastic pollution. Infrastructure for waste handling must also be addressed. Policies that catalyse behavioural change encourage PEB. The results will encourage local legislators to advocate for policies that minimize plastic usage particularly single–use and boost municipal recycling facilities.

1.4. Research aim, objectives, and key questions

1.4.1. Aims

This study aims to assess the spatial distribution, composition, human perception, and PEB towards plastic pollution in the Nkomazi Local municipality, Mpumalanga Province, South Africa. Importantly, the study aims to determine whether residents' PEB and perceptions have an impact on plastic pollution.

1.4.2. Specific objectives

- To determine the spatial distribution, abundance, and composition of plastic pollution in Nkomazi Local Municipality.
- To assess human perception towards plastic pollution across different towns and villages in Nkomazi Local Municipality.

- To assess the relationship between plastic pollution and PEB across different towns and villages in Nkomazi Local Municipality.
- To assess the relations between waste management knowledge and PEB.

1.4.3. Key questions

(i) What is the spatial distribution and composition of plastic pollution at illegal solid waste dumps in different towns and villages in Nkomazi Local Municipality?

(ii) What are the local people perceptions and knowledge on plastic pollution effects in different towns and villages in Nkomazi Local Municipality?

(iii) Do members of the community consider plastic pollution to be a significant threat to the natural environment and human health?

(iv) Do members of the community already practice PEB related to plastic pollution reduction and municipal by laws?

1.4.4. Research hypothesis

Due to the complexity of the research problem and the requirement to achieve specific objectives, this study proposes two research hypothesis which will assist in answering the primary research aim.

(i) the abundance of plastic pollution within the natural environment will be greatly influenced by human knowledge, perceptions and behaviours and we expect to see a strong relationship among perceptions and behaviour with education levels, age, and gender.

(ii) there will be an increase in abundance of plastic pollution in areas where individuals are unaware of plastic waste management and have low perceptions and PEB.

Theories of positive social conduct will be used to better understand plastic waste pollution as an environmental concern. Further investigation into the relationships between perceptions, PEB and plastic pollution within Nkomazi Local Municipality, as well as the reasons behind, will lead to a better understanding of local policy consequences and management outcomes related to this complex issue.

1.5. Thesis structure

This thesis consists of five chapters. **Chapter 1** provides the background, study context, rational and justification of the study, study area, and research aims and questions. **Chapter 2**

provides a critical review of the literature, including key research themes related to plastic pollution. **Chapters 3 and 4** address the specific research objectives of the study, and each of the results chapters is written in the form of a manuscript that is ready for submission to a journal outlet. Therefore, the two results chapters have an abstract, introduction, methods, results, discussion, and conclusion. **Chapter 5** provides conclusions and recommendations for the study. All references are at the end of the thesis. Given the journal paper manuscript style adopted in research Chapters 3 and 4, the study area section is not repeated to maintain reading flow. It should be noted that the study area section within chapters 3 and 4 have been edited and shortened to only include relevant information to the arguments presented in each chapter.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Inadequate understanding of how to reduce plastic waste always results in pollution (Borrelle et al., 2020). Certain toxic substances included in plastic products impact the atmosphere, water, and soil (Alimba and Faggio, 2019). For example, plastic waste burning in an open area is one of the primary sources of air pollution. Most often, the 12% of plastics in municipal solid waste that is burned releases dioxins, furans, mercury, and polychlorinated biphenyls into the atmosphere (Verma et al., 2016). According to Zen et al. (2013) and Cai et al. (2020), whilst public perceptions against plastics in western industrialized civilizations have evolved from favourable to negative, this transition has yet to occur in developing nations, notably in Africa. According to Heidbreder et al. (2019), the extensive usage of plastic materials has resulted in increased plastic litter. In 2019, 460 million tonnes of plastic were manufactured globally (Ritchie and Roser, 2018). The above–mentioned numbers show that from the three million tonnes produced in 1950, the quantity has increased significantly (Ritchie and Roser, 2023), due to population and economic growth, climate, and social behaviour change (Ayuba et al., 2013). Furthermore, the amount of waste generated through anthropogenic activities is influenced by the rate of population increase (Kumar et al., 2022). Consequently, the amount of waste generated in each community is proportional to the population (Liu et al., 2019).

While the scientific community has been researching about plastic pollution and proposed solutions, the statistics of plastics manufacturing appear to be heading in a contrary direction, with greater demand and productivity (Sembiring, 2023; Zilberbrant and Kassee, 2023). Without interventions, it appears that the world will be unable to shift away from plastics rapidly, prompting concerns regarding how individuals perceive and respond to the problem of plastic pollution (Soares et al., 2021). According to Grimmer and Woolley (2014), attitude is a forerunner to behaviour, hence knowing the attitude that supports behavioural patterns is required to improve human response to problems such as plastic waste and pollution. As a result, public perception is one of the most critical and pressing issues that must be addressed to boost public support for future management of plastic pollution. For example, perceptions related to waste pollution are generally negative (e.g., waste is a nuisance) yet changing that perception could imply the change in human behaviour that could lead to better ways of managing waste by local communities. A positive narrative to waste recycling could trigger

positive behaviour towards waste resulting in waste pollution reduction. Thus, changes in human behaviour and perceptions could trigger positive behaviour and management of an environmental problem such as waste pollution.

It is crucial to understand the community's perception of plastic pollution to establish approaches to mitigate the problem and support collective initiatives to curb plastic pollution (Oguge et al., 2021). Most of environmental challenges are typically described using attitudes as they have previously shown to influence certain perceptual standards that are translated into social behaviours (Dilkes–Hoffman et al., 2019). The perception that minimizes the utilization of plastic is difficult due to the availability of plastics in a variety of everyday products certainly led to the low perceived behavioural control. To address the management issue, Zwicker et al. (2019) argues that perceptions and awareness among the society about pollution and waste disposal are essential. An Australian study conducted by Davison et al. (2021) indicated that most of the population was concerned about plastic pollution. According to Dilkes et al. (2019), the generation of plastics and its disposal are also significant problems. According to Fihlo et al. (2021), it is important to determine whether these perceptions and awareness about plastic pollution are converted into attitudes and even activities to combat plastic pollution. It is worth noting that perception and attitude are connected, yet they are fundamentally distinct. According to Fischer (2017), perception precedes attitude since it determines how a person organizes and interprets sensory information without assessing the data. When an individual assesses data with a specific bias, an attitude is formed. For example, research findings influenced by ideological convictions that plastic pollution does not alter the natural environment rather than being solely motivated by the search for empirical truth (Kenis and Mathijs, 2012). Furthermore, Stanton et al. (2021) showed that the present discussion on plastic waste may conceal serious environmental and social problems, and efforts to reduce plastic pollution need to be motivated by improvements in consumer habits. Turner et al. (2018) investigated the effect of exposure to environmental art on environmental perceptions, indicating that artistic images can influence attitudes and behaviours pertaining to plastic bag pollution. Further studies done by Salazar et al. (2022), showed that to get people's attention and encourage pro–environmental behaviour, negative drawings depicting the consequences of plastic pollution were more effective than positive ones. These findings imply that creative imagery may influence attitudes and actions related to plastic bag pollution.

The increasing quantity and rate of solid waste generation in South African municipalities, specifically the study area of Nkomazi Municipality in Mpumalanga is prompting concern (Nkomazi Local Municipality Final Integrated Development Plan 2017–2021). According to research undertaken in the South African context by Gumbo and Simelane (2015) and lately Nyika and Onyari (2021), open and uncontrolled dumping landfill sites are the most common type of solid waste disposal in South Africa. Rodseth et al. (2020) indicated that the overall amount of general waste generated in South Africa is high, this likely to have implication on informal disposed which is also high. It is estimated that 29% (3.67 million tonnes annually) of general waste generated in South Africa is not collected or managed through official waste treatment facilities (Rodseth et al., 2020). Estimates seem to suggest that rural communities generate 85% of the above–mentioned waste (Rodseth et al., 2020). To aid in improving the management of indiscriminate dumping in Fisantekraal, Cape Town, Niyobuhungiro and Schenck (2021) investigated the dynamics of indiscriminate dumping. The findings reveal that indiscriminate dumping poses a major concern and has potential to be a source of plastic pollution. The inefficient management of plastic waste in communities within South Africa and our study area may be caused by several factors, such as the municipality's lack of resources, lack of by–law enforcement, human behaviour, and lack of financial and human resources. The above–mentioned reasons appear to be a reality for most South African municipalities, especially is small towns and villages where such municipalities have limited power over their financial resources compared to big cities and metropolitans. For example, research by Serge (2020) in Orlando east municipality (a subsidiary of the City of Johannesburg Metropolitan), indicated that the municipality has little resources to successfully handle unlawful dumping activities. This is exacerbated by the fact that most households in troubled municipalities do not pay waste disposal fees. In our study municipality, only 8 375 of the 82 126 households pay for waste disposal services, this likely to trigger financial challenges to the municipality. According to Statistics SA (2011), the municipality's population has increased by a total of 1.61%, resulting in a population increase in most municipalities, especially urban centres. Population increase within the municipality and urban areas puts a strain on municipal waste collection services, resulting in waste collection delays (CSIR, 2011). Such waste collection delays tend to trigger illegal dumping behaviours and residents just want to get rid of the waste from their household yards. The dumping of waste then triggers plastic pollution since most illegally dumped waste is of plastic nature. It is important to emphasize residents' roles, perspectives, waste disposal practices, and interactions with other parties such as

municipality and private waste treatment facilities involved in the collection and disposal of the waste as they are the facilities' primary ultimate users (Negussie et al., 2017).

Most South African's municipalities continue having difficulties in achieving their goals as outlined in the constitution, even though municipalities are granted the authority to deliver and manage municipal services (Glasser and Wright, 2020). According to Shongwe and Meyer (2023) most municipalities are troubled by both internal and external problems that contribute to substandard service delivery for which waste handling is one of them. Most municipalities have problems such as corruption, lack of financial and human resources, and maladministration, that ultimately affect service delivery. Poor waste collection is typically prevalent in low–income communities resulting in residents disposing waste in the closest unoccupied land, watercourses, or practice incineration in their backyards (Haywood et al., 2021). If waste is not collected, residents' resort to opening illicit dumps, which has become the traditional way of disposal in most South African municipalities, because of insufficient waste collection services (Ngalo and Thondhlana, 2023). Other studies (see Polasi, 2018; Ngalo and Thondhlana, 2023) showed evidence that the primary cause of the prevalence of illicit disposal was the lack of or inconsistent waste pickup from the municipality.

Government involvement is required to address the impact of waste disposal habits. Interventions could be in the form of enforcing measures to reduce dumping through plastic payment fees, awareness campaigns on recycling, strengthening plastic pollution by–laws, and engaging companies to reduce plastic production and advocate for plastic substitutes (Deng et al., 2020). According to Bartolotta et al. (2018) and of late Gupta and Roy (2022) government assistance is required since taking individual action to combat plastic pollution can be exceedingly difficult, especially when practical alternatives are lacking and there are other impediments such as inadequate political change objectives, waste management scalar disconnects and poor public and private sector accountability for plastic waste management. While education and social pressure can help communities develop positive perspectives and behaviour, they are also tied to government regulations (Heyes and Kapur, 2012). It has been highlighted by Chen (2021) that plastics prohibition ought to be accompanied with enforcement and monitoring, alternatively the prohibition would fail. This was particularly apparent in Africa, where legal restrictions on the usage, production, and distribution of plastic bags had little effect due to the minimal enforcement, improper execution, and lack of cooperation (Deng et al., 2020).

2.2. Extent of plastic pollution

Globally, waste dumping which is associated with plastic pollution is a problem that need to be well studied. Close to 2.1 billion tonnes of waste is produced a year, of which 38% of the waste is uncontrolled (illegally dumped) (UNEP, 2024). Of the above–mentioned waste, a significant amount is plastic waste that is most produced in urban areas, and factors that cause increased waste pollution in urban areas include increase urbanisation, rural to urban migration, inefficiencies linked to municipalities, lack of effective waste management plans, and human behaviour (Maalouf and Mavropoulos, 2023; Lu et al. 2024). Once disposed, plastic waste becomes a problem to the environment. Most of the plastic waste is deposited on open areas, vacant spaces, and along road verges (Ngalo and Thondhlana, 2023). This is because these areas are close to houses (households just want to get rid of the waste) and are free for all open spaces with less rules that govern their uses (communal areas). Studies in South Africa have shown that dumping of waste in general (including plastic) is prevalent in poor communities due to poor waste management and collection services (Polasi et al., 2018; Ngalo and Thondhlana 2023; Swanepoel and Marlin 2024).

Waste in South African is governed by the National Environmental Management Waste Act 59 of 2008, which advocates for local municipalities to development integrated waste management plans. These integrated waste management plans are meant to outline specific steps to manage waste within municipalities (DEA, 2012). With several municipalities struggling to manage waste in general and specifically plastic pollution, some innovative solutions are needed, yet these solutions need to be research based, including geo–locating the current waste sites to develop immediate clean–up campaigns. The National Waste Management Strategy (NWMS) of South Africa promoted waste minimisation, re–use of plastic, recycling, and waste recovery. The strategy is hierarchical because it tries to deal with waste before it is deposed so that what is disposal is minimal. Plastic pollution and waste in general should be dealt with by managing it across its life cycle ranging from production reduction, plastic use avoidance, to treatment and recovery of the already used plastic. This strategy is globally effective; however, its implementation is South Africa is ineffective thus resulting in the current challenge of waste in the country. The increase in plastic dumping in most South African urban and rural areas is evident that the problem is on the rise (Swanepoel and Marlin 2024). Statistics in South Africa show that the country produces approximately 12.7 million tonnes of domestic waste (plastic included) and an estimated 3.7. million tonnes are

not collected (Polasi et al., 2018; Rodseth et al., 2020). Interrogating why humans dump waste and where they dump is important in developing effective methods to manage waste. Waste and plastic pollution as a complex problem that is driven by several social, economic, and political factors (Polasi et al., 2018), thus studies on pollution should integrate these issues.

2.3. Public perception on plastic pollution

According to Efron (1969), perceptions involve the cognitive interaction with the outside setting surrounding a person. Rogers (2017) further elaborates the term perception as the study of how we direct and regulate our behaviour by using the information received from our senses to generate our unique, subjective views of the outside world. Maloney (2018), distinguished perception from two perspectives; thus, intentionalisms and theorist. Intentionalisms define perception as a form of psychological state realised by an unusually contently mental representation, while a theorist may characterise a perceptual state as sensual because it contains the content of a complex mental state (Maloney 2018). The definitions above present plausible observations to conclude that an individual's perceptions are shaped by a variety of factors, which in turn affect their behaviour. Park and Chun (2014) reported a variety of factors that affect how we see local phenomena; thus, what we see is greatly dependent on how our brain tries to understand the scene rather than being only a reflection of its physical attributes. In addition, the context in which local characteristics are given, our prior visual experiences, and our anticipation of what is going to be in front of us all influence our perceptions (Gilbert, 1996). Gitelson and Kerstetter (1990) and Andersen et al. (2022) both found a link between sociodemographic factors and the advantages of certain behaviours. Sociodemographic variables are defined as attributes of a population, such as age, race, ethnicity, gender, sexual orientation, income, education, and marital status. These kinds of variables are frequently utilised to comprehend whether such characteristics differ in relation to one another (Ishitani, 2023). For instance, differences in education level and how it varied by race and individually or in iteration explain changes in a social research variable. Soares et al. (2021) examined how sociodemographic features affect perceptions and revealed that participants understand how crucial it is for society to create mitigation plans and improve public awareness.

The perception of plastic pollution has been explored in previous studies (see Molloy et al., 2022; Soares et al., 2021; Syberg et al., 2018). The use of factor analysis has proved to be efficient in closing a significant knowledge gap and raises public awareness, both of which aid to improve communities waste management. For example, Koelmans et al. (2017) examined

the risk perception towards plastic waste and reported that it is necessary that we cease characterising impacts, issues, risks, and threats as a 'possibility' and that the greatest foundation for minimising plastic waste in the environment is an objective evaluation of both benefits and costs. Considering that studies and mitigation initiatives are costly and have limited resources, Koelmans et al. (2017) define perceptions of plastic pollution as moral problems. However, scientists play a critical role in providing the most accurate knowledge (Weichselgartner and Kasperson, 2010). The study demonstrated systematic assessment based on ecologically appropriate metrics for exposure, the results encourage legislators to act based on scientific evidence. Gnimadi et al. (2022) investigated the influence of individual views on the disposal of plastic waste. To assess the mental mindset that encourages individual's utilisation of plastic products, a factor analysis was utilised. According to the perspectives of the respondents, several problems, including municipally inadequate waste collection, lack of education and knowledge, were regarded as being influential.

2.4. Pro–environmental behaviours

Pro–environmental behaviour (PEB) can be defined as behaviour that "harms the environment as little as possible or even benefits the environment" (Steg and Vlek, 2009). Decisions made by individuals to adopt and use new and environmentally friendly innovations that protects the environment are referred to as PEB (Chauhan, 2020). Kurisu (2015) defined PEB as behaviours that contribute or are perceived to contribute to environmental conservation. Understanding PEB and ways to promote them is critical in relation to environmental challenges where there is broad recognition that human action is the primary contributor of plastic pollution (Doran and Zimmerman, 2009; Maibach et al., 2014; Muncke et al., 2020). According to Gifford and Nilsson (2014), psychological and social variables can predict future PEB trends, whilst Turreira–Garca et al. (2018) highlighted empowerment as a factor that informs PEB. Yue et al. (2022) did a study with students to evaluate the effectiveness of environmental education in promoting PEB and minimising students' use of plastics. The results show that when environmental education was implemented, students' perceptions, attitudes, and self–reported pro–environmental conduct towards plastic usage and pollution considerably increased. Additionally, Chib et al. (2009) employed educational campaigns to empower Singaporean youth and change their attitudes towards plastic consumption. With the prevalence of internet culture among Singaporean youth, the use of the internet was found to be effective in shifting the attitudes of the campaign audience in question. As a result, educational empowerment may be concluded to be the most effective in fostering pro–environmental conduct.

Studies by Liobikienė and Juknys (2016) and Syberg et al. (2018), highlighted risk perception as a factor that informs PEB. Risk perception has an important role in promoting PEB intention (Težak et al., 2023). A conceptual model developed by Zhou et al. (2020) shows the links between the PEB and the aspects of Chinese farmers' perceptions on the risk of soil contamination, as well as the moderating influence of the income level of the farms on these correlations. According to the study, farmers' risk perceptions about the of soil pollution had a favourable impact on their PEB. Furthermore, Yoon et al. (2021) carried out an investigation to determine the association between people's risk perception of microplastics and PEB intention. The findings were that risk perception has a considerable impact on PEB behavioural intention and is impacted by knowledge as an environmental stimulus.

According to Cheng and Monroe (2012), nature–connectedness (nature–relevant experiences) has been found to influentially predict PEB. Wilson (1984) biophilia's concept hypothesised that all people are intrinsically and emotionally attached to nature. According to the study conducted by Cheng and Monroe (2012) factor analyses were carried out to investigate and validate many elements in the connection to nature index. To investigate the relationship between variables, a route analysis was used. The outcomes of the study showed that connection young people have with nature impacts their desire to engage in nature–based activities in the future. Children's connection to nature, prior experience in nature, perceived family value towards nature, and perceived control all affected their willingness to engage in PEB. Studying sociodemographic and psychological aspects, according to Soares et al. (2021), can help us better understand how to improve PEB and help reduce the amount of plastic in the environment. According to Wahid et al. (2020), environmental education can increase PEB and help reduce plastic pollution. Furthermore, PEB assists individuals in minimising the negative environmental repercussions of their behaviours (Hossain et al., 2022). Use of PEB knowledge to understand global problems like waste can help uncover knowledge gaps and act as a catalyst for raising awareness and exposing people to environmentally friendly practises that help individuals to avoid inappropriate plastic disposal, e.g., recycling plastics or reducing plastic consumption.

2.5. Impacts of plastic pollution on the environment

Mass plastic manufacturing and inadequate end–of–life plastic product control have resulted in yearly increases in plastic entering the marine environment (Welden, 2020). Jassim (2023)

defines micro plastics as tiny plastic fragments that form because of the breakdown of bigger plastics and the production of commercial products. Micro– and nanoplastics have an impact on marine life, including primary producers such as microalgae and predatory species like fish, on a variety of endpoints like survival, reproduction, behaviour, ability to reproduce, energy reserves, and immune function (e.g., Soares et al., 2021, Pisani et al., 2022). According to several recent studies (e.g., Jambeck et al., 2018; Soares et al., 2021; Pisani et al., 2022) plastics are eventually carried to the marine environment via drainage and sewage systems, rivers, and wind resulting in significant effects on the marine system. Plastic pellets are estimated to account about 10% of beach litter (Moore, 2008), this is likely to influence beach ecosystems and tourism at large. Polystyrene, a common kind of plastic in the ocean which can leak into the water causing negative effects on river systems (Reddy et al., 2014). The most prevalent kinds of maritime debris are polystyrene fragments and plastic pellets (Barnes et al., 2009).

Toxic chemicals such as dioxins released by chlorinated plastics into the surrounding soil can seep into ground water or other nearby watercourses (Reddy et al., 2014). Moreover, the process of plastics manufacturing includes the utilisation of colouring substances and initiators that are toxic when exposed to animals that live in the natural environment, resulting in a severe impact on the biological system (Darensbourg, 2007). According to Chitotombe and Gukurume (2014) most people dispose plastics waste post consumption since it is the most convenient and least expensive approach. However, this act results in unmanaged plastic debris spreading on the natural environment (Abalansa et al., 2020). Additionally, these plastic elements eventually end up in unmanaged dump sites and are deposited as a covering layer over the land surface on the surrounding area. If these hazardous degraded polymeric components permeate the earth's surface and blend with groundwater aquifers, the quality of the ground water changes, resulting in ground water contamination (Biswal., 2020). According to Agnes et al. (2016), all anthropogenic activities that cause environmental degradation must be reduced. Given the increased amount of waste generated by the increasing usage of plastics, greater efforts should be placed upon recycling, waste–handling, and pro–environmental solutions.

2.6. Impacts of plastic pollution on humans

In the world's oceans, inland watercourses, and terrestrial habitats, extremely persistent plastic waste is gathering and fragmenting, posing a concern on a global scale (Vethaak and Leslie, 2016). Humans are being subjected simultaneously to plastic particles and substances emitted by commercial plastic waste. According to Bouwmeester (2015), microplastics are

fragmenting, leaking, and spreading across the ecological system, including air, soil, and watercourses. Plastic particles can enter the body through the ingestion of marine food products, drinking water, and the atmosphere (Zhang et al., 2020). Proshad et al. (2018) explored numerous toxic and dangerous compounds including brominated flame retardants, thalates, antiminitroxide, and polyfluorinated chemicals that are found in plastics, they pose a major risk to both the environment and human health. According to Huang et al. (2018), the aforementioned substances are likely to induce cardiovascular disease when exposed to them. Microplastics have been proven in studies to severely harm cells in the human body, resulting in major health impacts such as cancer, lung illness, and birth abnormalities Yee et al., (2021).

Communities that reside close to plastic dumpsites have a higher chance of having pollution related diseases such as breast cancer, depression, and asthma (Fazzo et al., 2023). Tomita et al. (2020) reported that residents that live close to dumpsites (which we know are dominated by plastic) have a high risk for health problems compared to those that reside far, this linked to the toxic chemicals that are associated with plastic at dumpsites. Plastic dumpsites attract flies and other animals like rats, which can end up in houses thus contaminating food, resulting in health effects. Apart from health effects, plastic pollution affects humans by affecting the economic value of the area (Ngalo and Thondhlana, 2023). For example, properties that are close to plastic dumpsites could be less valued economically compared to properties that are far from the plastic dumpsites (Ngalo and Thondhlana 2023). The above–mentioned studies seem to suggest that plastic waste affects humans directly (e.g., health) and indirectly (e.g., property value). Putting everything together, the effect of plastic pollution is regarded as a social justice problem because certain members of the community are affected more compared to other. Studies have shown that it is mostly the poor and less privileged members of the society that are mostly affected by waste pollution (Couth and Trois, 2012; Kubanza and Simatele, 2016). The poor tend to bare most of the impacts related to plastic pollution compared to the rich, yet the poor have limited financial resources to deal with waste problems.

2.7. Conceptual framework – Theory of planned behaviour

Theory of planned behaviour is defined as psychological framework that integrates beliefs with behaviour (Anderson, 2007). The theory was introduced by Azjen (1991) and is remarkably precise in predicting intentions to engage in various types of behaviours, moreover the theory attains data through experiments and observations. This study will use the Theory of Planned Behaviour (TPB) to examine how residents of Nkomazi Local Municipality perceive and act

in favour of the environment in relation to plastic pollution. According to Prati et al. (2015), the theory is made up of three variables namely, attitude, subjective norm, and perceived behavioural control (PBC). These variables are determinants of intention–behaviour which will foresee actual behaviour (Fielding et al., 2008). Additionally, the qualities of these variables influence an individual's behaviour, therefore this theory will be applied in the study to examine the community's intention to engage in ecologically unfriendly habits that promote plastic pollution. This approach has previously been explored in understanding environmental issues collectively, also applicable to the study of PEB and perceptions of plastic pollution. For instance, a previous study by Hasan et al. (2015), investigated the link between factors that influence behavioural intention of students in decreasing plastic use. Results of the above–mentioned study reported that perceived behavioural control (PCB) had the strongest link with behaviour when compared to other factors. Using the TPB framework, De Leeuw et al. (2015) examined the beliefs that affect young people's PEB and reported that framework elements of attitude, perceived control and subjective norm contributed prediction pollution behaviours. It is important to assess residents' perceptions and behaviours regarding plastic usage given that they have basic knowledge to issues concerning sustainability. Individuals have a basic comprehension of the environmental consequences of their anthropogenic activities, thus more research that interrogate human behaviour and environmental problems is needed. There exists a research gap on understanding human behaviour when it comes to waste pollution.

CHAPTER THREE: SPATIAL DISTRIBUTION, LOCATION, AND COMPOSITION OF ILLEGAL PLASTIC WASTE DUMPING IN NKOMAZI LOCAL MUNICIPALITY, MPUMALANGA, SOUTH AFRICA

Abstract

Plastic pollutants are widely distributed in urban and rural areas of South Africa, yet few studies have been conducted to examine their spatial distribution, abundance, and composition. Although plastic pollution awareness programmes have intensified in various communities, the problem of plastic disposal continues with significant socio–economic, environmental, and human health problems. This study aimed to assess the spatial distribution, abundance, and composition plastic pollutants in the Nkomazi Local Municipality, Mpumalanga Province, South Africa. The study was conducted across nine areas that were randomly selected across three big towns (i.e., Komatipoort, Malelane, Hectorspruit), three small towns (i.e., Tonga, Kamhlushwa, Schoemansdal), and three villages (i.e., Phiva, Ntunda, Schulzendal). Using a drive–by survey method, results show that illegal dumping of plastics was common across all urban and rural areas but was more prevalent in low–income areas in big and small towns. More than 90% of the encountered illegal plastic dumpsites were categorised as of large size with most of these located in big and small towns than villages. Across all sampled areas, illegal plastic dumpsites were located along roadsides and vacant plots. Polypropylene (PP) and polyethylene terephthalate (PET) were the most common plastic identified across most dumpsites, being more visible in rural than urban areas. The study concludes that illegal plastic dumping is prevalent across the study areas, however, it was more prevalent in low–income areas in big and small towns than in villages, an indication that urban waste collection is not being done efficiently. The study recommends, increased public awareness, improved waste collection infrastructure (e.g., putting bins in public places), and policing waste management by–laws as measures aimed to reduce illegal plastic dumping.

Keywords: Plastic dumping, plastic pollution, municipalities, waste perceptions, waste composition.

3.1. Introduction

Plastic pollution presents a significant global challenge, affecting both humans and the environment (Bidashimwa et al., 2023). The Global Plastic Outlook (2021) reported that plastic production has increased from 2 million tonnes in 1950 to 460 million tonnes in 2019. It is estimated that only 15% of the plastic produced globally is managed properly, meaning the bulk of the plastic is mismanaged i.e., it is not disposed adequately (Global Plastic Outlook, 2021). A recent study on plastic pollution estimates that plastic pollution, mainly due to plastic mismanagement, will reach up to 66.1 million tonnes annually (Yan et al., 2024). Plastic pollution is exacerbated by several factors such as increased human population, urbanisation, the rise of plastic production to meet human use demand, excessive dependence on single–use plastics, and inadequate waste management systems (Stoett, 2022; Bidashimwa et al., 2023). Most of the mismanaged plastic waste end up at uncontrolled illegal dumpsites or burned in open areas (Global Plastic Outlook, 2021). Illegal plastic dumping refers to the unlawful disposal of various types of waste, including plastics, on public or private land without authorization (Bukova et al., 2016). Illegal waste dumping is also known as littering, fly dumping, or fly tipping to refer to the unauthorizes way of dumping waste (Al Fariz et al., 2024). Previous studies have reported that illegal plastic waste dumping can lead to significant damage to the environment through plastic leakage which subsequently affect human health (Ahmed et al., 2018; Gambhir et al., 2024).

Although most of the plastic is produced in developed countries, who also have better plastic disposal mechanisms and technologies, developing countries particularly in Africa are projected to significantly contribute to the increase of plastic waste generation and disposal in future (Lebreton and Andrady, 2019; Yan et al., 2024). This is simply because Africa is on a positive economic and population growth, thus it will require more plastics in future. Yet, most African countries presents severe plastic waste generation and disposal challenges due to several factors that are unique to the continent, such as inability to collect waste by municipalities, lack of financial resources to manage waste, corruption, dysfunctional municipalities, inefficient collection methods, and illegal waste dumping as a social and behavioural problem (Ngalo and Thondhlana, 2023). For example, a study in Nigeria showed that plastic waste illegal disposal and dumping was prevalent at universities, mainly due to lack of laws that prohibits plastic disposal (Dumbili and Henderson, 2020). Ngalo and Thondhlana (2023) reported that plastic was one of the main products found on illegal dumpsites that were in Komani town, South Africa. Bigger African economies tend to produce a lot of plastic waste

e.g., South Africa (11.6%), Nigeria (16.9%), and Egypt (18.4%) (Babayemi et al., 2019), therefore it is projected that these countries will also have high waste disposal in future.

The illegal dumping of plastic waste in African countries has been well researched (Onifade and Nwabotu 2014). Firstly, illegal waste dumping, mostly plastic dumping is more prevalent in low–income and informal settlements due to poor waste management services and issues of accessibility (Palamuleni and Tshabalala, 2023; Jakeni et al., 2024). For example, Ngalo and Thondhlana (2023) reported that low–income households recorded more dumpsites in Komani town located in South Africa and this was mostly due to social and economic reasons. Tombe (2024) compared high and low–income areas and noted a high number of illegal waste dumping in low–income than high–income areas of Makhanda and Knysna. Secondly, illegal waste dumping is mainly due to poor municipal service delivery, particularly in South Africa where service delivery is a challenge. Haywood et al. (2021) reported that most dumping in low–income areas in South Africa is due to poor solid waste collection services. The poor who do not have the financial means to dispose waste on designated areas tend to illegally dump waste due to lack of collection by municipalities. Thirdly, the above makes illegal waste dumping a financial issue. When it comes to finance as a driver of illegal waste dumping, there are two factors at play, (i) failure by individuals to dispose waste because they do not have transport to go and dump at the designated dumping site, and (ii) financial failures by municipalities to collect the waste. Fourthly, illegal waste dumping is a behavioural problem, meaning people dump because they see others dumping. Ngalo and Thondhlana (2023) used household interviews to conclude that some people dumped because they saw others dumping and because they saw it as a better way to get waste away from their property. Lastly, illegal waste dumping is treated as a social justice issue, since dumping is prevalent in areas were low–income people stay, thus the negative effects of dumping affect the most vulnerable members of society more. Generally, illegal waste dumping is perceived as a negative social issue, and this is evident in property value with houses close to dumpsites being cheaper than those far away (Tombe, 2024).

Plastic pollution, particularly if dumped on illegal dumpsites has significant environmental, social, and health effects (Gambhir et al., 2024). Plastics' inability to biodegrade poses long–term harm to the quality of soil, water, and air (Panthi et al., 2023). For example, illegally dumped plastics can become a source of pollution along urban rivers and drainage systems thus affecting water flow and causing flooding during rain seasons (Zhou et al., 2023). Dumped

plastics can choke fresh water and marine life causing severe loss of animals. Other studies have shown that dumped plastic can damage soils and poison groundwater causing serious health effects to communities that depend on ground water (Witbooi, 2003). In some urban areas where animals roam around streets, donkeys and cattle have been reported to ingest plastic on dumpsites which can lead to animal death (Tombe, 2024). A study by Katlam et al. (2018) documented that over 250 animals unintentionally ingested plastic or become entangled in plastic, this likely to cause animal death. Furthermore, substantial amounts of plastic pollutants have been discovered in animal milk samples, affecting the livelihood of the animals (Nagy, 2019). Economically, illegal dumpsites dominated by plastics have negative effects on aesthetical displeasure thus negatively affecting tourism and even economic activities for shops that are close to dumpsites. Onifade and Nwabotu (2014) reported economic challenges linked to plastic waste dumping such as increased healthcare costs to people leaving adjacent to dumpsites and decreased property values in dumpsite affected areas. With close to 29% of household waste in South Africa not being collected regularly (Rodseth et al., 2020), illegal dumping of waste is now associated with service delivery protests, thus one can easily say that waste dumping is associated with social unrest. Lastly, illegal waste dumping has a financial cost liked to clean–up programmes. For example, the annual cost of removing urban garbage from rivers in South Africa is estimated at two billion Rands (Armitage and Rooseboom, 2000), meaning waste is a cost to the country's economy.

Research across different countries has revealed the presence of various types of plastics on illegal waste dumpsites (Witbooi, 2003; Mazhandu et al., 2020; Banik et al., 2023), meaning composition tend to differ. Plastic waste composition on illegal dumpsites differs due to (i) the type of products that communities use within an area, (ii) waste collection regularity, (iii) household income, (iv) pre–disposal measure that are being implemented e.g., recycling before disposal, and (iv) post disposal interventions such as plastic waste picking by waste pickers for income generation. Adewuyi et al. (2024) highlighted that the most encountered plastics in African nations include polyethylene terephthalate (PET), polyurethane (PU), polystyrene (PS), polyvinyl chloride (PVC), polypropylene (PP), polyester, polyethylene (PE), and polyamide (PA), also referred to as nylon. In Nigeria, PET bottles were the most common (28.5%) disposed plastic waste, followed by PP and LDPE (Ibor et al., 2022). Similarly, in Poland, illegal dumping sites are primarily dominated by plastics and glass products (Wolny–Koładka et al., 2015). In countries where plastic recycling is common, few plastic products are found on dump sites because of the recycling policies. For example, Nagpure (2019) reported

that households in India tend to segregate waste for saleable recyclable waste such as paper and plastic and this has positive effects on the waste composition. However, recycling works if there is a good market for recyclable material so that one can economically benefit from collecting recyclable material. This therefore means that there is need for financial incentivising recycling if it is going to have a positive effect on illegal waste dumping and waste composition.

Several measures to reduce illegal plastic waste dumping have been put in place, such as municipal by–laws that prohibit waste dumping, development of national legislations, awareness campaigns, plastic recycling programmes, erecting of bins and dumping areas, and fines for illegal dumping of plastic waste. In South Africa, the National Environmental Management: Waste Act of 2008 advocated for the development of waste management strategies aimed at developing plans and programmes to tackle waste. To be able to develop effective waste management plans and programmes, it is imperative to know the spatial distribution and composition of waste within each area, particularly illegal dumpsites. Having an inventory of where dumping is happening, its abundance, and waste composition can assist municipalities develop comprehensive and effective waste management strategies. Unfortunately, this information remains anecdotal since waste dumping is dynamic because it is perceived illegal, so dumpsites change locations overtime. However, spatially locating dumpsites using drive–by road–street–surveys have been shown to be an effective way of locating waste dumping in urban areas. Although GIS and remote sensing are effective tools to identify waste in a landscape, the effectiveness of these tools is limited especially in vegetated areas and where dumpsites are small, thus drive–by road–street–surveys are effective. Given the above, this study used a drive–by road–street–surveys to examine the spatial distribution and composition of illegal plastic waste dumping in Nkomazi local municipality located in Mpumalanga Province of South Africa. The specific research objectives were (i) assessing the abundance and spatial distribution of illegal plastic waste dumping in Nkomazi local municipality in Mpumalanga province of South Africa, and (ii) assessing plastic composition found on illegal plastic waste dumpsites in Nkomazi local municipality located in Mpumalanga Province of South Africa.

3.2. Methods

3.2.1 Study area

The study was conducted across nine study areas, six towns and three villages located in Nkomazi local municipality, in Mpumalanga province of South Africa (Figure 3.1). The nine study areas were categorised as three big towns, namely Komatipoort, Malelane, and Hectorspruit, three small towns of Schoemansdal, Kamhlushwa, Tonga, and three villages, namely Phiva, Ntunda, and Schulzendal. The rational of conducting the research across the above–mentioned study towns and villages was to gather plastic pollution data across varied urban and rural context. Nkomazi Local Municipality is a category B municipality located within Mpumalanga province, which is in northeast South Africa. Nkomazi Local Municipality falls under Enhlazeni Dstrict municipality which is situated in the eastern part of the Mpumalanga province. It is bounded to the north by the south–eastern portion of the Sabie River in the Kruger National Park, Mozambique to the east, Swaziland to the south, Mbombela city to the west, and Mbombela local municipalities to the southwest. The geographical area of Nkomazi local municipality is 478 754.28 hectares in size (Statistics, 2011). It is the smallest of the four municipalities in the district, covering 17% of the district's total geographical area. Nkomazi municipality is largely a rural region, and it has a high percentage of unemployment (IDP 2014). Nkomazi local municipality is situated in a summer rainfall zone, with the rainy season typically occurring in austral summer from October to March. Annual precipitation in the region ranges between 750mm to 860mm (IDP 2014), and summers are hot averaging 26.2°C whilst winters mild averaging 18.4°C (Abiodun et al., 2018). The Nkomazi Local Municipality falls within the savannah biome which is characterised by grassy ground layer and a distinct upper layer of woody vegetation which makes up around 33% of South Africa's total land area (IDP 2014). Soils are generally loamy, derived from quartz monzonite, basalt and arenite and lava rocks.

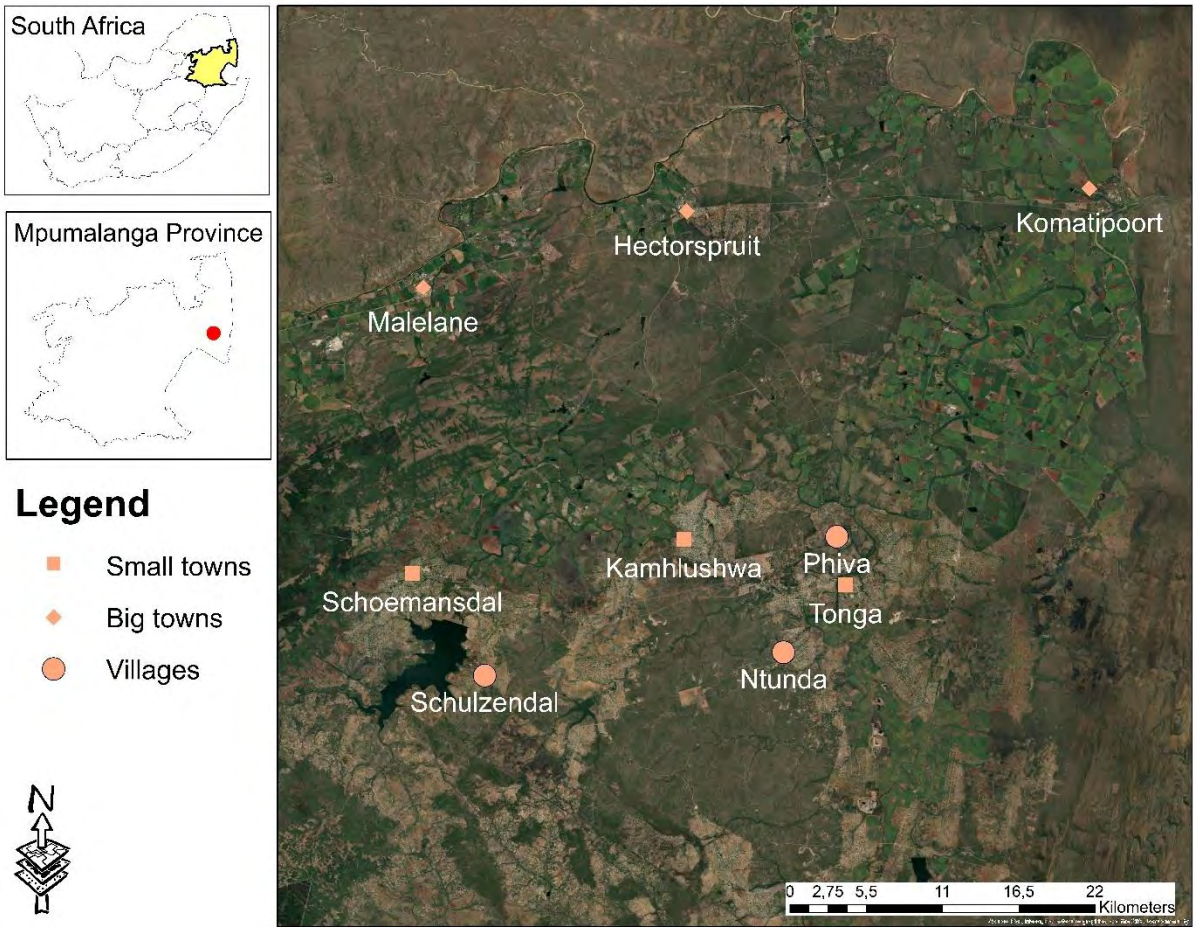

Figure 3.1: Location of the study towns and villages in Nkomazi local municipality in Mpumalanga, South Africa.

The municipality's overall population is 591,928 with 134,143 households (Statistics SA, 2022). Poverty levels in the study areas are high and most of the people are illiteracy and unemployed (IPD, 2014). Nkomazi Local Municipality's primary economic sectors include coal mining, forestry, agriculture, and tourism (Gininda et al., 2014). Tourism is mostly driven by proximity to Kruger National Park which attracts many local and international visitors due to its rich biodiversity. See Table 3.1 for town and village details.

Table 3.1: Details of the six towns and three villages in Nkomazi local municipality.

Place name	Status/category	Geographic Location	Main economic activity	Area (km^2)	Population	Population density (km^2)	Demography (% African black)
Komatipoort	Big	25°26′S 31° 57′E	Tourism	11.71	4683	400	61
Malelane	Big	25°29′S 31° 31′E	Agriculture	2.94	3 486	1200	43
Hectorspruit	Big	25°26′S 31° 41′E	Agriculture and tourism	10.26	3 096	300	78
Tonga	Small	25.675°S 31.877°E	Agriculture and tourism	7.47	17333	2300	99
Kamhlushwa	Small	25.652°S 31.684°E	Agriculture and tourism	9.45	21800	2311	98
Schoemansdal	Small	25.703°S 31.506°E	Agriculture and tourism	12.91	23257	1800	99
Phiva	Village	25.639°S 31.776°E	Agriculture	4.61	4832	1110	100
Ntunda	Village	25.730°S 31.751°E	Agriculture	4.42	3425	757	100
Schulzendal	Village	25.749°S 31.540°E	Agriculture	2.74	3659	1300	100

3.2.2. Experimental design and data collection

Within Nkomazi local municipality, three big towns, three small towns, and three villages were selected for the study. The distinction between big and small towns was based on the services that are provided within each urban area and the existing colonial legacy that shaped the urban areas. Mostly big towns are regarded as towns with bigger economic activities and service provision, whilst small towns have less economic activities and less service provision. Villages were regarded as settlements with a rural setting. The study towns and villages were randomly selected through (i) identifying all the towns and villages in the area using google earth and listing them in excel spreadsheet, (ii) assigning numbers to all the identified towns and villages, and (iii) using the excel randomisation function to select three big towns, small towns, and villages. It is possible that some villages were omitted on google earth identification process due to accuracy in visibility and google earth naming challenges, therefore some sampling bias is possible, however, the strength of the study is not in the selection of towns and villages but in the collected data which can be used to make plastic pollution generalisation outcomes across the study area. Within each selected town and village, a drive–by survey method was used to gather plastic pollution data. Using google earth, all town and village streets and pavements were identified and marked for field visits to identify illegal solid waste dumpsites. The drive–by survey method was conducted using a moving vehicle with field workers observing each side of the road and pavements that were identified in each study area. In some cases, street and pavement walking was conducted in cases where driving was impossible. The

drive–by survey method is effective at identifying illegal plastic waste dumpsites which justifies the use of the method in this study (Ngalo and Thondhlana, 2023).

At each identified illegal plastic waste dumpsite, the following information was collected (i) coordinates of the dumpsite, (ii) location of the dumpsite, (iii) size of the dumpsites, and plastics composition on the dumpsite. Illegal plastic waste dumpsite coordinates were recorded using a Garmin global positioning system (GPS) device. Illegal plastic waste dumpsite location was recorded based on proximity features such as roadsides, river/wetlands, parks (e.g., green parks), vacate land/plots, and commonages. This was based on categories that have been used in previous studies such as Ngalo and Thondhlana (2023) and Tombe (2024). Dumpsite sizes were estimated based on the number of illegally dumped plastics at the encounter dumpsite, as small (1–50 plastics), medium (51–100 plastics), and large (>100 plastics). The plastic composition was categorised as polyethylene terephthalate (PET or PETE), high–density polyethylene (HDPE), polyvinyl chloride (PVC), low–density polyethylene (LDPE), polypropylene (PP), polystyrene (PS) and other plastics. Additionally, photographs were taken to assist in identifying the different types of plastics. Data on notable activities around dumpsites was obtained, e.g., proximity to public spaces such as (cemeteries and clinics), proximity to homes and shopping marketplaces. Activities such as children picking artefacts, animals grazing, domestic animals foraging, and incineration were also noted.

3.2.3. Data analysis

All the identified illegal plastic waste dumpsite counts were used to calculate the abundance and proportions of dumpsites per town or village in the study area. The recorded GPS coordinate dumpsite locations were used to create spatial distribution maps and cluster distribution maps (heat maps) based on dumpsite density and average distance between dumpsites. Heat maps were generated to examine dumpsite abundance across the three big towns, three small towns, and three villages within the Nkomazi Local Municipality. ArcGIS 10.8, software was used to create high resolution GIS heat maps to visually represent the presence and heat map distribution of plastic dumps in the study areas. Colour gradient was used on the dumpsite heat maps, with shades of red representing areas of high plastic dump abundance and shades of blue representing areas with low abundance. Variations in dumpsite counts, sizes, and locations were compared across the towns and villages using chi–squared analysis since the data was categorical, i.e., present/absent data, size, and location categories. Variations in the plastic category counts per each dumpsite across the towns and villages were

analysed using one–way ANOVA since data was numerical. All, statistical analysis was conducted using STATISTICA version 14 (TIBCO Software Inc, 2022).

3.3. Results

3.3.1 Illegal plastic waste dumpsite abundance and distribution

A total of 100 illegal plastic waste dumpsites were identified across all towns and villages, with the bulk of the dumpsites located in small towns (45%) compared to big towns (35%) and villages (20%). Amongst all the big towns, Hectorspruit (16%) had the highest number of illegal plastic waste dumpsites compared to Komatipoort (11%) and Malelane (8%). Within small towns, Schoemansdal had the highest (17%) number of illegal plastic waste dumpsites compared to Kamhlushwa (13%) and Tonga (15%) (Figure 3.2). The village of Phiva had 8% of the illegal plastic dumpsites compared to both Ntunda and Schulzendal which had 6% of the illegal plastic dumpsites, respectively (Figure 3.2). Statistical analysis on the presence of illegal plastic waste dumpsites across the towns and villages showed significantly ($\chi^2 = 200$, $p < 0.001$) higher counts of dumpsites in big and small towns than in villages.

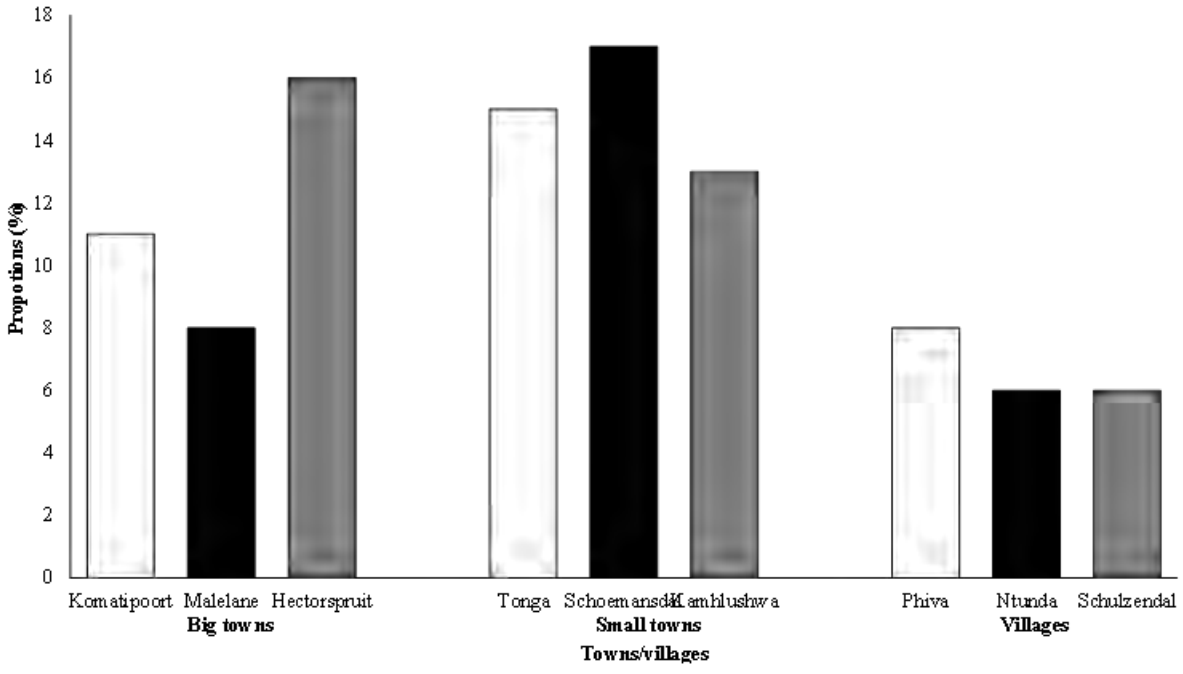

Figure 3.2: Illegal plastic waste dumping uncounted across the selected towns and villages in Nkomazi local municipality, Mpumalanga province of South Africa.

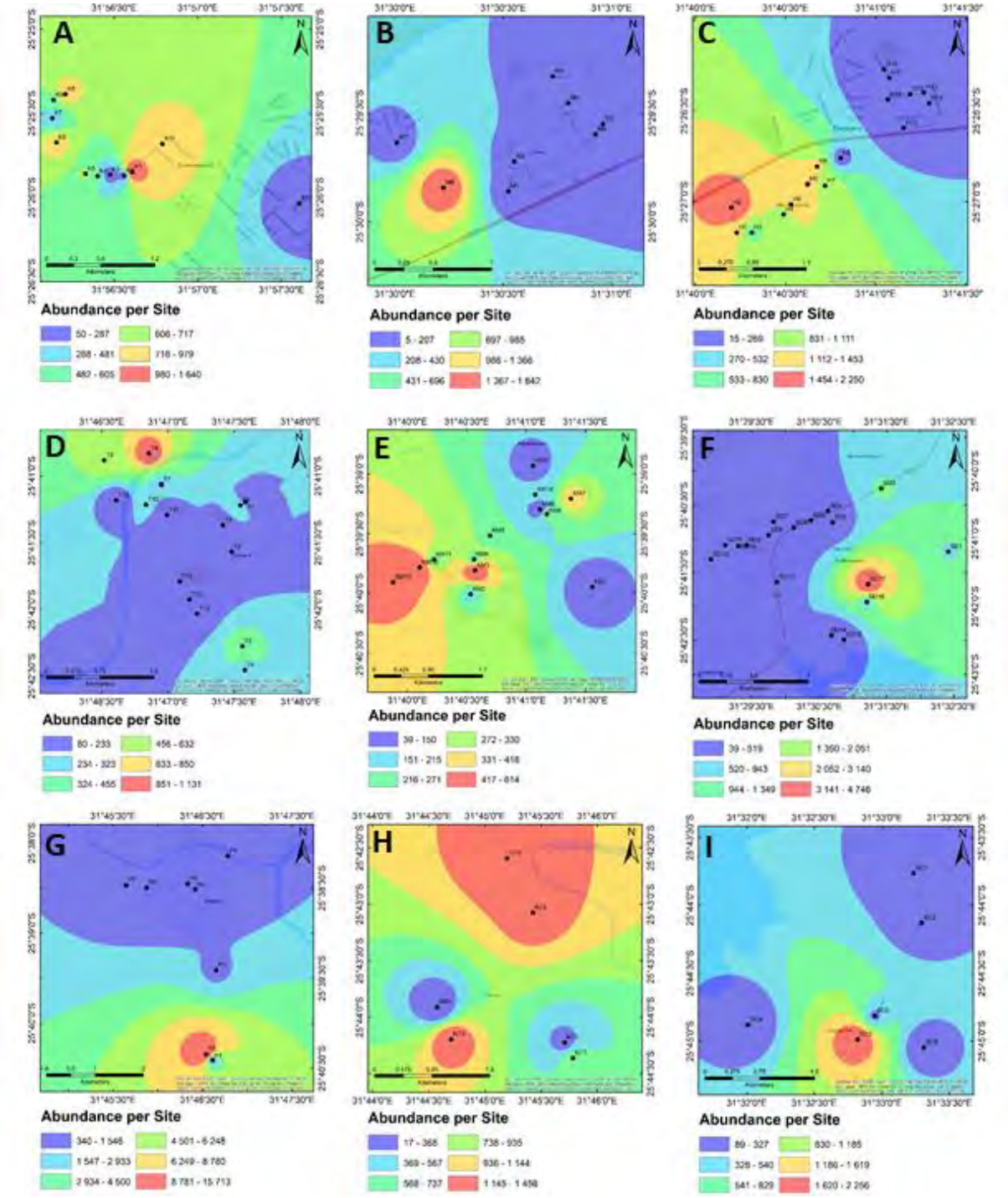

Figure 3.3: Heatmaps of plastic distribution across samples towns and villages of (a) Komatipoort, (b) Malelane, (c) Hectorspruit, (d) Tonga, (e) Kamhlushwa, (f) Schoemansdal, (g) Phiva, (h) Ntunda, and (i) Schulzendal in Nkomazi Local Municipality.

Within the big towns most of the illegal plastic waste dumpsites were found in densely populated low–income residential areas with plastic abundances of greater that 900 plastic particles in Komatipoort to above 1,454 plastic particles in Hectorspruit (Figure 3.3a–c).

However, low populated high income residential areas in big towns had low plastic counts on illegal plastic waste dumpsites ranging from 5 plastic particles in Malelane to 50 plastic particles in Komatipoort (Figure 3.3a–c). Although the high–income areas in big towns were characterized by low plastic waste counts, observations at dumpsites showed the high prevalence of garden–related waste. Across all small towns, most illegal plastic waste dumpsites had low abundance of plastic waste counts, and these were more prevalent in low–income areas in towns such as Tonga (abundance per site 80–233 plastics) and Schoemansdal (abundance per site 30–519 plastic particles) (Figure 3.3d–f). The counts of plastic waste at dumpsites varied notably across the three villages (Figure 3.3g–i). In Phiva, heat maps showed that densely populated dumpsite had plastic counts of more than 8,000 plastic particles compared to Ntunda with 1,500 plastic particles and Schulzendal with 1,600 plastic particles on densely populated dumpsites. In Phiva, plastic waste dumpsites with low abundances were located within the village, compared to those with high abundances which were located along roadsides that are in the peripheries of the village (Figure 3.3g). In Ntunda, plastic waste dumpsite with both low and high abundances were scattered across the villages (Figure 3.3h), whereas in Schulzendal village, these were at the centre of the village and these abundances decreased as one moves away from the village (Figure 3i). Generally, across all three villages plastic waste dumpsites were mostly located along roadside and around graves.

3.3.2. Illegal plastic waste dumpsite sizes and location

About 70% of the illegal plastic waste dumpsites were of large size, with most of these being in small towns (32%) compared to big towns (20%) and villages (18%) (Figure 3.4). Within big towns, Komatipoort (8%) and Hectorspruit (8%) had twice more the number of large illegal plastic waste dumpsites compared to Malelane (4%). The highest proportion of large illegal plastic waste dumpsites were in Tonga (13%) compared to Schoemansdal (9%). The village of Phiva (8%) had the highest number of large illegal plastic waste dumpsites compared to Ntunda and Schulzendal with 5% large dumpsites (Figure 3.4). Medium sized illegal plastic waste dumpsites were prevalent in big (8%) and small (10%) towns compared to villages (1%). Most of the small illegal plastic waste dumpsites were in big towns (9%), particularly Malelane and Hectorspruit than in small towns (3%) and villages (1%) (Figure 3.4). Comparisons of illegal plastic waste dumpsite size categories showed no significant ($\chi^2 = 0.469$, $p > 0.199$) differences across towns.

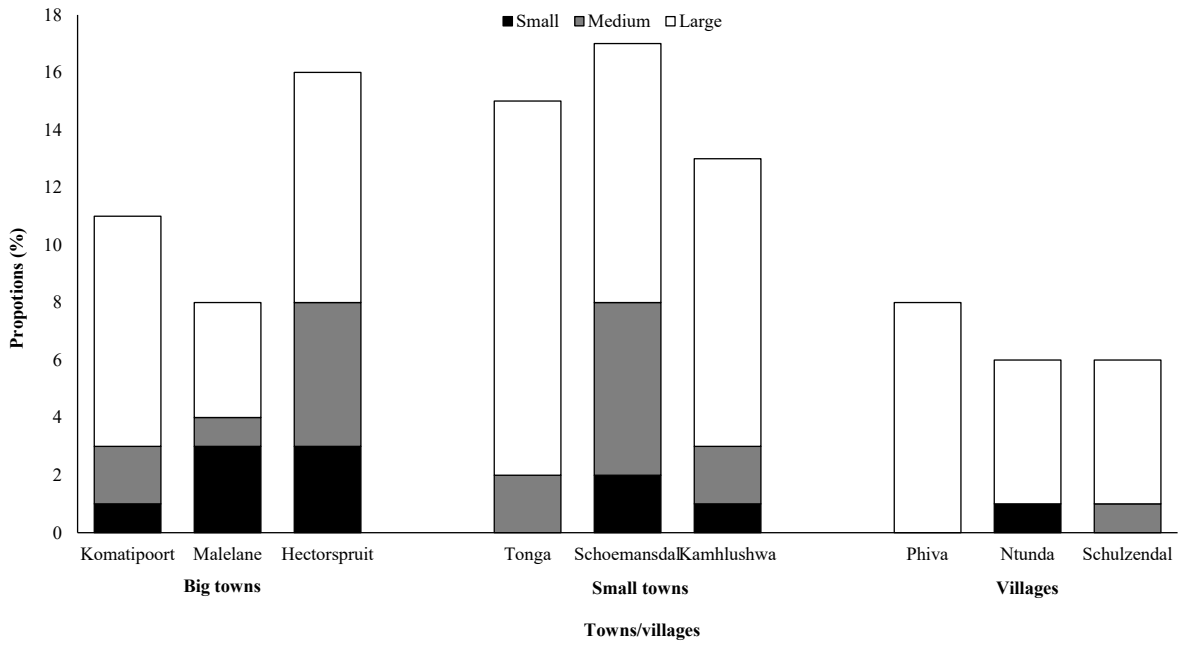

Figure 3.4: Illegal plastic waste dumpsites size across the selected towns and villages in Nkomazi local municipality, Mpumalanga province of South Africa.

A third (66%) of the illegal plastic waste dumpsites were located along roadsides and most of these were in small towns (32%) compared to big towns (22%) and villages (12) (Figure 3.5). Illegal plastic waste dumpsites that were located on vacant land constituted less than a quarter (19%) of all the enumerated dumpsites, with most of these being in small towns (8%) and villages (6%) than in big towns (5%). Across all towns and villages, illegal plastic waste dumpsites located along rivers and on parks and commonages were less than 10% of the identified dumpsites (Figure 3.5). Within big towns, Hectorspruit (12%) had the highest number of dumps along road sites compared to Komatiport (7%) and Malelane (3%). Within small towns, Tonga (11%) and Schoemansdal (12%) had the most dumping along roadsides compared to Kamhlushwa (9%), whereas dumping along village roadsides was evenly distributed (4% across all villages). Overall, no significant ($\chi^2 = 37.222$, $p > 0.241$) differences were observed across towns and villages for illegal plastic waste dumping at various locations.

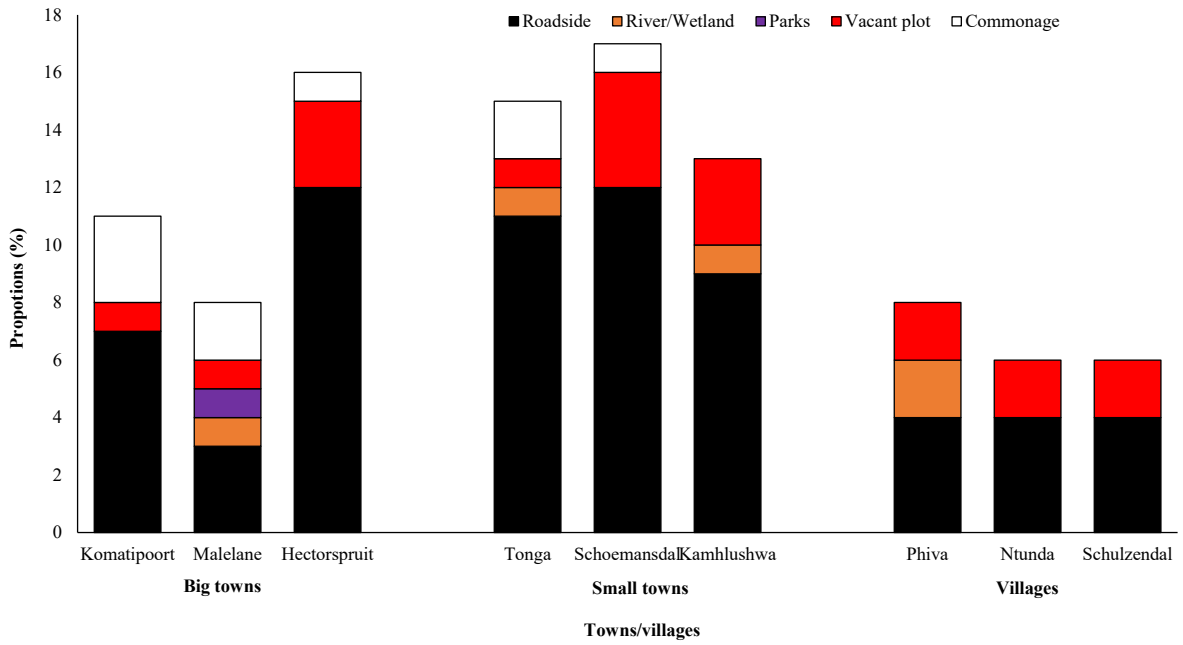

Figure 3.5: Location of illegal plastic dumpsites across different towns and villages in Nkomazi Local Municipality.

3.3.3. Plastic types/composition on illegal dumpsites

A total of 61,374 different plastics were enumerated across all the illegal plastic dumpsites that were counted in all towns and villages (Table 3.2). Interestingly, most of the enumerated plastic were in illegal plastic waste dumpsites located in villages (30,663 plastic particles) than those in big towns (16,100 plastic particles) and small towns (14,611 plastic particles). Polypropylene (PP) were the most prevalent (36 %; n = 21,887 plastic particles) plastics across the all the illegal plastic waste dumpsites in all study areas. Most PP plastics were in villages (33% plastic particles) compared to big towns (28%) and small towns (30%) (Table 2). Notably, diapers comprised 72% of all PP waste disposed. Apart from PP plastics, polyethylene terephthalate (PET) plastics accounted for 26% (16,929 plastic particles) of plastics found on illegal plastic waste dumpsites across the towns, with villages constituted 7,100 plastic particles compared to 5,414 plastic particles counted in small towns and 4,415 plastic particles in big towns (Table 3.2). Commonly occurring PET waste included beer bottles, plastic containers, and personal care products. The low–density polyethylene (LDPE) constituted 16% of the identified plastics across all towns and villages. Apart from plastics that were categorised as others (0.3% in total), PVC were the least counted plastics across all towns, with only 224 plastic particles counted in villages, 322 plastic particles in small towns, and 195 in big towns (Table 3.2). When data was analysed per study area, the village of Phiva (20,192 plastic particles) had the highest

number of plastics counted per illegal plastic waste dumpsites followed Schoemansdal (8,199 plastic particles) and Ntunda (7,426 plastic particles). Malelane had the least count of plastics on illegal plastic waste dumpsites (Table 3.1). Overall, villages accounted for most of the plastic on illegal plastic waste dumpsites followed by big towns and small towns. Statistically, there was a significant ($F = 2.218$, $p < 0.05$) difference across towns and villages for the total plastic type count, with the village of Phiva (mean = 2,884 plastic particles) having more counts compared to the towns of Malelane (mean = 285) and Schulzendal (mean = 435 plastic particles). In contrast, there were no significant ($F = 1.745$, $p > 0.05$) differences for the total plastic type count across the town and village categories, namely big towns, small towns, and villages.

Field observations showed that most dumpsites in the small towns and villages showed evidence of incineration, a practice commonly done to reduce and manage the waste on dumpsites (Figure 3.6a). Apart from plastic illegal dumping on river systems (Figure 3.6b), observations showed that the most dominant activity within plastic dumpsites were livestock grazing (Figure 3.6c–d). Common domestic animals encountered included goats, cattle, chickens, and pigs. Comparisons showed that animals were prevalent in plastic waste dumpsites located in village, while large and small towns had few animals roaming at their dumpsites.

Table 3.2: Proportions of plastic categories within towns and villages in Nkomazi Local Municipality. The values in parenthesis () represent plastic particles. Abbreviations: LPDE – low density polyethylene, PET – polyethylene, HDPE – high density polyethylene, PVC – polyvinyl chloride, PP – polypropylene, PS – polystyrene

	Small towns			**Big towns**			**Villages**		
Plastic polymer	**Schoemansdal**	**Tonga**	**Kamhlushwa**	**Malelane**	**Hectorspruit**	**Komatipoort**	**Phiva**	**Ntunda**	**Schulzendal**
LDPE	11% (1,079)	12% (476)	18% (607)	19% (419)	9% (582)	13% (866)	24% (4,929)	9.3% (446)	7% (215)
PET	17% (1,576)	26% (1,634)	32% (1,205)	27% (562)	32% (2,239)	40% (2,613)	19% (3,974)	11% (665)	78% (2,461)
HDPE	14% (1,430)	10% (282)	11% (378)	6% (154)	3% (210)	8% (523)	3% (591)	24% (1,307)	1.4% (52)
PVC	2% (104)	1% (63)	1% (28)	0.2% (7)	1% (69)	4% (246)	1% (162)	0.3% (36)	1% (23)
PP	28% (2,730)	29% (1,284)	27% (966)	21% (465)	44% (2,819)	26% (1,753)	43% (9,217)	46% (2,369)	9% (284)
PS	13% (1,275)	13% (608)	9% (335)	24% (384)	3% (217)	7% (430)	6% (1,224)	5% (2,602)	1% (8)
Other	1% (5)	0	1% (35)	1% (6)	0.1% (18)	0.4% (29)	0.4% (92)	0.01% (1)	0.01% (2)

Figure 3.6: Photographs showing incineration of plastic waste and the presence of livestock in dumpsites located in (A) Schoemansdal, (B) Tonga, (C and D) Phiva located in Nkomazi Local Municipality.

3.4. Discussion

Results of this study show that although illegal plastic dumping is common in both urban and rural areas, it is more prevalent in big and small towns due to the high number of dumpsites in both big and small towns compared to villages. However, it is important to note that although counts of dumpsites was higher in urban areas, plastic type/composition was higher in villages than urban areas. Previous studies conducted in South Africa have confirmed that illegal plastic dumping is common in urban areas due to several factors such as poor municipal services, corruption, lack of financial and human resources, human behaviour linked to dumping, and lack of municipal by–law enforcement (Polasi, 2018; Adeniran and Shakantu, 2022; Ngalo and Thondhlana, 2023; Grangxabe et al., 2023; Jakeni et al., 2024). For example, Adeniran and

Shakantu (2022) reported that a significant number of plastic waste is being disposed in a haphazard manner in South African township, yet residents in these areas are not aware of the adverse environmental and human health effect of plastic waste disposal. Ngalo and Thondhlana (2023) noted that most dumpsites in Komani have illegally disposed plastics that can cause negative health effects to people who reside next to these dumpsites. South African local municipalities have struggled financially to provide municipal services such as waste collection, this likely to explain why most illegal dumpsites are dominated by plastics. For example, Swanepoel and Marlin (2024) reported that the waste collection rate in most municipalities range from as low as 20% to 80%, meaning the struggles to collect waste in urban areas tend to force residents to dump waste illegally. In the same above–mentioned study, illegal dumping of waste increased in Nelson Mandela Bay by 57% between 2015 to 2021, this attributed to municipal poor waste management and increase in urban population and informal sectors. Some informal sectors in urban areas are inaccessible, thus municipal vehicles cannot drive in such areas thus residents are left with no option but to dump the waste. The problem of illegal plastic dumping is not only common in South Africa alone, but it has also been reported in other countries such as India, Poland, Nigeria, and Kenya (Ichipi, 2023; Jakie et al., 2019; Sharma et al., 2018).

Results of this study noted that more illegal plastic waste dumping is taking place in high density areas compared to low density areas. Across most of the surveyed urban areas, dumping was prevalent in low–income areas than in high income areas. This result concurs with previous studies which have noted similar patterns (Niyobuhungiro and Schenck, 2021; Ngalo and Thondhlana, 2023; Swanepoel and Marlin 2024; Tombe, 2024). For example, Tombe (2024) conducted a study in Makhanda and Knysna and reported that illegal waste dumping is more concentrated in low–income areas that in high income areas and attributed this to poor municipal services being rendered to low–income areas. In Knysna, Tombe (2024) noted service delivery disparities between high– and low–income areas, with observations showing that most low–income areas did not have skip waste collection bins whilst most high–income areas have these dumping bins, this likely to explain why dumping is prevalent in low–income areas. Besides municipal services, some studies have noted that most people in high income areas have financial resources and means to take their waste to landfills as compared to residents of low–income areas who do not have financial resources to take their waste to landfills (Ngalo and Thondhlana, 2024; Tombe, 2024). In Western Cape Province, indiscriminate waste dumping in the town of Fisantekraal was mainly concentrated in the

densely populated areas and was becoming a serious health threat to residents in the area (Niyobuhungiro and Schenck, 2022). Obvious issues of accessibility are regarded as the main challenge of waste picking in densely populated low–income areas, however, human behaviour of indiscriminate bumping should be considered. It is possible that people dump plastic because they do not have anywhere to put the uncollected plastic or to get rid of the waste from their property. Indeed, some studies have shown that illegal plastic dumping is a behavioural problem although issues of service delivery are applicable (Allison et al., 2022). This therefore implies that solutions to illegal plastic waste dumping should be frames along the change behaviour framing that emphasises the need to mainstream human behavioural change (Allison et al., 2022).

The proliferation of illegal plastic waste dumping in low–income areas, has several animal and human health as well as environmental implication to those leaving close to dumpsites. For example, plastic disposal threatens soil, plant, and aquatic life, as well as surrounding ecosystems which subsequently affects human health since humans benefit directly and indirectly from this ecosystem (Van Emmerik and Schwarz 2020). Plastic in general contain chemicals and hazardous substances such as Bisphenol A (BPA), thus disposal illegally near households can cause human health and environmental risks such as lung problems, skin diseases, and gastral problems linked to toxic plastic substances (Proshad et al., 2018). Norsa'adah et al (2020) reported that proximity to waste dumpsites exposes people to diseases such as sore throat, diabetes, and hypertension, which means living close to a dumpsite is a health risk. Putting everything together, it is possible to conclude that the prevalence of illegal plastic waste dumping in low–income areas combined with the potential health risks make the problem a social justice issue. According to Kubanza and Simatele (2016) waste dumping is a social justice issues given that certain groups of people (in this case low–income areas) are being deprived of equal opportunities when it comes to waste, i.e., with their waste not being collected, dumping creates political, economic, and socially unequal opportunities for them. This speaks to issues of interventions in the long run, thus waste management plans and investments for effective waste collection should be tilted towards low–income areas that high income areas. For example, more bins, collection frequency, and financial resources should be committed to low–income areas than high income areas given the high population density which results in high number of dumping, which needs more cleaned up resources.

Besides the fact that most dumpsites were large, which speaks to issues of dumping prevalence, most of the illegal plastic waste dumpsites were along roadsides. Previous studies have reported that roadside and commonage dumping is common and the most preferred form of getting rid of the waste (Ngalo and Thondhlana, 2024; Tombe, 2024). Swanepoel and Marlin (2024) used GIS and remote sensing to show that illegal waste dumping is prevalent along roadsides in Nelson Mandela Bay. Ngalo and Thondhlana (2024) used drive–by–road surveys to show that dumpsites are mostly located along roadsides, underneath electricity poles, and on commonages of Queenstown in Eastern Cape Province of South Africa. In India, Vij (2012) noted that solid waste dumping is prevalent along roadsides and vacant land due to lack of waste collection. Similarly, in Indonesia, public roads are frequently utilised as illegal dumping grounds, due to limited community engagement and a lack of subsidies from the government for waste management (Penyalahgunaan et al., 2024). Research conducted in Europe indicated that roads greatly influence the occurrence of illegal dumpsite, with regional variances impacting the aesthetics of various road types for dumping (Matos et al., 2012). Roadside dumping results in visual obstructions, unpleasant odours, negative environmental impacts, and increased accident risks (Karimi and Faghri, 2021; Penyalahgunaan et al., 2024). Apart from that, dumping plastic waste along roadsides has its own negative effects such as plastic blocking water drainage systems causing flooding and loss of aesthetic beauty of the area. The sampled area is close to Krugger National Park thus aesthetic beauty of the towns is important for tourism purposes. It is possible that the loss of aesthetic beauty due to plastic dumping will have knock–on effects on the towns economy as tourists might shame the towns. These knock–on effects have serious societal implication such as loss of employment and livelihood income, thus plastic waste dumping has serious indirect effects to communities and the town at large.

The abundance of plastic waste type/composition was more on dumpsites located in villages than on dumpsites located in urban areas. For example, the study enumerated more PET and PP plastics on dumpsites in rural villages than across most urban towns. A few factors could explain our results, firstly, it is possible that some form of plastic recycling is taking place in urban areas households than in rural areas prior dumping, thus some types of plastics are not being disposed in urban than rural areas. The above assumption is supported by studies that have shown that in towns were recycling is taking place at household level, some types of plastics are not disposed on dumpsites because they are removed prior to disposal (Srivastava et al., 2015). However, household recycling prior disposal is only effective in areas where it generates income through the same of recyclable material, thus some form of financial benefits

stimulated the behavioural change to collect recycling material. Secondly, within most urban than rural areas, plastic waste collection at dumpsites by informal waste pickers is common (Godfrey, 2021). In South Africa, informal waste picking is a lucrative business generation approximately 872 million Rands in 2017 from the sale of recyclable material. This speaks to the second level of recycling where useful recyclable material is collected at illegal dumpsites by informal waste pickers, thus some plastic types are no longer available on dumpsites as they are removed by pickers. This is common in urban than rural areas thus explaining why plastic waste type/composition was prevalent in rural areas. Thirdly, collection of waste in rural South Africa is rare (Zondi et al., 2023). The above–mentioned study stated that over 90% of villagers in Vulindlela, located in Msunduzi Municipality do not have their waste collected and end up disposing the waste along roadsides or opt to burn the waste within their property yard. The lack of proper waste collection in rural areas could explain the high number of dumped waste type/composition that was observed in this study. Lastly, like urban areas, plastic dumping as a behavioural issue by villagers can also not be ruled out. Within these villages, the illegal dumping of PP products is a course of concern given that PP takes up to 30 years to degrade naturally (Alsabri et al., 2022). For example, burning PP triggers the release of toxins such as dioxins which have negative effects on human immune system and can cause cancer (Verma et al., 2016). On the other hand, the release of PET products on illegal plastic dumpsites can trigger release of PET material in river systems, particularly consumable river water leading to health effects such as allergies (Yaka et al., 2015).

3.5. Conclusions and recommendations

This study showed that, based on dumpsite counts, illegal plastic waste dumping is prevalent in urban than rural areas. Within urban areas, illegal plastic dumping shows an uneven distribution, being prevalent in low than high income areas, this likely to speak to issues of illegal waste dumping as a social justice issue. However, count of the specific plastic waste types/composition showed that more PP and PET plastics were in villages than urban areas, an indication of poor waste collection municipal services in rural areas. Drivers of illegal plastic waste dumping are many including poor municipal waste collection services, lack of implementation and monitoring of municipal by–laws, and behavioural issues among people. To address the challenge of illegal plastic waste dumping, the study proposes the following interventions. Firstly, current dumpsites need to be removed through clean–up campaigns. These could be championed by municipalities or communities themselves. Secondly, municipalities need to put more financial and human resources to effectively collect waste in

both urban and rural communities. Municipalities need to develop well–funded and resourced waste collection plans to the extent that if properly implemented illegal plastic dumping will be eliminated. Thirdly, programmes aimed at promoting recycling of waste at household level or even by waste pickers at dumpsite need to be promoted to reduce the type of plastic that is being dumped. Such programmes could involve incentivising recycling through promoting sale of recyclable material, with the potential of municipalities getting into the recycling business. Fourthly, from an infrastructure standpoint, municipalities must consider installing more bins on strategies positions to allow people to dump plastic. Besides, municipalities must hand over bins or waste containers to residents to use for waste disposal. Lastly, to change illegal plastic dumping behaviour, enhancing public education on plastic waste and outreach programs is needed. Such education and outreach programmes should educate people on all aspects of waste disposal ranging from safe waste disposal techniques to recycling and highlighting the impacts of illegal plastic dumping.

CHAPTER FOUR: PERCEPTION AND PRO–ENVIRONMENTAL BEHAVIOURS TOWARDS PLASTIC POLLUTION IN NKOMAZI LOCAL MUNICIPALITY

Abstract

Humans are at the center of plastic pollution, thus any proposed solution related to addressing the problem should consider understanding human perception. Most studies on human perceptions linked to waste pollution are in urban areas leaving rural areas neglected. Understanding pro–environmental behaviors linked to plastic pollution could assist in developing effective human centered solutions to plastic pollution. This study used household face–to–face interviews to assess human perception towards plastic pollution across different towns and villages in Nkomazi Local Municipality. The study further assessed plastic consumption patterns and choices and how these behaviours can inform potential waste management strategies. Results show that most respondents have knowledge about plastic pollution, however, such knowledge varies between towns and villages with most urbanites having more knowledge about plastic pollution compared to those in villages. Respondents were aware of both the health and environmental effects of plastic pollution, with knowledge of impacts varied across the study towns and villages. Pro–environmental behaviours showed varied results, positive relationships with plastic pollution perception (sustainability knowledge vs pollution effects), but that was not the case for some variables were negative relationships were reported (plastic separation vs impact knowledge). The study concludes that interventions such as (i) financial investment towards plastic pollution reduction, (ii) enhancing pro–environmental attitudes and behaviour, and (iii) municipal investment in plastic pollution management facilities like bins and recycling centres should be prioritised.

Keywords: Plastic pollution, pro-environmental behaviours (PEB), knowledge, waste management, human perception

4.1. Introduction

Plastic pollution is the buildup of plastic items and particles, such as plastic bottles, bags, and microbeads, in the earth's environment, which negatively impacts humans, wildlife, and their habitats (Obebe and Adamu, 2020). Globally, billions of plastic wastes are produced every year and a significant amount of this waste end up into natural ecosystems such as oceans, rivers, and lakes, thus altering ecosystem's ability to provide key services like food to humans (UNEP, 2019). Plastic is important to day–to–day life, however, the increase in human use of plastic and its illegal disposal is of concern (UNEP, 2019). Generally, the practice of illegally disposing waste, plastic being part of the waste along public roadsides, vacant plots, or in areas not designated for waste disposal is referred to as illegal dumping (Walters et al., 2020). This illegal dumping is one of the main drivers of plastic pollution which is also described as illicit dumping and fly–tipping and it predominantly in urban areas due to increase population density in urban areas, urban migration, increased industrialisation and maladministration by urban municipalities (Hodsman and Williams, 2011). Sangawar and Deshmukh (2012) suggest that the increase in plastic waste is driven by population growth, modern lifestyles, and increased developmental activities in urban areas. The modern lifestyle's preference for disposable items has made plastic a prominent choice for both industrial and household applications, yet its sustainable disposal is a challenge (Adak, 2020). The rise in plastic consumption has resulted in a decrease in non–biodegradable waste, contributing to a disconnect between municipal solid waste (MSW) generation and personal consumption expenditure (Tsiamis et al., 2018). If current trends persist, global estimates indicate that 25,000 million metric tons of plastic waste could be produced by 2050 (Geyer et al, 2017), of which more than half will be disposed illegally thus contributing to plastic pollution. In South Africa, Gauteng Province is the largest producer of plastic waste, with projections indicating that Johannesburg alone could generate 6.7 megatons of plastic waste between 2021 and 2050 (Ayeleru et al., 2024). The increasing generation and disposal of plastic waste will create significant challenges for municipal waste management services, which in turn will add to the plastic pollution problem (Ayeleru et al., 2020).

To reduce plastic pollution, South Africa implemented some regulations in 2003 on plastic bags and imposed a minor levy that mandated that bags be sold instead of given away for free (Dikgang et al., 2012). Prior to that, South Africa launched a waste management program in 2019 aimed at addressing local waste challenges and educating citizens on how to combat plastic pollution in the environment (Hanekom, 2020). Despite these and several other

interventions and initiatives, consumption of plastic remains high due to plastic's conveniences (O'Brien and Thondhlana, 2019). Several other countries have also implemented plastic bag levies aimed at reducing plastic consumption, and results vary from country to country. For example, Ireland implemented an environmental tax policy, changing €0.15 per plastic bag, resulting in a substantial decrease of over 90% in plastic bag consumption (Killian, 2004; McDonnell et al, 2024). The above–mentioned plastic consumption decrease is associated with a decline in plastic waste (Killian, 2004; McDonnell et al, 2024). Several other global north countries have implemented these taxes resulting in mixed results when it comes to plastic consumption and disposal. The effectiveness of these interventions is frequently constrained by inconsistent implementation of the laws, inadequate evaluation of successes, and in the global south context human behaviour towards plastic usage (Xanthos and Walker, 2017; Madigele and Mogomotsi, 2017). In Botswana, the plastic levy was unsuccessful because of institutional shortcomings and ineffective waste collection services (Madigele and Mogomotsi, 2017), and to some extent human behaviour linked to convenience linked to usage of plastic (O'Brien and Thondhlana, 2019). Therefore, research linked to human perceptions related to plastic pollution are needed in various areas, to gather site specific information that could inform effective policy interventions.

Perception refers to how an individual interprets, understands, and assigns meaning to information, events, or their environment (Cong–Lem, 2025). It involves recognizing and processing sensory input, which then informs thoughts, beliefs, or judgments (Foley, 2019). Human behaviour encompasses the diverse actions and reactions that individuals or groups express in response to both internal and external stimuli (Erensoy et al., 2024). This behaviour is shaped by a combination of psychological, biological, social, and environmental factors (Gerrig and Zimbardo, 2018). Research indicates that both perception and behaviour are significant drivers of plastic pollution (Pahl et al., 2020). Human decisions at various stages of the plastic lifecycle, which is from production, consumption to disposal contribute to pollution, highlighting the importance of integrating social and behavioural sciences to implement effective interventions (Pahl et al., 2020). Furthermore, an individual's perception of their social context plays a key role in shaping their actions toward plastic pollution. Social identification can either foster conformity to PEB or promote resistance to environmental initiatives (Huet and Armelle, 2022). People's perceptions and attitudes toward plastic waste can also influence how they engage with plastic products, which can lead to either excessive consumption, improper disposal, or participation in recycling efforts. Subsequently, consumer

perceptions of plastic management can be affected by variety of factors, including product characteristics, personal attitudes, societal influences, and regulations (Mugobo et al., 2022). For instance, Northen et al. (2023) highlight that supply, cost, and accessibility play a crucial role in determining consumer behaviour toward plastics, which in turn affects plastic management. Hameed et al. (2021) further emphasize that recycling intentions are influenced by informative and normative social factors, as well as perceived behavioural control.

There are numerous causes and impacts of plastic pollution that necessitate extensive research on human perceptions to plastic pollution. It is essential to study how demographic factors such as age, gender, education level, and employment status, along with attitudinal factors, drive plastic pollution across different types of settlements in South Africa. There is limited research on the perception of plastic pollution and PEB in various settings, including across spatial human settlement dimensions such as town sizes (big towns, small towns, and villages) or across an income gradient (rich and poor suburbs). Research on plastic pollution perceptions and PEB in South Africa has primarily focused on urban areas such as Johannesburg and Cape Town and tends to be imbedded with the research on waste in general. For example, Jakeni et al. (2024) investigated the perceptions of residents and identified illegal dumpsites in Cape Town and reported that dumping is prone in poor communities and tend to occur in vacant lands. Polasi (2018) examined the factors contributing to illegal dumping in the Zondi area of the City of Johannesburg, South Africa, and overall concluded that waste dumping is a major problem that could have broader implications on poor communities compared to rich communities. Recently, Mashamba (2024) reported that villagers in Vhembe Biosphere Reserve prefer to use plastic because it is cheap, however, the same study also observed that females were prone to contribute less plastic and are keen to manage the plastic waste compared to males. These results seem to suggest that demographic factors could inform plastic waste behaviours, thus the need to gather more information to tailor interventions that are effective. Examining plastic pollution through demographic factors is important, as there is a connection between risk perception and community behaviour regarding plastic pollution. Age, gender, education, and income influence attitudes and behaviours towards plastic handling (Soares et al., 2021). Although large towns often possess more developed infrastructure for waste collection and disposal, including regular waste services and high levels of awareness and education among individuals, they also significantly contribute to improper plastic waste disposal. Conversely, small towns and villages have limited waste removal services, poor waste

infrastructure, and less awareness and education about proper plastic waste handling, leading to high levels of illegal plastic dump sites.

In most global south countries, plastic waste issues are worsened by insufficient legislation, ineffective waste management practices, and slow adaptation to PEB (Akan et al., 2021). This was particularly evident during the COVID–19 pandemic, when increased use of personal protective equipment added around 105,000 tonnes of face masks to the environment each month, worsening plastic pollution (Benson et al., 2021). Communities that prioritize sustainability are more likely to adopt pro–environmental habits, such as using reusable bags or participating in clean–up campaigns. On the other hand, in areas where plastic pollution is not seen as a major issue, individuals may either follow unsustainable practices or oppose environmental initiatives. According to Rhyner et al. (2017) waste management is a consequence of societal advancement and civilization. Additionally, industrialisation has worsened this issue, resulting to excessive generation of diverse and potentially hazardous waste (Souri and Haghi, 2017). A study conducted by Barles, (2014) indicates that waste management has developed over time, from simple disposal methods to more complicated systems that reflect shifting societal attitudes and environmental concerns.

Mpumalanga contributes less than 10% of South Africa's total general waste, generating approximately 3,831,000 cubic meters of waste annually (Mnisi, 2008). Over time, the province has produced approximately 1.37 million tons of waste per capita compared to the national average of 1.04 million, making the province a big waste generator (DWAF, 1998; Stats SA, 2002). Although recycling activities take place in the province, they lack proper coordination. The extent of waste collection services in Mpumalanga reflects its predominantly rural characteristics. In the Nkomazi Local Municipality, only 8,375 out of 82,126 households pay for waste removal services. These paying households are mainly situated in urban areas compared to rural areas. Within most urban areas, waste collection services are provided multiple times a week (although not consistent), while rural communities may have collections just once a week or not at all (Mihai and Grozavu, 2018). The waste accumulation problem is aggravated by insufficient funding, outdated infrastructure, and the negative attitude by residents (Devi et al., 2016). Most of the plastic waste produced in South Africa and in Mpumalanga comes from households and industrial areas within urban areas (Ryan, 2020), with close to 50% of this waste usually end up as illegal dumps due to non–collection. With municipalities failing to collect waste, the problem of plastic pollution becomes a waste

management problem (Zurbrügg, 2002) that is linked to waste injustice, i.e., with most waste in road verges and vacant plots of low–income areas, posing risks to resident's health and the environment (Kumar and Chakrabarti, 2010). Although municipalities have put interventions such as mandatory waste separation at the source, recycling initiatives, and integrating informal waste pickers into the management process, the problem of plastic pollution and waste in general is on the rise in South Africa (Moreno–Sánchez and Maldonado, 2006; Sentime, 2011; Mazhandu et al., 2021). Research indicates that informal waste pickers play a vital role in reducing waste accumulation and managing improperly disposed waste (Moreno–Sánchez and Maldonado, 2006; Sentime, 2011; Medina, 2008), however, their role could be insignificant if human behaviour on plastic waste does not change. This calls for more research on human perceptions and PEB towards plastic pollution. In this regard, this study aims to assess human perception towards plastic pollution across different towns and villages in Nkomazi Local Municipality. The study will further assess plastic consumption patterns, choices, and behaviours can inform potential waste management strategies.

4.2. Methods

4.2.1. Study area

To avoid repetition, the study area is presented under Chapter 3, Section 3.2 entitled Methods, subsection 3.2.1 entitled study area.

4.2.2. Household surveys and data collection

A random sampling approach was used to selected towns and households in each area (big towns, small towns, and villages). The randomization process was implemented by first listing all towns and villages in the area by name and assigning them numbers. The classes of big towns, small towns and villages represented the stratified random sampling divisions used in this study and these were based on population, area size, and general information on how the areas are administered. After assigning the towns and villages numbers, the random function in excel was used to select the above–mentioned sampling areas. Within each study area, survey households were then randomly selected within each subgroup to ensure proportional representation. Google maps were used to identify all the houses and assign them numbers. After that, a random function in excel was used to select 30 households in each study area. A total of 270 households participated in the study (30 households x 9 study areas (3 big towns, 3 small towns, and 3 villages).

The interviews schedule contained structured questionnaires with closed–ended questions. Household survey interviews gathered data on residents' demographic attributes, general knowledge about plastic pollution, perceptions about plastic pollution, impacts of plastic pollution on the environment and PEB (see Appendix 4.1 with the interview guide). The interviews were conducted in the respondents' preferred language, either English or IsiSwati, the local indigenous languages in the area. Each interview session lasted approximately 20 to 30 minutes. When respondents from the selected households were unavailable, or had no individuals over 18 years old, the next selected household was chosen for the survey. Interviews were conducted in March 2024. Ethical approval for the study was issued by the Rhodes University Human Research Ethics Committee (Approval Number 2023–7503–8255). Informed consent was sort prior to conducting any interview. Participation was voluntary and all participants had the right not to answer any question. Participants had the option to withdraw at any given time without any negative repercussions. Assurance of confidentiality and anonymity of responses was explained prior to starting the interviews. all data were anonymised prior analysis and no personal information was collected.

4.2.3. Data analysis

Descriptive statistics were applied to examine participants' demographic profiles, their perceptions, the frequency of waste collection services, waste disposal methods, and their views on the causes and impacts of illegal plastic dumping. Thematic content analysis was conducted to identify recurring themes related to the factors contributing to illegal plastic dumping, its perceived effects, and possible interventions suggested by residents. Additionally, participant comments were analysed to uncover new insights that may not have been captured through the semi–structured survey questionnaire. A non–parametric Spearman correlation was used to explore the relationships of between sociodemographic variables (i.e., age, gender, education) and pro–environmental behaviours towards various plastic pollution responses (knowledge, perceptions, and effects). All statistical analyses were performed using TIBCO STATISTICA version 14.0 software (TIBCO Software Inc, 2020). A limitation of this study is that respondents may already have strong opinions about plastic pollution, potentially leading to biased results. Regardless of this limitation the study still provides potentially valuable insights on perceptions and behaviours and impacts regarding plastic pollution across different location setting in South Africa.

4.3. Results

4.3.1. Demographic information of the sampled population

Except in big towns, most of the sampled population were female respondents compared to males. In both small towns (56%) and villages (72%), more than half of the respondents were females (Table 4.1). Although comparisons within the categorised towns and villages showed no significant differences for age, overall significant differences were observed with the towns and villages were put together ($\chi^2 = 24.793$, $p < 0.05$; Table 4.1). The dominant age range across all study towns and villages was 25–34 and 35–44 ages (Table 4.1). More than 10% of the respondents in both big towns (16%) and villages (17%) were above 55 years compared to 7% in small towns. Age showed no significant differences across the study areas ($\chi^2 = 42.936$, $p > 0.05$; Table 4.1). Across all the towns and villages, more than a quarter of the respondents had high education, with less than 5% of the respondents across all towns and villages having a post–graduate qualification (Table 4.1). For education, statistical differences were observed in big towns only ($\chi^2 = 37.909$, $p < 0.001$) and when comparisons were done across all towns and villages ($\chi^2 = 85.660$, $p < 0.001$). Most of the respondents in big towns were employed (60%), but with no significant differences across the big towns ($\chi^2 = 11.265$, $p > 0.05$; Table 4.1). In contrast, most of the respondents in small towns and villages were unemployed (42% and 54%, respectively), with significant differences only observed in small towns ($\chi^2 = 15.225$, $p < 0.05$) but not in villages ($\chi^2 = 7.971$, $p > 0.05$; Table 4.1).

Table 4.1: Sociodemographic information across the study area. Results are percentages and Chi–squared results are shown. * = $p < 0.05$, ** = $p < 0.01$, and *** = $p < 0.001$.

Variables	**Study areas**			**Comparisons across towns**			
	Big towns	**Small towns**	**Villages**	**Big towns**	**Small towns**	**Villages**	**All**
Gender							
Female	37	56	72	0.861^{ns}	0.630^{ns}	0.443^{ns}	24.793^{**}
Male	63	44	28				
Age group (years)							
18–24	8	26	19	8.627^{ns}	9.606^{ns}	9.581^{ns}	42.936^{ns}
25–34	31	37	30				
35–44	30	19	23				
45–54	16	12	11				
<55	16	7	17				
Education							
Uneducated	8	1	11	37.909^{***}	18.699^{ns}	9.090^{ns}	85.66^{***}
Primary School	19	12	14				
High School	36	40	48				

Certificate	16	21	12				
Diploma	14	13	12				
Degree	6	8	2				
Post–graduate Degree	2	4	0				
Employment							
Student (%)	4	16	8	11.265^{ns}	15.225^{*}	7.971^{ns}	87.671^{***}
Self–Employed (%)	14	22	12				
Unemployment (%)	20	42	54				
Employment (%)	60	18	22				
Retired (%)	1	2	3				

4.3.2. Knowledge and perceptions about plastics

Most of the respondents across the study area are concerned that plastic waste is a problem, with a significant number being in big towns (58%) compared to small towns (53%) and villages (37%) (Table 4.2), with no significant differences across the different towns and villages ($\chi^2 = 21.310$, $p > 0.05$). When respondents were asked about worries of plastic pollution on the environment, more than half of the respondents in big towns (61%) and villages (53%) strongly agreed, with no significant differences recorded across all towns and villages ($\chi^2 = 39.302$, $p > 0.05$). More than 60% of the respondents across all the sampled towns and villages are aware of ways to dispose plastic waste without affecting the environment (Table 4.2). However, only few of the responds strongly agree that they are handing waste disposal properly across the study area (big towns 48%, small towns 43%, and villages 33%). When asked if they take the environment into accountability when littering plastic waste, less than 30% of the respondents strongly agree, with significant differences across the different towns and villages ($\chi^2 = 49.839$, $p < 0.05$; Table 4.2). Less than a quarter of the respondents across all the towns and villages strongly agree or agree that municipalities are solely responsible for picking waste. Fewer respondents strongly agree (big towns =, 17%, small towns =, 10%, and villages = 19%) that it is only the government and business facilities that should practice recycling, reuse, and reduce of plastic products (Table 4.2). The above response was statistically significant in among villages ($\chi^2 = 25.420$, $p < 0.01$) than big ($\chi^2 = 13.27$, $p > 0.05$) and small ($\chi^2 = 13.267$, $p > 0.05$) towns that showed on significant differences. Across all towns, and villages, fewer than 20% of the respondents strongly agree that plastic products are convenient for everyday use and cannot be substituted by environmentally friendly products, with no significant differences across samples areas ($\chi^2 = 34.015$, $p < 0.05$; Table 4.2).

Table 4.2. Responses to questions related to knowledge and perceptions on plastic pollution in the study area. Results are percentages (strongly agree and agree) and Chi–squared results are shown. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, and ns = not significant $p > 0.05$.

Interview question	**Study areas**						**Comparisons across towns**			
	Big towns		**Small towns**		**Villages**		**Big towns**	**Small towns**	**Villages**	**All**
	% strongly agree	**% agree**	**% strongly agree**	**% agree**	**% strongly agree**	**% agree**				
Concerned about plastic waste problems	58	32	53	38	37	53	0.428^{ns}	7.183^{ns}	5.011^{ns}	21.310^{ns}
Worried about plastic pollution environmental problems	61	30	46	42	53	41	3.321^{ns}	9.447^{ns}	2.679^{ns}	39.302^{ns}
Knowledge of plastic waste disposal without harm to the environment	61	24	62	33	61	38	8.672^{ns}	4.636^{ns}	8.351^{ns}	38.859^{*}
Knowledge of plastic waste handling	48	29	43	39	33	33	16.961^{*}	7.183^{ns}	2.868^{ns}	37.609^{ns}
Knowledge of plastic littering vs environmental accountability	27	21	16	24	14	36	9.211^{ns}	6.619^{ns}	12.548^{ns}	49.839^{*}
Municipal is responsible for plastic waste	23	12	21	16	11	20	14.907^{ns}	6.455^{ns}	12.902^{ns}	42.663^{ns}
RRR is govt and business mandate	17	12	10	17	19	21	13.277^{ns}	13.267^{ns}	25.420^{**}	59.992^{**}
Plastic is convenient and cannot be replaced	17	19	11	15	13	30	10.729^{ns}	6.639^{ns}	10.318^{ns}	34.015^{ns}

4.3.3. Plastic pollution effects and pro–environmental behaviour

More than half of the respondents in big towns (61%), small towns (52%), and villages (51%) strongly believe that plastic pollution has effects on human health (Table 4.3), however, statistical comparisons across all villages showed no significant differences ($p > 0.05$). However, most respondents in big towns (70%), acknowledged that microplastic affects aquatic organisms, with no statistical differences within big towns ($\chi^2 = 5.656$, $p > 0.05$; Table 4.3). Responses in villagers regarding the effects of plastic pollution showed significant differences across the villages ($\chi^2 = 21.029$, $p < 0.001$; Table 4.3). Responses that strongly agree that plastic pollution affects the aesthetics appeal of the environment were higher in big towns (50%) than small towns (40%) and villages (47%), with no significant differences across the study areas ($\chi^2 = 32.542$, $p > 0.05$; Table 4.3). More than 60% of the respondents in big towns strongly agree that plastic pollution take up land and impacts the economy, with close to half alluding to the same strong views in small towns and villages (Table 4.3.). More than 50% of the respondents across all study areas always dispose plastic correctly, with less than 30% often disposing the plastic correctly (Table 4.3). Less than 40% of the respondents said they always or often recycling of plastics across the different towns and villages, with significant differences recorded across the study area ($\chi^2 = 48.520$, $p < 0.05$; Table 4.3). Responses related to always or often adhering to PEB were low less than 30%) across all the study areas (Table 4.3). However, statistical differences on PEB responses across all study towns and villages were observed for plastic reuse ($p < 0.05$), plastic recycling ($p < 0.05$), paying attention to sustainability issues ($p < 0.05$), and participation in pro–environmental campaigns and by–law compliance ($p < 0.05$; Table 4.3.).

Table 4.3: Responses to questions related to plastic pollution effects and pro–environmental behaviours in the study area. Results are percentages (strongly agree and agree) and Chi–squared results are shown. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$, and ns = not significant $p > 0.05$.

Interview question	**Big towns**		**Small towns**		**Villages**		**Big towns**	**Small towns**	**Villages**	**All**
	% strongly agree	**% agree**	**% strongly agree**	**% agree**	**% strongly agree**	**% agree**				
Plastic pollution effects										
Plastic pollution affects human health	61	22	52	21	51	36	6.118ns	10.8007ns	8.870ns	43.308ns
Microplastic affects aquatic organisms	70	17	56	28	49	36	5.656ns	7.920ns	21.029***	50.099*
Plastic waste affects aesthetics appeal of the environment	50	29	40	30	47	26	7.841ns	8.393ns	10.766ns	32.642ns
Plastics end up in landfills that take up land	63	27	49	31	54	28	12.35*	11.576ns	16.011*	50.088*
Plastic pollution impacts economy and food supply	66	27	46	37	32	37	6.286ns	6.516ns	5.488ns	38.945ns
Pro–environmental behaviours	**% always**	**% often**	**% always**	**% often**	**% always**	**% often**	**Big towns**	**Small towns**	**Villages**	**All**
I dispose plastic correctly	61	20	57	27	52	22	6.883n	6.718ns	12.983ns	30.777ns
I try to reuse plastic	46	10	38	29	32	13	8.049ns	7.691ns	12.842ns	48.520*
I do waste separation	21	8	16	12	17	9	11.413ns	4.067ns	2.903ns	30.614ns
I use recyclable paper	17	12	21	19	4	10	13.115ns	4.825ns	3.832ns	45.868*
I pay attention to sustainability issues	29	20	23	21	20	11	15.689*	12.278ns	9.395ns	48.233*
I participate in pro–environmental campaigns and comply with local by–laws	27	17	13	26	13	18	3.655ns	8.534ns	19.521**	46.472*

4.3.4. Relationship between sociodemographic variables, pro–environmental behaviours, and plastics responses

All sociodemographic variables (gender, age, education, and employment) showed significantly positive corelation ($p < 0.05$) with some pollution effects response (Table 4.4), implying older respondents, employed respondents strongly agreed that plastic pollution caused effects such as loss of aesthetic value and taking up land. In contrast, education negatively correlated with the notion that only the government and business facilities should practice recycling, reuse, and reduce of plastic products. Regarding PEB, most variables showed positive significant relationships (Table 4.4). The above–mentioned positive correlations were more visible across most PEB for plastic picking municipal responsibilities and knowledge about plastic disposal, implying respondents who often and always promote PEB also had knowledge of plastic pollution disposal. Significantly negative correlations were only recorded for plastic disposal vs waste handling, plastic reuse *vs* RRR by government, waster separation vs impact on economy, and pro–environmental campaigns and by–law compliance vs effects on environmental aesthetics (Table 4.4).

Table 4.4: Relationship between sociodemographic and pro–environmental behaviours towards plastic pollution responses. Values in Bold are significant at $p < 0.05$.

Interview questions	**Sociodemographic**				**Pro–environmental behaviours**					
	Gender	**Age**	**Education**	**Employment**	**Plastic disposal**	**Plastic reuse**	**Waste separation**	**Plastic recycling**	**Sustainability issues**	**Pro–environmental campaigns and by–law compliance**
Plastic pollution knowledge and perceptions										
Knowledge of plastic waste disposal	0.055	0.013	0.060	0.031	**0.120**	**0.156**	0.092	**0.153**	**0.124**	0.088
Plastic pollution effects on environment	0.046	0.025	0.055	0.009	0.014	0.115	0.102	0.086	**0.136**	**0.194**
Knowledge of plastic littering vs environmental accountability	0.080	0.100	0.057	0.098	**0.204**	**0.171**	–0.039	0.010	–0.034	–0.013
Municipal is responsible for plastic picking	0.022	–0.066	**0.196**	0.069	0.043	**0.293**	**0.187**	**0.214**	**0.259**	0.099
Concerned about plastic waste	–0.098	–0.062	0.039	0.090	–0.010	0.050	0.111	0.048	0.087	0.033
Knowledge of plastic waste handling	–0.058	–0.096	–0.025	–0.036	**–0.132**	0.021	0.062	0.039	0.013	–0.010
RRR is for govt and business only	–0.062	0.023	**–0.199**	0.018	–0.084	**–0.142**	0.005	0.062	–0.057	–0.059
Plastic is convenient and cannot be replaced	–0.049	–0.075	–0.062	0.084	0.007	0.092	0.086	**0.134**	0.090	–0.003
Plastic pollution effects										
Plastic pollution affects human health	–0.030	–0.053	0.003	0.104	–0.039	0.099	–0.047	–0.041	–0.072	–0.036
Microplastic affects aquatic organisms	**0.141**	–0.019	**0.160**	**0.136**	–0.022	**0.132**	–0.037	0.002	0.031	–0.056
Plastic waste affects aesthetics appeal of the environment	0.023	0.009	**0.135**	0.080	0.013	**0.148**	–0.053	–0.092	–0.022	**–0.178**
Plastics end up in landfills that take up land	0.057	**0.124**	0.053	**0.136**	**0.127**	0.095	–0.015	0.003	0.067	0.059
Plastic pollution impacts economy and food supply	0.016	0.098	0.010	0.170	0.095	0.047	**–0.130**	0.026	0.045	0.093

4.4. Discussion

This study aimed to assess human perception towards plastic pollution as well as the relationship between plastic pollution and PEB across different towns and villages in Nkomazi Local Municipality. Results of the study show that most respondents have knowledge about plastic pollution, although such knowledge varies between towns and villages. Most respondents in urban areas (both big and small towns) had knowledge about plastic pollution compared to those in villages. Our results concur with previous studies that have showed that knowledge of plastic pollution in prevalent in communities (Mashamba et al., 2024; Miguel et al., 2024) but varies across an urban rural gradient (Kunz et al., 2023). In selected areas of Vhembe Biosphere Reserve of South Africa, Mashamba et al. (2024) reported that residents had knowledge about plastic pollution and its impacts on the environment. In Taiwan, Kunz et al. (2023) reported that residential areas have a positive correlation with microplastic pollution whilst forests have a negative relationship with microplastic pollution. The above could imply that densely populated urban residential areas could be associated with high plastic pollution which trigger microplastic pollution compared to rural areas which are typically forested with sparse village houses, thus less microplastic pollution. Some studies have shown that knowledge about plastic pollution could be influenced by age and level of education (Miguel et al., 2024), a result that we also observed, i.e., age/education level relationship with plastic pollution knowledge was positive, but not statistically significant. It seems like older and educated people appreciated the challenges associated with plastic pollution on the environment. Although it is not clear why rural communities had relatively less knowledge about plastic pollution, it is possibility because plastic pollution has been found not to be a major challenge in rural communities (Nxumalo et al., 2020), compared to other social challenges like poverty. This could also be linked to the idea that most rural areas do not generate a lot of plastic compared to industrialised urban areas. Since human perceptions are shaped by the context of the surrounding area, the fact that rural areas do not generate a lot of plastic waste could explain the low knowledge levels (Kunz et al., 2023). In addition, variations in plastic pollution between urban and rural areas could also be explain by the fact that plastic waste is influenced by consumerism and the ability to buy as well as dispose plastic which seem to be high in urban than rural areas. Indeed, de Sousa (2023) reported that a huge proportion of plastic pollution is caused by consumerism and a lack of awareness by plastic consumers to dispose the plastic correctly.

Although, respondents in this study are aware of both the health and environmental effects of plastic pollution, these responses varied across the study towns and villages. In this study, more than half of the respondents in big towns were aware of both human and environmental effects of plastic pollution compared to less than half in villages. Although this could be linked to differences in plastic pollution levels between urban and rural areas, which influences knowledge on plastic pollution effects, this could also be linked to differences in information exposure across the study area. In comparison to urban areas, rural communities in South Africa have inadequate access to information due to lack of facilities like poor internet connectivity, television transmission, and libraries (Boloka and Ngoepe, 2024), yet knowledge on key issues like plastic pollution effects is shared through these information dissemination modes. For example, most respondents in rural compared to urban areas had knowledge about plastic waste handling, reuse, and health effects, yet this information in publicly shared on the internet and television, for which some rural communities do not have access too. Rapada et al. (2023) confirmed that information dissemination on plastic sustainability could influence positive community behaviour towards plastic sustainability, an indication that some of the low responses we noted across the sampled villages could be linked to lack of basic information on plastic pollution. Indeed, disseminating plastic information via online platforms can effectively increase knowledge about the plastic problem this likely to trigger behavioural change, which can contribute towards plastic pollution solutions (Rapada et al., 2023).

Except for the PEB linked to plastic disposal procedure, most of the respondents in both urban and rural areas are unaware of the PEB linked to plastic management such as recycling, separation, reuse, and participation in pro–environmental campaigns. In South Africa, Ngalo and Thondhlana (2023) reported that most household in Komani do not separate waste, including plastic before disposal. In Kenya, approximately 79% of the surveyed population acknowledged that they dump plastic bags on dump sites, an indication that effort to reuse or recycle the plastic is minimal, thus increasing the chances of pollution on the environment (Otsyina et al., 2018). In contrast, studies in some countries have shown a high percentage of residents who reuse and recycle plastic (Northern et al., 2023) including separating plastic before disposing it. Reason for increase reuse and recycle of plastic before disposal do vary, but include, environmental consciousness, behavioural change towards environmental sustainability, income, education level, availability of recycle infrastructure (e.g., bins), and access to information. Increased reuse and recycle has potential to reduce plastic pollution. For example, research in India has shown that plastic recycling, and waste segregation prior to

disposal can reduce illegal waste dumping, which in turn reduces plastic pollution since a significant amount of plastic would have been removed prior disposal (Agarwal et al., 2002; Nagpure, 2019). However, recycling of any waste need to be incentivised so that it is effective, e.g., waste pickers for recycling purposes need to have a reasonable financial benefit that will push them towards collecting waste for recycling.

A key aspect of this study was to assess how PEB influences plastic pollution perception, based on the theory of planned behaviour as articulated by O'Brien and Thondhlana (2019). Results of this study were varied, because in some cases PEB showed positive relationships with plastic pollution perception (sustainability knowledge vs pollution effects), but that was not the case were negative relationships were reported (plastic separation vs impact knowledge). Generally, an individual's attitude towards the environment influences their perceptions and behaviour towards plastic pollution, this have been reported in other studies (O'Brien and Thondhlana 2019; Mashamba et al., 2024). Therefore, nurturing a positive environmental attitude can create opportunities for communities to act positively towards pollution reduction. A study in Thailand showed that human morality behaviour explained resident's positive action on single–use plastic (Oludoye et al., 2024). In Portugal, Soares et al (2021) reported that plastic pollution impacts were associated with PEB. However, it is important to note that pro–environmental behaviour is influenced by several factors such as sociodemographic (age and gender), financial, and psychological factors (Soares et al., 2021). This therefore means that any intervention to promote PEB needs to consider these factors, however, more emphasis should be put on investment in environmental education to mitigate plastic pollution.

4.5. Conclusion

Plastic pollution is a global environmental problem that knows no boundary since it is common in both urban and rural areas. Our results show that, although knowledge on plastic pollution is prevalent across the study area, it varies between urban and rural areas with urban respondents being more knowledgeable than rural respondent. The above was also observed with it comes to perceptions regarding plastic pollution impacts. Both sociodemographic variables (e.g., age and education level) as well as PEB (e.g., reuse and sustainability) informed some of the respondents' positive perception regarding plastic pollution. From a plastic pollution management standpoint, these results suggest (i) financial investment towards plastic pollution reduction e.g., promoting reuse and recycling need to be more in rural than urban areas where information is lacking, (ii) measures to enhance pro–environmental attitudes and

behaviour (awareness campaigns and citizen science) need to be strengthened, and (iii) municipalities should invest in plastic pollution management facilities like bins and recycling centres.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

The production of plastic and its unlawful disposal have a major effect on communities. Current plastic manufacturing and waste generation are exceeding existing limits, causing extensive environmental damage (Walker and Fequet, 2023). If current patterns persist, plastic waste generation could triple by 2060 (Lebreton and Andrady, 2019), with global plastic pollution expected to reach 66 million tonnes per year by 2050 (Yan et al., 2024). Research suggests that low–income countries and Sub–Saharan Africa are projected to be significant contributors to plastic pollution (Yan et al., 2024). The prevalence of illegal plastic waste is driven by insufficient waste management infrastructure, poor recycling capacity, ineffective regulatory enforcement, urbanisation, change in human behaviour, and lack of public awareness (Kibria et al., 2023; Clayton et al., 2020). The illegal disposal of plastic waste in rural and urban areas is largely attributed to factors such as inadequate waste collection infrastructure, and a lack of awareness regarding proper waste management practices (Lakhan, 2024; Mihai and Grozavu, 2019). This challenge is further worsened by the absence of mandatory waste collection services in most rural regions (Tunnell, 2017). It has been further emphasized that weak waste management regulations, insufficient waste facilities, lack of proper training for waste collectors, and household behaviours regarding waste disposal are major contributors to illegal dumping (Ngalo and Thondhlana, 2023). The prominence of illegal plastic dumpsites across different locations is influenced by various geographical and behavioural factors. Spatial factors such as industrial sites, open fields, and rural areas increase the likelihood of illegal dumping, whereas the presence of recycling centres, strict laws and regulations, and awareness programs help reduce it. Additionally, closeness to densely populated communities, ease of street access, and the presence of vacant land influence illegal dumping activities (Ángel Luis Lucendo–Monedero et al., 2015; Yamkela Jakeni et al., 2024). Ngalo and Thondhlana (2023) also linked the occurrence of illegal dumping in towns to insufficient waste collection services, a shortage of proper disposal facilities, and negative attitudes toward waste management.

The illegal disposal of plastic waste in residential areas poses significant environmental and health risks to humans, wildlife, and the ecosystem (Mihai et al., 2021). Plastics contain hazardous compounds like phthalates and heavy metals, which can seep into food and water sources (Hahladakis et al., 2018; Okunola et al., 2019). When animals ingest plastic, it can lead

to fatal digestive blockages or toxic effects. Additionally, plastic pollution contaminates the soil and air, posing risks to human health (Okunola et al., 2019). Plastics contain harmful substances such as phthalates and heavy metals, which can seep into food and water sources (Hahladakis et al., 2018; Okunola et al., 2019). Ingestion of plastic by animals can lead to fatal digestive blockages or toxic effects. Additionally, illegal dumps contaminate the soil and air, posing risks to human health (Okunola et al., 2019). Communities living within industrial zones with inadequate waste management face increased occurrences of respiratory issues and chronic illnesses (Bande and Keni, 2024). A study in South African townships showed that unregulated plastic waste disposal harms both the environment and human health (Adeniran and Shakantu, 2022). The above–mentioned study also showed that plastic pollution was largely due to a lack of awareness (Adeniran and Shakantu, 2022). To mitigate the impacts of plastic pollution, it is essential to implement effective interventions. Developing such measures requires comprehensive data on the location, scale, composition, and public perceptions of plastic waste. This study sought to address this by employing both quantitative and qualitative methods to evaluate plastic dumping and perceptions across three large towns, three small towns, and three villages within Nkomazi Local Municipality, Mpumalanga Province, South Africa.

5.2. Summary of key findings

5.2.1. Plastic dumping distribution, abundance, and composition in dumpsites

Although dumpsites were more common in towns than villages, larger dumpsites were predominantly found in big towns and villages. In big towns, illegal plastic waste dumpsites were mostly located in densely populated, low–income residential areas, whereas high–income residence with low population densities had fewer occurrence of illegal plastic waste disposal. The distribution of dumpsites in small towns was inconsistent, with some areas having a higher abundance than others. In high–income residence of big towns, dumpsites were frequently found in parks and vacant plots, whereas in small towns, illegal dumping was more prevalent in low–income residential road verges. Plastic pollution was particularly noticeable along roadsides and river riparian zones. In villages, the presence and density of illegal dumpsites varied significantly. Some villages had dumpsites with both low and high abundance, often located at the centre of the village. As one moved outward, the density of these illegal dumpsites decreased, though plastic waste remained visible along roadsides, near rivers, and around graveyards. Previous studies have shown that dumping is prevalent in low–income areas and mostly happen along road verges and in open access areas (Niyobuhungiro and

Schenck, 2012; Swanepoel et al., 2023; Ngalo and Thondhlana, 2024; Swanepoel and Marlin, 2024). What is important in this study was that rural communities also have a plastic pollution problem, thus waste management plans by municipalities been to prioritise rural areas.

The composition of plastic waste in dumpsites varied across the sample areas. Polypropylene (PP) and polyethylene terephthalate (PET) were the most common plastic identified across most dumpsites, being more visible in rural than urban areas. The dominance of PP among other plastic types and its wide distribution highlights its extensive use in households' products and its notable contribution to microplastic pollution. The demand for PP is predicted to increase further due to its numerous applications, which include being durable, flexible, and lightweight (Seiler, 1995). These findings highlight the critical need for improved waste management and recycling techniques to address the growing issue of PP disposal in dumpsites.

5.2.2. Perception, pro–environmental behaviour and plastic pollution

The questionnaire survey revealed that participants had knowledge of plastic and its effects, however such information varied across rural and urban areas. Most rural areas have challenges related to waste handling and management, largely due to inadequate pollution knowledge and education. This issue was also noticeable in small towns than in large towns. Interviews with residents further revealed concerns about plastic pollution affecting daily activities. They also noted that plastic pollution occurrence along river margins trigger serious health risk. The inadequate of knowledge and plastic pollution in rural communities is linked to lack of facilities like poor internet connectivity, television transmission, and libraries (Boloka and Ngoepe, 2024).

Most respondents in both urban and rural areas are unaware of the PEB linked to plastic management such as recycling, separation, reuse, and participation in pro–environmental campaigns. Although some studies have showed that PEB influence plastic pollution perception (Mashamba et al., 2024), results of this study were varied, with some positive relationships between PEB and plastic pollution perception (sustainability knowledge vs pollution effects) but some negative relationships e.g., plastic separation vs impact knowledge. Generally, our results show that individual's attitude towards the environment influences their perceptions and behaviour towards plastic pollution, this have been reported in other studies (O'Brien and Thondhlana 2019; Mashamba et al., 2024).

5.3 Recommendations

Based on these findings, the following recommendations are proposed.

- Plastic pollution is a problem that affects both rural and urban communities. Therefore, municipal responses to address plastic pollution should prioritise waste removal services in both urban and rural communities, meaning financial and human resource investment to manage the problem should be the same.
- There is a need to enhance public awareness and education on plastic pollution. This can be effectively implemented by first understanding the local context where plastic pollution is prevalent. Community–based educational campaigns will help raise awareness about the issue, its environmental and health impacts, and promote sustainable waste disposal methods. Since different communities have varying literacy levels, it is essential to use culturally relevant content to ensure information accessibility and engagement. Additionally, municipalities should train local waste workers, including waste collectors, recyclers, and community groups, to facilitate recycling initiatives within their areas. This training will equip them with knowledge on effective waste management practices, recycling techniques, and the legal framework governing plastic waste disposal. For example, research in South Africa indicates that higher education levels are associated with a great awareness of plastic pollution problem, emphasising the need to incorporate environmental education into school curriculum (Dalu et al., 2020; Soares et al., 2021).
- Due to municipal budget constraints which may persist, implementing initiatives such as providing skip bins and waste collection services in all areas may take time, while the issue of plastic waste dumping continues to persist. To address this challenge, municipalities should focus on promoting sustainable plastic waste management methods to lessen dependence on traditional practices like incineration and backyard burial of plastic waste and the act of illegal dumping. One effective solution is upcycling, which encourages the creative reuse of plastic materials to prolong their lifespan and reduce environmental harm. For example, a study by (Zhao and You, 2023) found that upcycling technologies can have a much lower environmental effect than landfills and incineration. Apart from that, municipalities can promote plastic recycling at household level. This will ensure that plastic dumping is reduced since some of the plastics will have been recycled at household level. This was found to be effective in India were high levels of plastic separation at household level significantly reduced the plastic material at dumpsites (Nagpure, 2019). However, for this to be effective, plastic segregation and recycling at household level should be

incentivised so that it is effective. Incentivisation could be in the form of income to those who practice recycling at household level.

- Municipalities must enforce their existing waste management legislation and by–laws to ensure that dumping of plastics is reduced. Regardless of whether a municipality is metropolitan, district, or local, waste management by–laws should align with the National Environmental Management: Waste Act (NEMWA), Act No. 59 of 2008 and implemented with some penalties. However, these legislations are often not adequately enforced. To address this, municipalities should allocate sufficient funding for waste containment infrastructures and enforcement of illegal plastic disposal. Additionally, regular monitoring of areas within municipal jurisdiction is essential to assess changes in the prevalence of illegal plastic dumpsites. Utilising GIS technology can help track these changes over time, allowing for a comparative analysis of illegal dumping trends. This approach has the potential to significantly reduce the occurrence of illegal plastic dumpsites.
- Municipalities should consider socioeconomic factors when designing waste management strategies. This involves adopting waste management approaches to match community consumption patterns. For instance, a study in Pakistan found significant differences in household consumption behaviours between urban and rural areas, with income levels influencing structural and behavioural variations in expenditure (Burney and Khan, 1991). Moreover, waste disposal infrastructure, such as skip bins, can be provided at appropriate standards. In large towns, where the population is predominantly young and literate, waste bins can be labelled and colour–coded to promote waste segregation and recycling. Conversely, in rural areas, where most residents are older and less literate, general skip bins without labels or colour coding may be more effective for primarily managing waste. This ensures practical and efficient waste solutions tailored to different locations.
- Lastly, future research should investigate the following aspects of illegal plastic dumping: (i) assessing the effectiveness of current waste management policies, municipal by–laws, and regulations in mitigating illegal plastic pollution, (ii) assessing the differences in plastic pollution between rural and urban areas, identifying specific challenges faced by each settlement type, and recommending customized solutions for effective waste management. In addition, more research should be on, (iii) assessing the behavioural and psychological drivers behind illegal plastic dumping, and (iv) assessing the environmental impact of plastic pollution on soil, water bodies, and ecosystems, as well as assessing potential health risks, especially for communities living near unregulated dumpsites.

REFERENCES

Abalansa, S., El Mahrad, B., Vondolia, G.K., Icely, J., Newton, A., 2020. The marine plastic litter issue: A social–economic analysis. Sustainability 12, 8677.

Abiodun, G.J., Njabo, K.Y., Witbooi, P.J., Adeola, A.M., Fuller, T.L., Okosun, K.O., Makinde, O.S., Botai, J.O., 2018. Exploring the influence of daily climate variables on malaria transmission and abundance of Anopheles arabiensis over Nkomazi local municipality, Mpumalanga Province, South Africa. Journal of Environmental and Public Health 2018, 1–12.

Adak, P., 2020. Plastic wastes and its management. https://www.academia.edu/90001746/Plastic_Wastes_And_Its_Management (Accessed 18 March 2025).

Adeniran, A.A., Shakantu, W., 2022. The health and environmental impact of plastic waste disposal in South African Townships: A review. International Journal of Environmental Research and Public Health 19, 779.

Adewuyi, A., Li, Q., 2024. Emergence of microplastics in African environmental drinking water sources: A review on sources, analysis and treatment strategies. Journal of Hazardous Materials Advances 100465.

Agarwal, R., 2002. Recycling Responsibility: Traditional Systems and New Challenges of Urban Solid Waste in India. Srishti Publishers, New Delhi.

Agnes, N., Rajmund, K.U.T.I., 2016. The environmental impact of plastic waste incineration. AARMS–Academic and Applied Research in Military and Public Management Science 15, 231–237.

Ahmed, T., Shahid, M., Azeem, F., Rasul, I., Shah, A.A., Noman, M., Hameed, A., Manzoor, N., Manzoor, I., Muhammad, S., 2018. Biodegradation of plastics: Current scenario and future prospects for environmental safety. Environmental Science and Pollution Research 25, 7287–7298.

Akan, O.D., Udofia, G.E., Okeke, E.S., Mgbechidinma, C.L., Okoye, C.O., Zoclanclounon, Y.A.B., Atakpa, E.O., Adebanjo, O.O., 2021. Plastic waste: Status, degradation and microbial management options for Africa. Journal of Environmental Management 292, 112758.

Al Fariz, R.D., Rachman, I., Matsumoto, T., 2024. A spatio-temporal analysis of illegal waste disposal site activities at national strategic area in developing country – Deli Serdang

Regency, Indonesia. Ecological Engineering & Environmental Technology 25(9), 231–242. https://doi.org/10.12912/27197050/190755

Al–Haziazi, M., Muthuraman, S., 2019. Consumer environmental responsibility towards green consumption in Sultanate of Oman. Kuwait Chapter of Arabian Journal of Business and Management Review 8, 24–37.

Alimba, C.G., Faggio, C., 2019. Microplastics in the marine environment: Current trends in environmental pollution and mechanisms of toxicological profile. Environmental Toxicology and Pharmacology 68, 61–74.

Allison, A.L., Baird, H.M., Lorencatto, F., Webb, T.L., Michie, S., 2022. Reducing plastic waste: A meta-analysis of influences on behaviour and interventions. Journal of Cleaner Production 380, 134860.

Alsabri, A., Tahir, F., Al-Ghamdi, S.G., 2022. Environmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region. Materials Today: Proceedings 56, 2245–2251.

Andersen, J.A., Rowland, B., Ratcliff, S.M., Felix, H.C., McElfish, P.A., 2022. Relationship between sociodemographic factors, perceived COVID-–19 risk, and engagement with health protective behaviors. Southern Medical Journal 115, 340–346.

Anderson, N.B., 2007. Encyclopedia of Health and Behavior. SAGE Publications, Thousand Oaks, CA. from https://sk.sagepub.com/reference/behavior. Retrieved August 30, 2023.

Armitage, N., Rooseboom, A., 2000. The removal of urban litter from stormwater conduits and streams: Paper 1 – The quantities involved and catchment litter management options. Water SA 26, 181–188.

Ayeleru, O.O., Dlova, S., Akinribide, O.J., Ntuli, F., Kupolati, W.K., Marina, P.F., Blencowe, A., Olubambi, P.A., 2020. Challenges of plastic waste generation and management in sub–Saharan Africa: A review. Waste Management 110, 24–42.

Ayeleru, O.O., Fajimi, L.I., Onu, M.A., Nyam, T.T., Dlova, S., Ameh, V.I., Olubambi, P.A., 2024. Estimating plastic waste generation using supervised time–series learning techniques in Johannesburg, South Africa. Heliyon 10(7).

Ayuba, K.A., Manaf, L.A., Sabrina, A.H., Azmin, S.W., 2013. Current status of municipal solid waste management practise in FCT Abuja. Research Journal of Environmental and Earth Sciences 5, 295–304.

Azjen, I., 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes 50, 179–211.

Babayemi, J.O., Nnorom, I.C., Osibanjo, O., Weber, R., 2019. Ensuring sustainability in plastics use in Africa: Consumption, waste generation, and projections. Environmental Sciences Europe 31, 1–20.

Barles, S., 2014. History of waste management and the social and cultural representations of waste. In: Pfister, C., Krausmann, F. (Eds.), The Basic Environmental History. Springer, Cham, pp. 199–226.

Barnes, D.K., Galgani, F., Thompson, R.C., Barlaz, M., 2009. Accumulation and fragmentation of plastic debris in global environments. Philosophical Transactions of the Royal Society B: Biological Sciences 364, 1985–1998.

Bartolotta, J.F., Hardy, S.D., 2018. Barriers and benefits to desired behaviors for single use plastic items in northeast Ohio's Lake Erie basin. Marine Pollution Bulletin 127, 576–585.

Benson, N.U., Fred-–Ahmadu, O.H., Bassey, D.E., Atayero, A.A., 2021. COVID-–19 pandemic and emerging plastic-–based personal protective equipment waste pollution and management in Africa. Journal of Environmental Chemical Engineering 9, 105222.

Bidashimwa, D., Hoke, T., Huynh, T.B., Narkpitaks, N., Priyonugroho, K., Ha, T.T., Burns, A., Weissman, A., 2023. Plastic pollution: How can the global health community fight the growing problem? BMJ Global Health 8(Suppl 3), e012140.

Biswal, T., Kar, P.K., 2020. Plastic pollution and its effect on the environment. In: Borthakur, A., Singh, P. (Eds.), Handbook of Research on Environmental and Human Health Impacts of Plastic Pollution. IGI Global, pp. 1–28.

Boloka, M., Ngoepe, M., 2024. Leaving no one behind: Information (re)packaging for rural dwellers in South Africa. Information Development. https://doi.org/10.1177/02666669241227877

Borrelle, S.B., Ringma, J., Law, K.L., Monnahan, C.C., Lebreton, L., McGivern, A., Rochman, C.M., 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science 369, 1515–1518.

Bouwmeester, H., Hollman, P.C., Peters, R.J., 2015. Potential health impact of environmentally released micro– and nanoplastics in the human food production chain: Experiences from nanotoxicology. Environmental Science and Technology 49, 8932–8947.

Bukova, M., Bondal, A., Skvortsova, O., Nikonova, O., Kholodiakov, A., Guseva, I., Makarova, T., Mirschel, W., 2016. Reclamation of the illegal dump for sustainable development the environment in Sverdlovo of Leningrad Oblast, Russia. MATEC Web of Conferences 73, 03002.

Cai, K., Song, Q., Peng, S., Yuan, W., Liang, Y., Li, J., 2019. Uncovering residents' behaviors, attitudes, and willingness to pay for recycling e-–waste: A case study of Zhuhai city, China. Environmental Science and Pollution Research 27, 2386–2399.

Calculli, C., D'Uggento, A.M., Labarile, A., Ribecco, N., 2021. Evaluating people's awareness about climate changes and environmental issues: A case study. Journal of Cleaner Production 324, 129244.

Census 2011: Population Dynamics / Statistics South Africa. Pretoria: Statistics South Africa, 2012. Report No. 03–01–67, 106–124.

Chauhan, R.S., 2020. Environmental awareness and environmental attitude of in-–service secondary school teachers (With special reference of Uttarakhand State). Mukt Shabd Journal 9, 87–101.

Chen, C., 2021. Treatment of plastic pollution based on the perspective of Internet+"Plastic ban". IOP Conference Series: Earth and Environmental Science 692, 032013.

Chen, X., Peterson, M.N., Hull, V., Lu, C., Lee, G.D., Hong, D., Liu, J., 2011. Effects of attitudinal and sociodemographic factors on pro–environmental behaviour in urban China. Environmental Conservation 38, 45–52.

Cheng, J.C.–H., Monroe, M.C., 2010. Connection to nature. Environment and Behavior 44, 31–49.

Chib, A., Chiew, H.J., Kumar, C., Choon, L.G., Ale, K., 2009. [minus] plastic: Influencing pro-environmental attitudes among Singaporean youth. Environmental Education Research 15, 679–696.

Chitotombe, J.W., Gukurume, S., 2014. The plastic bag 'ban' controversy in Zimbabwe: An analysis of policy issues and local responses. International Journal of Development and Sustainability 3, 1000–1012.

Cong–Lem, N., 2025. The relation between environment and psychological development: Unpacking Vygotsky's influential concept of perezhivanie. Human Arenas 8, 225–243.

Conservancy, O., Lardinois, I., van de Klundert, A., Lohri, C.R., Joseph, E., 2014. Managing waste in emerging markets. Waste Management 34, 542–552.

Couth, R., Trois, C., 2012. Cost effective waste management through composting in Africa. Waste Management 32, 2518–2525.

CSIR, 2011. Municipal waste management – good practices. Edition 1. Council for Scientific and Industrial Research, Pretoria.

Dalu, M.T., Cuthbert, N.R., Muhali, H., Chari, D.L., Manyani, A., Masunungure, C., Dalu, T., 2020. Is awareness on plastic pollution being raised in schools? Understanding perceptions of primary and secondary school educators. Sustainability 12, 677.

Dalu, M.T., Ngobeni, B.S., Dalu, T., 2023. Assessing pro–environmental behaviour towards plastics among staff and students at a South African university. Sustainability 15, 16904.

Dalu, M.T., Ngobeni, B.S., Dalu, T., 2023. Human perceptions and reports of pro–environmental behaviours in the context of plastic pollution in rural communities within a UNESCO subtropical biosphere reserve. Journal of Environmental Studies and Sciences, https://doi.org/10.1007/s13412-–023-–00846-–1

Dalu, T., Malesa, B., Cuthbert, R.N., 2019. Assessing factors driving the distribution and characteristics of shoreline macroplastics in a subtropical reservoir. Science of the Total Environment 696, 133992.

Darensbourg, D.J., 2007. Making plastics from carbon dioxide: Salen metal complexes as catalysts for the production of polycarbonates from epoxides and CO2. Chemical Reviews 107, 2388–2410.

Davison, S.M.C., White, M.P., Pahl, S., Taylor, T., Fielding, K., Roberts, B.R., Fleming, L.E., 2021. Public concern about, and desire for research into, the human health effects of marine plastic pollution: Results from a 15–country survey across Europe and Australia. Global Environmental Change 69, 102309.

De Leeuw, A., Valois, P., Ajzen, I., Schmidt, P., 2015. Using the theory of planned behavior to identify key beliefs underlying pro–environmental behavior in high–school students: Implications for educational interventions. Journal of Environmental Psychology 42, 128–138.

de Sousa, F.D.B., 2023. Consumer awareness of plastic: An overview of different research areas. Circular Economy and Sustainability 3, 2083–2107.

Deng, L., Cai, L., Sun, F., Li, G., Che, Y., 2020. Public attitudes towards microplastics: Perceptions, behaviors and policy implications. Resources, Conservation and Recycling 163, 105096.

Devi, K., Swamy, A.V.V., Nailofer, S., 2016. Municipal solid waste management in India: An overview. Asia Pacific Journal of Research 1, 118–126.

Dey, A., Dhumal, C.V., Sengupta, P., Kumar, A., Pramanik, N.K., Alam, T., 2020. Challenges and possible solutions to mitigate the problems of single–use plastics used for packaging food items: A review. Journal of Food Science and Technology 58, 3251–3269. https://doi.org/10.1007/s13197-–020-–04885-–6

Dikgang, J., Leiman, A. and Visser, M., 2012. Elasticity of demand, price and time: Lessons from South Africa's plastic–bag levy. Applied Economics 44(26), 3339–3342.

Dilkes–Hoffman, L.S., Pratt, S., Laycock, B., Ashworth, P., and Lant, P.A. 2019. Public perceptions of plastics. Resource Conservation and Recycling 147, 227–235.

Doran, P. T., and Zimmerman, M. K., 2009. Examining the scientific consensus on Climate Change. Eos, Transactions American Geophysical Union, 90(3), 22.

Dorigoni, A. and Bonini, N.,2023 "Water bottles or tap water? A descriptive–social–norm based intervention to increase a pro–environmental behavior in a restaurant. Journal of Environmental Psychology 86, 10.

Dumbili, E., Henderson, L., 2020. The challenge of plastic pollution in Nigeria. In: Letcher, T.M. (Ed.), Plastic waste and recycling: Environmental impact, societal issues and the circular economy. Academic Press, Cambridge, MA, USA, 569–583.

DWAF (1998) Waste Generation in South Africa: Baseline Studies. Waste Management Series. DWAF, Pretoria,77.

Efron, R., 1969. What is perception? In: Cohen, R.S., Wartofsky, M.W. (Eds.), Proceedings of the Boston Colloquium for the Philosophy of Science 1966/1968. Boston Studies in the Philosophy and History of Science, vol. 4. Springer, Dordrecht, 137–173.

Erensoy, A., Mathrani, A., Schnack, A., Elms, J. and Baghaei, N., 2024. Consumer behaviour in immersive virtual reality retail environments: A systematic literature review using the stimuli-organisms-responses (S-O-r) model. Journal of Consumer Behaviour, 23(6), 2781–2811.

Fazzo, L., Manno, V., Iavarone, I., Minelli, G., De Santis, M., Beccaloni, E., Scaini, F., Miotto, E., Airoma, D. and Comba, P., 2023. The health impact of hazardous waste landfills and illegal dumps contaminated sites: An epidemiological study at ecological level in Italian Region. Frontiers in public health, 11, 996960.

Ferronato, N., and Torretta, V., 2019. Waste mismanagement in developing countries: A Review of Global Issues. International Journal of Environmental Research and Public Health, 16(6), 1060.

Fielding, K.S., McDonald, R., Louis, W.R., 2008. Theory of planned behaviour, identity and intentions to engage in environmental activism. Journal of Environmental Psychology 28, 318–326. https://doi.org/10.1016/j.jenvp.2008.03.003.

Fischer, A. R., 2017. Perception, attitudes, intentions, decisions and actual behavior. Consumer Perception of Product Risks and Benefits, 303–317.

Foley, H.J., 2019. Sensation and perception. 6th ed. Routledge, New York.

Gambhir, V., Shah, M.D., Sharma, N., Bhagwan, S., 2024. Environmental degradation of ordinary plastic wastes: a review on present awareness and disposal prospects. Multidisciplinary Reviews 6, Article 2023ss026. https://doi.org/10.31893/multirev.2023ss026.

Gerrig, R.J., Zimbardo, P.G., Campbell, A.J., Cumming, S.R., Wilkes, F.J., 2015. Psychology and life. Pearson Higher Education AU.

Geyer, R., 2020. Production, use, and fate of synthetic polymers., Plastic Waste and Recycling, 13–32.

Geyer, R., Jambeck, J.R. and Law, K.L., 2017. Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782.

Gifford, R., Nilsson, A., 2014. Personal and social factors that influence pro-environmental concern and behaviour: a review. International Journal of Psychology 49(3), 141–157. https://doi.org/10.1002/ijop.12034.

Gilbert, C. D.,1996. Plasticity in visual perception and physiology. Current Opinion in Neurobiology, 6(2), 269–274.

Gininda, P.S., Antwi, M.A. and Oladele, O.I., 2014. Smallholder sugarcane farmers' perception of the effect of micro agricultural finance institution of South Africa on livelihood outcomes in Nkomazi local municipality, Mpumalanga Province. Mediterranean Journal of Social Sciences, 5(27), 1032–1040.

Gitelson, R.J. and Kerstetter, D.L., 1990. The relationship between sociodemographic variables, benefits sought and subsequent vacation behavior: A case study. Journal of travel Research, 28(3), 24–29.

Glasser, M.D. and Wright, J., 2020. South African municipalities in financial distress: What can be done?. Law, Democracy & Development, 24(1), 413-–441.

Gnimadi, C. J., Aboah, M., Gawou, K.,2022. Using factor analysis to understand the influence of individual perception on plastic waste disposal. Indonesian Journal of Social and Environmental Issues (IJSEI), 3(3), 194–204.

Godfrey, L., 2021. Quantifying economic activity in the informal recycling sector in South Africa. South African Journal of Science 117(9/10), 138–144. Article #8921. https://doi.org/10.17159/sajs.2021/8921.

Grebitus, C., Roscoe, R.D., Van Loo, E.J., Kula, I., 2020. Sustainable bottled water: How nudging and Internet search affect consumers' choices. Journal of Cleaner Production 267, 121930. https://doi.org/10.1016/j.jclepro.2020.121930.

Grimmer, M., Woolley, M., 2014. Green marketing messages and consumers' purchase intentions: promoting personal versus environmental benefits. Journal of Marketing and Communication, 20(4), 231–250.

Gumbo, T., and Simelane, T., 2015. Innovations in municipal solid waste management: Future Directions of Municipal Solid Waste Management in Africa, 202–217.

Gupta, A. and Roy, A., 2022. A study on plastic waste in households, Journal of Academic Advancement, 1(2), 49–57.

Hameed, I., Khan, K., Waris, I. and Zainab, B., 2022. Factors influencing the sustainable consumer behavior concerning the recycling of plastic waste. Environmental Quality Management, 32(2),197–207.

Hammami, M.B.A., Mohammed, E.Q., Hashem, A.M., Al–Khafaji, M.A., Alqahtani, F., Alzaabi, S., Dash, N., 2017. Survey on awareness and attitudes of secondary school students regarding plastic pollution: Implications for environmental education and public health in Sharjah city, UAE. Environmental Science and Pollution Research, 2, 24.

Hanekom, A., 2020. South African initiative to end plastic pollution in the environment. South African Journal of Science, 116(5–6), 1–2.

Hasan, S. N., Harun, R., and Hock, L. K., 2015. Application of theory of planned behaviour in measuring the behaviour to reduce plastic consumption among students at Universiti Putra Malaysia, Malaysia. Procedia Environmental Sciences, 30, 195–200.

Haywood, L.K., Kapwata, T., Oelofse, S., Breetzke, G. and Wright, C.Y., 2021. Waste disposal practices in low–income settlements of South Africa. International Journal of Environmental Research and Public Health, 18(15), 8176.

Heidbreder, L. M., Bablok, I., Drews, S., and Menzel, C., 2019. Tackling the plastic problem: A review on perceptions, behaviors, and interventions. Science of The Total Environment, 668, 1077–1093.

Heyes, A. and Kapur, S., 2012. Community pressure for green behavior. Journal of Environmental Economics and Management, 64(3), 427–441.

Hodsman, C. and Williams, I., 2011, March. Drivers for the fly–tipping of household bulky waste in England. In Proceedings of the institution of civil engineers–municipal engineer (Vol. 164, No. 1, 33–44). Thomas Telford Ltd.

Hopewell, J., Dvorak, R. and Kosior, E., 2009. 'Plastics recycling: Challenges and opportunities', Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 2115–2126.

Hossain, R., Islam, M.T., Shanker, R., Khan, D., Locock, K.E.S., Ghose, A., Schandl, H., Dhodapkar, R. and Sahajwalla, V., 2022. Plastic waste management in India: Challenges, opportunities, and roadmap for circular economy. Sustainability, 14(8), 4425.

Houssini K., Li J., Tan Q., 2025. Complexities of the global plastics supply chain revealed in a trade-linked material flow analysis. Communications Earth & Environment, 6(1), 257. https://doi.org/10.1038/s43247-025-02169-5.

Huang, M., Jiao, J., Zhuang, P., Chen, X., Wang, J. and Zhang, Y., 2018. Serum polyfluoroalkyl chemicals are associated with risk of cardiovascular diseases in national US population. Environment International, 119, 37–46.

Huet, S., Nugier, A., 2022. The effect of perceived individual social contexts on behaviors against plastic pollution. SSRN Electronic Journal. https://ssrn.com/abstract=4188717 [Accessed 13 May 2025]. https://doi.org/10.2139/ssrn.4188717.

Ichipi, E.B., 2023. Assessing the Environmental and Health Impact of Illegal Dumping of Solid Waste in Lagos State. Master's thesis, University of Johannesburg, Johannesburg.

Ishitani, T.T., 2003. A longitudinal approach to assessing attrition behavior among first–generation students: Time–varying effects of pre–college characteristics. Research in Higher Education, 44(4), 433–449.

Jaikumar, I.M., Tomson, M., Pappuswamy, M., Krishnakumar, V., Shitut, A., Meyyazhagan, A., Balasubramnaian, B. and Arumugam, V.A., 2022. Detrimental effects of microplastics in aquatic fauna on marine and freshwater environments–A comprehensive review. Journal of Applied Biology and Biotechnology, 11(1), 28–35.

Jakeni, Y., Maphanga, T., Madonsela, B.S. and Malakane, K.C., 2024. Identification of Illegal Dumping and Community Views in Informal Settlements, Cape Town: South Africa. Sustainability, 16(4), 1429.

Jambeck, J., Hardesty, B.D., Brooks, A.L., Friend, T., Teleki, K., Fabres, J., Beaudoin, Y., Bamba, A., Francis, J., Ribbink, A.J. and Baleta, T., 2018. Challenges and emerging solutions to the land–based plastic waste issue in Africa. Marine Policy, 96, 256–263.

Jambeck, J.R., Geyer, R., Wilcox., Siegler, T., Perryman, M., Andrady, A., Narayan, R, Law, K., 2015. Plastic waste inputs from land into the Ocean. Science, 347(6223), 768–771.

Jassim, A.K., 2023. Effect of microplastic on human health. In: Salama, E.S. (Ed.), Advances and Challenges in Microplastics. IntechOpen, London: IntechOpen. https://doi.org/10.5772/intechopen.107149.

Katlam, G., Prasad, S., Aggarwal, M. and Kumar, R., 2018. Trash on the menu. Current Science, 115(12), 2322-–2326.

Keizer, K., and Schultz, P. W., 2018. Social norms and pro–environmental behaviour. Environmental Psychology, pp.179–188. doi:10.1002/9781119241072.ch18.

Kenis, A. and Mathijs, E., 2012. Beyond individual behaviour change: The role of power, knowledge and strategy in tackling climate change. Environmental Education Research, 18(1), 45–65.

Koelmans, A.A., Besseling, E.; Foekema, E.,Kooi, M., Mintenig, S., Ossendorp, B.C., Redondo–Hasselerharm, P.E., Verschoor, A.,van Wezel, A.P., Scheffer, M., 2017. Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, and Belief. Environmental Science Technology 51, 11513–11519.

Kubanza, N.S. and Simatele, D., 2016. Social and environmental injustices in solid waste management in sub–Saharan Africa: a study of Kinshasa, the Democratic Republic of Congo. Local Environment, 21(7), 866–882.

Kumar, D.P., Ramakrishna, C.S., Tiwari, P., Saxena, N.V., Mishra, S.K., Tiwari, S., Kumar, P., Yadav, A.S. and Sharma, A., 2022. Challenges and prospects of waste management in Rajasthan. Materials Today: Proceedings, 63, A15-A21.

Kumar, S., Chakrabarti, T., 2010. Effective municipal solid waste management in India. In: Kumar, S. (Ed.), Integrated Waste Management. InTechOpen, Rijeka, Croatia. https://doi.org/10.5772/8509.

Kunz, A., Schneider, F., Anthony, N. and Lin, H.–T. 2023. Microplastics in rivers along an urban–rural gradient in an urban agglomeration: Correlation with land use, potential sources and pathways. Environmental Pollution, 321, 121096.

Kurisu, K., 2015. What are pro-environmental behaviors (PEBs)? In: Pro-environmental Behaviors. Springer Japan, Tokyo, 1–26. https://doi.org/10.1007/978-4-431-55834-7_1.

Khoaele K.K., Gbadeyan O.J., Chunilall V., Sithole B., 2023. The devastation of waste plastic on the environment and remediation processes: A critical review. Sustainability, 15(6), 5233. https://doi.org/10.3390/su15065233.

Laabidi, H. and Charafi, M., 2023. Environmental knowledge, attitudes and behavior of English as foreign language students: A case study in FLSH, Meknes, Morocco. Journal on Studies in English Language Teaching (JOSELT), 4(2), 74-–88.

Lebreton, L. and Andrady, A., 2019. Future scenarios of global plastic waste generation and disposal. Palgrave Communications, 5(1), 1-–11.

Leitão, M., Hackradt, C.W., Silva, Í.L.E., Ciancio, J.E. and Félix-–Hackradt, F.C., 2023. Effect of human impact on coral reef herbivorous fish niche. Marine Biology, 170(5), 59.

Li, W.C., Tse, H.F., Fok, L., 2016. Plastic waste in the marine environment: A review of sources, occurrence and effects. Science of The Total Environment 566–567, 333–349. https://doi.org/10.1016/j.scitotenv.2016.05.084.

Li, D., Zhao, L., Ma, S., Shao, S., and Zhang, L., 2019. What influences an individual's pro–environmental behavior? A literature review. Resources, Conservation and Recycling, 146, 28–34.

Liobikienė, G., and Juknys, R., 2016. The role of values, environmental risk perception, awareness of consequences, and willingness to assume responsibility for environmentally–friendly behaviour: The Lithuanian case. Journal of Cleaner Production, 112, 3413–3422.

Liu, J., Li, Q., Gu, W., andamp; Wang, C., 2019. The impact of consumption patterns on the generation of municipal solid waste in China: Evidences from Provincial Data. International Journal of Environmental Research and Public Health, 16(10), 1717.

Lu, J., Qiu, Y., Zhang, L., Wang, J., Li, C., Wang, P. and Ren, L., 2024. Effects of Fe3O4 NMs based Fenton-–like reactions on biodegradable plastic bags in compost: new insight into ‘

plastisphere community succession, co-–composting efficiency and free radical in situ aging theory. Journal of Hazardous Materials, 467,133689.

Maalouf, A. and Mavropoulos, A., 2023. Re-–assessing global municipal solid waste generation. Waste Management & Research, 41(4), 936-–947.

Madigele, P.K. and Mogomotsi, G.E.J., 2017. "Polluter pays or polluter enriching the retailers": the case of plastic bag levy failure in Botswana. Ethiopian Journal of Environmental Studies and Management, 10(4), 472–481.

Maibach, E., Myers, T., and Leiserowitz, A., 2014. Climate scientists need to set the record straight: There is a scientific consensus that human-caused climate change is happening. Earth's Future, 2(5), 295–298.

Maloney, J.C., 2018. What it is like to perceive: Direct realism and the phenomenal character of perception. Oxford University Press, New York.

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., and Bezirtzoglou, E., 2020. Environmental and health impacts of Air Pollution: A Review. Frontiers in Public Health, 8, 14.

Mashamba, R., Dalu, M.T.B., Cuthbert, R.N., Dondofema, F., Dalu, T., 2024. Human perceptions and reports of pro-environmental behaviours in the context of plastic pollution in rural communities within a UNESCO subtropical biosphere reserve. Journal of Environmental Studies and Sciences. https://doi.org/10.1007/s13412-024-00957-7.

Niyobuhungiro, R.V., Schenck, C., 2022. Exploring community perceptions of illegal dumping in Fisantekraal using participatory action research. South African Journal of Science 118(special issue). https://doi.org/10.17159/sajs.2022/12563.

Mazhandu, Z.S., Muzenda, E., Belaid, M., Nhubu, T., 2021. A narrative review of plastic waste pyrolysis: Challenges and opportunities. Proceedings of the International Conference on Sustainable Materials Processing and Manufacturing (SMPM 2021), 2–4 March 2021, Kruger National Park, South Africa. Available at: https://hdl.handle.net/10210/490427.

McDonnell, T., 2024. The Irish Tax System: Challenges Ahead. Studies: An Irish Quarterly Review, 113(452), 477–487.

McKinley, S. Fletcher., 2012. Improving marine environmental health through marine citizenship: a call for debate, Marine Policy 36, 839–843.

Medina, M., 2008. The informal recycling sector in developing countries: Organizing waste pickers to enhance their impact. Gridlines No. 44. World Bank, Washington, DC. Available at: https://hdl.handle.net/10986/10586.

Merrill, G.B., Hermabessiere, L., Rochman, C.M. and Nowacek, D.P., 2023. Microplastics in marine mammal blubber, melon, & other tissues: Evidence of translocation. Environmental Pollution, 335, 122252.

Miguel, I., Santos, A., Venâncio, C. and Oliveira, M., 2024. Knowledge, concerns and attitudes towards plastic pollution: An empirical study of public perceptions in Portugal. Science of The Total Environment, 906, 167784.

Mihai, F.C., Minea, I. and Grozavu, A., 2018. Assessment of waste dumping practices in mountain creeks. In International Multidisciplinary Scientific GeoConference on Ecology, Economics, Education and Legislation SGEM, 89–96. MISC.

Mnisi, F., 2008. Environmental risk assessment associated with unregulated landfills in the Albert Luthuli Municipality, Mpumalanga Province, RSA. MSc dissertation, University of South Africa. Available at: http://hdl.handle.net/10500/2274.

Modak, P., and Wilson, D.C., 2015. Waste management—social and environmental impacts. In M. Kutz (Ed.), Handbook of Environmental Engineering. McGraw–Hill Education, New York.

Molloy, S., Medeiros, A.S., Walker, T.R. and Saunders, S.J., 2022. Public perceptions of legislative action to reduce plastic pollution: a case study of Atlantic Canada. Sustainability, 14(3), 1852.

Molstad, E.P., Martin, K., Sardi, P., Heyer, K.P., 2018. Reducing single-use plastic in a Thai school community: A sociocultural investigation in Bangkok, Thailand. Worcester Polytechnic Institute, Bangkok. Available at: https://digitalcommons.wpi.edu/iqp-all/206.

Moore, S. A., 2008. Garbage matters: Concepts in new geographies of waste. Progress in Human Geography, 32(5), 780–799.

Moreno–Sánchez, R.D.P. and Maldonado, J.H., 2006. Surviving from garbage: the role of informal waste–pickers in a dynamic model of solid–waste management in developing countries. Environment and Development Economics, 11(3), 371–391.

Mugobo, V.V., Ntuli, H. and Iwu, C.G., 2022. Consumer Perceptions of the Use of Nondegradable Plastic Packaging and Environmental Pollution: A Review of Theories and Empirical Literature. Journal of Risk and Financial Management, 15(6), 244.

Muncke, J., Andersson, A.-M., Backhaus, T., Boucher, J.M., Carney Almroth, B., Castillo Castillo, A., Chevrier, J., Demeneix, B.A., Emmanuel, J.A., Fini, J.-B., Gee, D., Geueke, B., Groh, K., Heindel, J.J., Houlihan, J., Kassotis, C.D., Kwiatkowski, C.F., Lefferts, L.Y., Maffini, M.V., Martin, O.V., Myers, J.P., Nadal, A., Nerin, C., Pelch, K.E., Scheringer, M., et al., 2020. Impacts of food contact chemicals on human health: A consensus statement. Environmental Health 19(1), 25. https://doi.org/10.1186/s12940-020-0572-5.

Nagpure, A.S., 2019. Assessment of quantity and composition of illegal dumped municipal solid waste (MSW) in Delhi. Resources, Conservation and Recycling, 141, 54–60.

Nagy, K., 2019. Plastic cows: Purity, pollution, and polymers. PhD thesis, University of Oxford, School of Geography and the Environment & St. Antony's College.

National Program of Cancer Registries (NPCR)., 2023. The National Cancer Institute, and National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention. U.S. Cancer Statistics: Cancer Mortality by Sex | Alabama | Non–Hodgkin Lymphoma | Crude Rate | Male | Female, 1999 – 2019. Sage Data. Sage Publishing Ltd.

Nazareth, M., Marques, M., Leite, M.C., Castro, B. 2019. Commercial plastics claiming biodegradable status: Is this also accurate for marine environments? Journal of Hazardous Materials 366, 714–722.

Negussie, B. and Mustefa, J., 2017. Community's perception of utilization and disposal of plastic bags in Eastern Ethiopia. Pollution, 3(1), 147-–156.

Ngalo, N. and Thondhlana, G., 2023. Illegal Solid–Waste Dumping in a Low–Income Neighbourhood in South Africa: Prevalence and Perceptions. International journal of environmental research and public health, 20(18), 6750.

Niyobuhungiro, R.V. and Schenck, C.J., 2021. The dynamics of indiscriminate/illegal dumping of waste in Fisantekraal, Cape Town, South Africa. Journal of Environmental Management, 293, 112954.

Nkomazi Local Municipality. 2019. Integrated Development Plan: 2020/2021. Malelane: Nkomazi Municipality Office of the Municipality Manager. Available at: http://cgta.mpg.gov.za/IDP/ Ehlanzeni2018–19/NkomaziPart–1.pdf

Nkomazi Local Municipality. Final Integrated Development Plan: 2017–2021. Retrieved August 28, 2023, from https://www.cogta.gov.za/cgta_2016/wp–content/uploads/2021/02/Nkomazi–Municipality.pdf

Norsa'adah, B., Salinah, O., Naing, N.N. and Sarimah, A., 2020. Community health survey of residents living near a solid waste open dumpsite in Sabak, Kelantan, Malaysia. International Journal of Environmental Research and Public Health, 17(1), 311.

Northen, S.L., Nieminen, L.K., Cunsolo, S., Iorfa, S.K., Roberts, K.P. and Fletcher, S., 2023. From shops to bins: a case study of consumer attitudes and behaviours towards plastics in a UK coastal city. Sustainability Science, 18(3), 1379–1395.

Nxumalo, S.M., Mabaso, S.D., Mamba, S.F. and Singwane, S.S., 2020. Plastic waste management practices in the rural areas of Eswatini. Social Sciences and Humanities Open, 2(1), 100066.

Nyika, J.M., Onyari, E.K., 2021. A review on solid waste management using the DPSIR framework in a Southern Africa case study. In: Rathoure, A.K. (Ed.), Handbook of Research on Waste Diversion and Minimization Technologies for the Industrial Sector. IGI Global, 13–34. https://doi.org/10.4018/978-1-7998-4921-6.ch002.

Obebe, S.B. and Adamu, A.A., 2020. Plastic pollution: Causes, effects and preventions. International Journal of Engineering Applied Sciences and Technology, 4(12), 85–95.

O'Brien, J. and Thondhlana, G., 2019. Plastic bag use in South Africa: Perceptions, practices and potential intervention strategies. Waste Management, 84, 320–328.

Oguge, N., Oremo, F., and Adhiambo, S., 2021. Investigating the knowledge and attitudes towards plastic pollution among the youth in Nairobi, Kenya. Social Sciences, 10(11), 408. doi:10.3390/socsci10110408.

Okeke, E.S., Okoye, C.O., Atakpa, E.O., Ita, R.E., Nyaruaba, R., Mgbechidinma, C.L. and Akan, O.D., 2022. Microplastics in agroecosystems-–impacts on ecosystem functions and food chain. Resources, Conservation and Recycling, 177, 105961.

Oludoye, O.O., Supakata, N., Srithongouthai, S., Kanokkantapong, V., Van den Broucke, S., Ogunyebi, L. and Lubell, M., 2024. Pro–environmental behavior regarding single–use

plastics reduction in urban–rural communities of Thailand: Implication for public policy. Scientific Reports, 14(1), 4713.

Omarova, L. and Jo, S.J., 2022. Employee pro-–environmental behavior: The impact of environmental transformational leadership and GHRM. Sustainability, 14(4), 2046.

Organisation for Economic Co-operation and Development, 2022. Global plastics outlook: Economic drivers, environmental impacts and policy options. OECD Publishing, Paris. https://doi.org/10.1787/de747aef-en [Accessed 13 May 2025].

Otsyina, H.R., Nguhiu–Mwangi, J., Mogoa, E.G.M., Mbuthia, P.G. and Ogara, W.O., 2018. Knowledge, attitude, and practices on usage, disposal, and effect of plastic bags on sheep and goats. Tropical animal health and production, 50, 997–1003.

Pahl, S., Richter, I. and Wyles, K., 2020. Human perceptions and behaviour determine aquatic plastic pollution. In Plastics in the Aquatic Environment–Part II: Stakeholders' Role Against Pollution . 13–38. Cham: Springer International Publishing.

Pahl, S., Wyles, K.J., 2017. The human dimension: how social and behavioural research methods can help address microplastics in the environment. Analitcal. Methods 9, 1404–1411.

Park, S., Chun, M.M., 2014. The constructive nature of scene perception. In: Kveraga, K., Bar, M. (Eds.), Scene Vision: Making Sense of What We See. Boston Review, Boston, 45–72.

Pelletier, D., Claudet, J., Ferraris, J., Benedetti-–Cecchi, L. and Garcìa-–Charton, J.A., 2008. Models and indicators for assessing conservation and fisheries-–related effects of marine protected areas. Canadian Journal of Fisheries and Aquatic Sciences, 65(4), 765-–779.

Pisani, X. G., Lompré, J. S., Pires, A., and Greco, L. L., 2022. Plastics in scene: A review of the effect of plastics in aquatic crustaceans. Environmental Research, 212, 113484.

Polasi, L.T., 2018. Factors associated with illegal dumping in the Zondi area, City of Johannesburg, South Africa. WasteCon 2018, Emperors Palace, Kempton Park, Johannesburg, 15–19

Prati, G., Mazzoni, D., Zani, B., 2014. Perceived behavioral control, subjective norms, attitudes and intention to use condom: A longitudinal cross-lagged design. Psychology & Health 29, 1–26. https://doi.org/10.1080/08870446.2014.913043.

Proshad, R., Kormoker, T., Islam, M.S., Haque, M.A., Rahman, M.M. and Mithu, M.M.R., 2018. Toxic effects of plastic on human health and environment: A consequences of health risk assessment in Bangladesh. International Journal of Health, 6(1), 1–5.

Rampedi, I. T., and Ifegbesan, A. P., 2022. Understanding the determinants of pro–environmental behavior among South Africans: Evidence from a structural equation model. Sustainability, 14(6), 3218. doi:10.3390/su14063218.

Rapada, M.Z., Yu, D.E., Janairo, J.I. and Yu, K.D., 2023. Impact of online–based information and interaction to proenvironmental behavior on plastic pollution. Cleaner and Responsible Consumption, 9, 100126.

Rasmeni, Z.Z. and Madyira, D.M., 2019. A review of the current municipal solid waste management practices in Johannesburg City townships. Procedia Manufacturing, 35, 1025–1031.

Reddy, M.S., Reddy, P.S., Subbaiah, G.V., Subbaiah, H.V., 2014. Effect of plastic pollution on environment. Journal of Chemical and Pharmaceutical Sciences, Special Issue, 28–29.

Rhyner, C.R., Schwartz, L.J., Wenger, R.B., Kohrell, M.G., 2017. Waste management and resource recovery. 1st ed. CRC Press, Boca Raton. https://doi.org/10.1201/9780203734278.

Ritchie, H., Roser, M., 2018. Plastic pollution. Our World in Data. Available at: https://ourworldindata.org/plastic-pollution [Accessed 14 May 2025].

Ritchie, H., Samborska, V., Roser, M., 2023. Plastic pollution. Our World in Data. Available at: https://ourworldindata.org/plastic-pollution [Accessed 14 May 2025].

Rodseth, C., Notten, P., Von Blottniz, H., 2020. A revised approach for estimating informally disposed domestic waste in rural versus Urban South Africa and implications for waste management. South African Journal of Science, 116(1/2). doi:10.17159/sajs.2020/5635.

Rogayan, D., Nebrida, E., 2019. Environmental awareness and practices of science students: Input for ecological management plan. International Electronic Journal of Environmental Education 9, 106–119.

Rogers, B., 2017. Perception: A very short introduction. Very Short Introductions. Oxford University Press, Oxford. https://doi.org/10.1093/actrade/9780198791003.001.0001 [Accessed 13 May 2025].

Ryan, P.G., 2020. The transport and fate of marine plastics in South Africa and adjacent oceans. South African Journal of Science, 116(5–6), 1–9.

Salazar, C., Jaime, M., Leiva, M. and González, N., 2022. From theory to action: Explaining the process of knowledge attitudes and practices regarding the use and disposal of plastic among school children. Journal of Environmental Psychology, 80, 101777.

Sánchez, M., López–Mosquera, N., and Lera–López, F., 2015. Improving pro–environmental behaviours in Spain. the role of attitudes and socio–demographic and political factors. Journal of Environmental Policy and Planning, 18(1), 47–66.

Sangawar, V.S. and Deshmukh, S.S., 2012. A short overview on development of the Plastic waste management: Environmental issues and challenges. Scientific Reviews and Chemical Communication, 2(3), 349–354.

Sembiring, E., 2023. Driver, trends and fate of plastics and micro plastics occurrence in the environment. Plastic Pollution, 8–26.

Sentime, K., 2011. Profiling solid waste pickers: a case study of Braamfontein–Greater Johannesburg. Africanus, 41(2), 96–111.

seyyedi, S. reza, Kowsari, E., Ramakrishna, S., Gheibi, M., and Chinnappan, A. 2023. Marine Plastics, circular economy, and Artificial Intelligence: A comprehensive review of challenges, solutions, and policies. Journal of Environmental Management, 345, 118591.

Sharma, A., Ganguly, R. and Gupta, A.K., 2018. Matrix method for evaluation of existing solid waste management system in Himachal Pradesh, India. Journal of Material Cycles and Waste Management, 20, 1813–1831.

Shongwe, B.R. and Meyer, D.F., 2023. Service Delivery Challenges within Rural Communities: The Case of the Nkomazi Local Municipal Area. Administratio Publica, 31(2), 136–159.

Si, H., Shi, J.G., Tang, D., Wen, S., Miao, W., Duan, K., 2019. Application of the theory of planned behavior in environmental science: A comprehensive bibliometric analysis. International Journal of Environmental Research and Public Health 16(15), 2788. https://doi.org/10.3390/ijerph16152788.

Simelane, O.T. and AECOM SA, 2016. Implementing alternative waste treatment technologies: a comparative study of South Africa and the European Union. In Proceedings of the 23rd WasteCon Conference, 17–21. Institute of Waste Management of Southern Africa.

Sivakumar, K., 2018. Negative impacts of plastic pollution: A major threat to our environment. Oceanography & Fisheries Open Access Journal 8(2), 45–47. https://doi.org/10.19080/OFOAJ.2018.08.555735.

So, W.W.M., Cheng, I.N.Y., Cheung, L.T.O., Chen, Y., Chow, S.C.F., Fok, L. and Lo, S.K., 2021. Extending the theory of planned behaviour to explore the plastic waste minimisation intention of Hong Kong citizens. Australian Journal of Environmental Education, 37(3), 266-–284.

Soares, J., Miguel, I., Venâncio, C., Lopes, I., and Oliveira, M. 2021. Public views on plastic pollution: Knowledge, perceived impacts, and pro–environmental behaviours. Journal of Hazardous Materials, 412, 125227.

Sommer, Robert., 2004. Book review: The psychology of environmental problems (2nd ed.) by Deborah Du Nann Winter and Susan M. Koger, Journal of Environmental Psychology, 24(4), 405–408.

Souri, A. and Haghi, M., 2017. Development of technological industries and necessity of waste management to protect population health. Technology and Health Care, 25(2), 383–384.

South African waste information centre. (n.d.). South African Waste Information Centre. Retrieved August 31, 2023

Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P., 2015. Urban solid waste management in the developing world with emphasis on India: challenges and opportunities. Reviews in Environmental Science and BioTechnology, 14, 317–337.

Stanton, T., Kay, P., Johnson, M., Chan, F.K.S., Gomes, R.L., Hughes, J., Meredith, W., Orr, H.G., Snape, C.E., Taylor, M. and Weeks, J., 2021. It's the product not the polymer: Rethinking plastic pollution. Wiley Interdisciplinary Reviews: Water, 8(1), e1490.

State of play of plastics substitutes: Selected product groups. 2023. Plastic Pollution: The Pressing Case for Natural and Environmentally Friendly Substitutes to Plastics, 9–25. doi:10.18356/9789210027229c007

Statistics South Africa, 2011. South African Census Data. Available at: https://www.statssa.gov.za/?page_id=3839 [Accessed 7 September 2024].

Statistics South Africa, 2011. Local Municipality “Nkomazi”: Community profile databases and geographical areas. Available at: https://www.statssa.gov.za [Accessed 21 Jul 2024].

Stats, S.A., 2011. Statistics South Africa. Formal census.Statistical release (revised) – statssa.gov.za. Available at: http://www.statssa.gov.za/publications/P03014/P030142011.pdf Accessed: 06 October 2023.

Steg, L., and Vlek, C., 2009. Encouraging pro–environmental behaviour: An integrative review and research agenda. Journal of Environmental Psychology, 29(3), 309–317.

Stern, P. C., Kalof, L., Dietz, T., and Guagnano, G. A. (1995). Values, beliefs, and proenvironmental action: Attitude Formation toward emergent attitude Objects1. Journal of Applied Social Psychology, 25(18), 1611–1636.

Stoett, P., 2022. Plastic pollution: A global challenge in need of multi-–level justice-–centered solutions. One Earth, 5(6), 593–596.

Su, Y., Zhang, Z., Zhu, J., Shi, J., Wei, H., Xie, B. and Shi, H., 2021. Microplastics act as vectors for antibiotic resistance genes in landfill leachate: The enhanced roles of the long–term aging process. Environmental Pollution, 270, 116278.

Swanepoel, S. and Marlin, D., 2024. Mapping illegal dumping in Nelson Mandela Bay Metro: A study using image interpretation. Remote Sensing Applications: Society and Environment, 36, 101302.

Syberg, K., Hansen, S.F., Christensen, T.B., Khan, F.R., 2018. Risk perception of plastic pollution: Importance of stakeholder involvement and citizen science. In: Wagner, M., Lambert, S. (Eds.), Freshwater Microplastics. The Handbook of Environmental Chemistry, vol. 58. Springer, Cham.

Težak Damijanić, A., Pičuljan, M., and Goreta Ban, S., 2023. The role of pro–environmental behavior, environmental knowledge, and eco–labeling perception in relation to travel intention in the hotel industry. Sustainability, 15(13), 10103.

Tian, W., Song, P., Zhang, H., Duan, X., Wei, Y., Wang, H., Wang, S., 2023. Microplastic materials in the environment: Problem and strategical solutions. Progress in Materials Science 132, 101035. https://doi.org/10.1016/j.pmatsci.2022.101035.

Tombe, Y.C., 2024. The spatial extent, practices, and impacts of illegal solid waste dumping across an income gradient in Makhanda and Knysna, South Africa. Master's thesis, Rhodes University. Available at: http://hdl.handle.net/10962/464875.

Tomita, A., Cuadros, D.F., Burns, J.K., Tanser, F. and Slotow, R., 2020. Exposure to waste sites and their impact on health: A panel and geospatial analysis of nationally representative data from South Africa, 2008–2015. The Lancet Planetary Health, 4(6), e223-–e234.

Tsiamis, D.A., Torres, M. and Castaldi, M.J., 2018. Role of plastics in decoupling municipal solid waste and economic growth in the US. Waste Management, 77, 147–155.

Turner, R.P., Kelly, C.A., Fox, R. and Hopkins, B., 2018. Re-–formative polymer composites from plastic waste: novel infrastructural product application. Recycling, 3(4), 54.

Turreira-García, N., Lund, J.F., Domínguez, P., Carrillo-Anglés, E., Brummer, M.C., Duenn, P., Reyes-García, V., 2018. What's in a name? Unpacking "participatory" environmental monitoring. Ecology and Society 23(2). Available at: https://www.jstor.org/stable/26799115.

United Nations Environment Programme (UNEP) (2024) Global Waste Management Outlook 2024. Nairobi: UNEP. Available at: https://www.unep.org/resources/global-–waste-–management-–outlook-–2024. Accessed: 14 April 2025.

Van Der Walt, W. and Krige, F., 2023. Can formal education change attitudes towards waste? A case study of how basic waste management education can change waste dumping attitudes in a low–income settlement. Community Development Journal, 58(3), 694–711.

Van Emmerik, T. and Schwarz, A., 2020. Plastic debris in rivers. Wiley Interdisciplinary Reviews: Water, 7(1), e1398.

Verma, R., Vinoda, K. S., Papireddy, M., and Gowda, A. N. S., 2016. Toxic pollutants from plastic waste– A Review. Procedia Environmental Sciences, 35, 701–708.

Vethaak, A.D. and Leslie, H.A., 2016. Plastic debris is a human health issue.

Vij, D., 2012. Urbanization and solid waste management in India: present practices and future challenges. Procedia–Social and Behavioral Sciences, 37, 437–447.

Wahid, R., Purnamasari, E. and Fitriya, F., 2020. Environmental education to boost pro–environmental behaviour in reducing plastics consumption among students in Universitas Bina Darma Palembang. EPRA International Journal of Multidisciplinary Research, 6(8), 20–32.

Walters, R. and Fuentes Loureiro, M.A., 2020. Waste crime and the global transference of hazardous substances: A southern green perspective. Critical Criminology, 28, 463–480.

Wang, J., Wang, S., Wang, Y., Li, J., Zhao, D.2018. Extending the theory of planned behaviour to understand consumers' intentions to visit green hotels in the Chinese context. International Journal of Contemporary Hospitality Management 30, 2810–2825.

Weichselgartner, J. and Kasperson, R., 2010. Barriers in the science–policy–practice interface: Toward a knowledge–action–system in global environmental change research. Global environmental change, 20(2), 266–277.

Welden, N., 2020. The environmental impacts of plastic pollution. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter II. Elsevier, Amsterdam, 195–222. https://doi.org/10.1016/B978-0-12-817880-5.00008-6.

Widayat, W., Praharjo, A., Putri, V.P., Andharini, S.N., Masudin, I., 2021. Responsible Consumer Behavior: Driving Factors of Pro–Environmental Behavior toward Post–Consumption Plastic Packaging. Sustainability, 14, 425.

Wilson E.O., 1984. Biophilia. Harvard University Press, Cambridge, MA.

Xanthos, D. and Walker, T.R., 2017. International policies to reduce plastic marine pollution from single–use plastics (plastic bags and microbeads): A review. Marine pollution bulletin, 118(1–2), 17–26.

Yaka, M., Ehirchiou, A., Alkandry, T.T., Sair, K., 2015. Huge plastic bezoar: A rare cause of gastrointestinal obstruction. Pan African Medical Journal 21, 286. https://doi.org/10.11604/pamj.2015.21.286.7169.

Yee, M.S.L., Hii, L.W., Looi, C.K., Lim, W.M., Wong, S.F., Kok, Y.Y., Tan, B.K., Wong, C.Y. and Leong, C.O., 2021. Impact of microplastics and nanoplastics on human health. Nanomaterials, 11(2), 496.

Yoon, A., Jeong, D. and Chon, J., 2021. The impact of the risk perception of ocean microplastics on tourists' pro–environmental behavior intention. Science of the Total Environment, 774, 144782.

Yue, T., Gao, C., Chen, F., Zhang, L. and Li, M., 2022. Can empowering leadership promote employees' pro–environmental behavior? Empirical analysis based on psychological distance. Frontiers in Psychology, 13, 774561.

Zen, I.S., Ahamad, R. and Omar, W., 2013. No plastic bag campaign day in Malaysia and the policy implication. Environment, development and sustainability, 15, 1259–1269.

Zhang, Q., Xu, E.G., Li, J., Chen, Q., Ma, L., Zeng, E.Y. and Shi, H., 2020. A review of microplastics in table salt, drinking water, and air: direct human exposure. Environmental Science and Technology, 54(7), 3740–3751.

Zhao, S., Zhu, L., and Li, D., 2016. Microscopic anthropogenic litter in terrestrial birds from Shanghai, China: Not only plastics but also natural fibers. Science of The Total Environment, 550, 1110–1115.

Zhou, B., Wang, J., Zhang, H., Shi, H., Fei, Y., Huang, S., Tong, Y., Wen, D., Luo, Y. and Barceló, D., 2020. Microplastics in agricultural soils on the coastal plain of Hangzhou Bay, east China: Multiple sources other than plastic mulching film. Journal of Hazardous Materials, 388, 121814.

Zilberbrant, G., Kassee, E., 2023. Plastics and circular economy. In: Plastic Pollution. 1st ed. CRC Press, Boca Raton, 1–19. https://doi.org/10.1201/9781003137740.

Zondi, N., Qwatekana, Z. and Dube, S., 2023. Modernisation of rural communities: Solid waste management implication. African Journal of Inter/Multidisciplinary Studies, 5(1), 1–11.

Zurbrugg, C., 2002. Urban solid waste management in low–income countries of Asia how to cope with the garbage crisis. Presented for: Scientific Committee on Problems of the Environment (SCOPE) Urban Solid Waste Management Review Session, Durban, South Africa, 6, 1–13.

Zwicker, M. V., Nohlen, H. U., Dalege, J., Gruter, G. J. M., and van Harreveld, F. 2020. Applying an attitude network approach to consumer behaviour towards plastic. Journal of Environmental Psychology, 69, 101433.

APPENDICES

Appendix 4.1: Interview schedule used the plastic pollution study conducted in Nkomazi Local Municipality

Section 1: Demographical data

S 1.1	Gender	(1) Female (2) Male
S1.2	Age	(1) 18 – 24 (2) 25 – 34 (3) 35 –44 (4) 45–54 (5) 55+
S 1.3	Education level	(1) Uneducated (2) Primary/Secondary School (3) High School (4) Two–year degree (5) Degree (6) Post–graduate degree
S 1.4	Employment status	(1) Student/Unemployed (2) Self–employed (3) Retired (4) Unemployed (5) Employed

Section 2: General knowledge about plastic pollution

Please indicate the most appropriate one from the options 1 (Agree Strongly) to 5 (Strongly Disagree) below

		Strongly Agree	Agree	Neutral	Strongly disagree	Disagree
S 2.1	Plastic pollution affects my health and of those around me	5	4	3	2	1
S 2.2	I am aware that I have to utilize designated waste equipment (wheelie bins, skips) instead of disposing plastic waste on the natural ground	5	4	3	2	1
S 2.3	I worry about environmental problems	5	4	3	2	1
S 2.4	A better environment starts with me	5	4	3	2	1
S 2.5	I do not take the environment into accountability when littering plastic waste,	5	4	3	2	1

	regardless of the basic knowledge I have					

Section 3: Perceptions about plastic pollution

Please indicate the most appropriate one from the options 1 (Agree Strongly) to 5 (Strongly Disagree) below

		Strongly Agree	Agree	Neutral	Strongly disagree	Disagree
S 3.1	It is solely the municipality's responsibly to pick after plastic waste	5	4	3	2	1
S 3.2	I am concerned about plastic waste problems around my community	5	4	3	2	1
S 3.3	I am aware of correct and incorrect way of handling plastic waste	5	4	3	2	1
S 3.4	It is only the government and business facilities that should practice recycling, reuse and reduce of plastic products	5	4	3	2	1
S 3.5	Plastic products are convenient for everyday use and cannot be substituted by environmental–friendly products	5	4	3	2	1

Section 4: Impacts of plastic pollution on the environment

Please indicate the most appropriate one from the options 1 (Agree Strongly) to 5 (Strongly Disagree) below

		Strongly Agree	Agree	Neutral	Strongly disagree	Disagree
S 4.1	Environmental pollution affects the natural environment.	5	4	3	2	1
S 4.2	Microplastics endangers aquatic existence of the organisms	5	4	3	2	1
S 4.3	Plastic waste not only obstructs from the aesthetic appeal of the natural environment profiles	5	4	3	2	1
S 4.4	Plastic productions end up in illegal landfill site and occupy more land	5	4	3	2	1
S 4.5	Plastic pollution impacts on the economy and food supply for	5	4	3	2	1

	communities that rely on fishing.					

Section 5: Pro–environmental behaviours

Please indicate the most appropriate one from the options 1 (Never) to 5 (Always) below

		Always	Often	Sometimes	Rarely	Never
S 5.1	I make sure that I dispose plastic waste in a designated bin	5	4	3	2	1
S 5.2	I try as much as possible to reuse plastics	5	4	3	2	1
S 5.3	I ensure that I do waste separation and don't mix waste	5	4	3	2	1
S 5.4	I utilize more recyclable paper products instead of putting buying plastic products	5	4	3	2	1
S 5.5	When I purchase goods or services, I pay attention to sustainability	5	4	3	2	1
S 5.6	I participate on the pro–environmental campaigns and comply to the local municipality by–laws	5	4	3	2	1