

Review

A meta-analysis review of waste generation and collection in urban informal settlements South Africa

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Abstract

This study critically examines the challenges of waste generation and collection in South Africa's informal settlements, emphasizing the impact of inadequate waste management on environmental sustainability. As such, the current study conducted a systematic review to evaluate the generation and collection of waste in urban informal settlements in South Africa. Using the Preferred Reporting Items for Systematic Reviews and meta-analysis guidelines, a literature search was carried out in waste management. Findings reveal that infrastructural constraints (> 60%), such as limited access roads, and demographic factors (15%) are key determinants of ineffective waste collection (> 40%). Additionally, a lack of physical waste infrastructure (> 20%) and overpopulation (10%) exacerbate poor waste management practices. These challenges contradict the South African Constitution's mandate for a healthy environment for all citizens. The study underscores the need for a strategic, cost-effective waste collection approach that integrates socio-economic, environmental, and land-use considerations. It also advocates for policies to reduce rural–urban migration by fostering development in less-developed provinces. Furthermore, the establishment of a proactive human settlement department is recommended to enhance spatial planning and monitor settlement growth, ensuring sustainable urban development.

Keywords Economic development · Illegal dumping · Municipal waste management · Urban sprawl · Sub-Saharan Africa

1 Introduction

On a global scale, it has been extensively documented that formal (planned) settlements receive sufficient municipal services, including water supply, sanitation, and waste management, in contrast to informal (unplanned) settlements, which typically receive minimal or no services. The reasons for these variations have been well outlined by Grangxabe et al. [1] citing apartheid spatial planning and influx of people from other provinces into the metropolitan area. However, it is important to highlight that since the dawn of democracy, South African municipalities have achieved fundamental progress in advancing waste management services to previously marginalized communities. This was implemented to remedy South Africa's inequality, an important contributor to environmental degradation [1]. However, the persistent inequalities continue to drive and influence access to these services, determining who can benefit from sustainable waste management.

South Africa generates approximately 12.7 million tonnes of domestic waste annually, placing immense pressure on municipalities to manage growing waste volumes effectively. Yet, an estimated 3.67 million tonnes of waste go

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uncollected each year, leading to widespread illegal dumping and environmental hazards [2]. While local governments are responsible for waste management, there are significant disparities in service provision. Larger municipalities, particularly in urban areas, generally offer comprehensive waste collection and disposal services. In contrast, smaller and rural municipalities often lack the infrastructure and capacity to provide even basic waste management. In South Africa, these are remnants of decades of apartheid that have led to pervasive poverty and inequality that persist to this day [1]. It is for this reason that for millions living in urban informal settlements and rural areas, municipal waste collection is either inadequate or non-existent, thus reliable and regular waste management is a distant reality in these neighbourhoods [3]. This inequality is evident in waste collection rates across provinces, Gauteng and the Western Cape lead with 92% collection coverage, followed by Northwest (59%), Mpumalanga (38%), Eastern Cape (40%), and KwaZulu-Natal (45%) [4]. This is evidence that several South African households in the urban areas have access to regular waste removal services. In contrast in the informal settlements of these very urban areas, service delivery is significantly lower and, in some instances, absent [3]. In South Africa, while service gaps are most pronounced between urban and rural areas, variations also exist across provinces, district councils, and local municipalities. Even within cities, informal settlements frequently lack proper waste removal due to challenges such as high population density, poor spatial planning, limited road access, and insecure land tenure [5, 5]. Subsequently, this lack of proper waste management infrastructure has led to the proliferation of illegal dumping sites, littering, and open waste burning, exacerbating environmental and public health risks. Addressing these challenges requires policy reforms, investment in infrastructure, and innovative waste management strategies to ensure equitable and sustainable service delivery across all communities.

Cities such as Cape Town and Nairobi have seen a rapid increase in urbanization due to economic growth which has resulted in expanding informal settlements often situated on the periphery of major cities and towns [6–8]. It is for this reason that in some cities the accumulation of waste has been associated with industrialization and urbanization [9, 10]. Access to municipal solid waste collection services is limited to some areas around the world due to population growth but more so in Sub-Saharan African cities [11, 12]. Literature suggests that over 3 billion people do not have access to designated waste management facilities [13, 14], while half of the world's population is estimated to lack access to regular waste management services [15–17]. The factors that determine municipal solid waste management practices vary in the informal settlements of the Sub-Saharan African cities. For example, open waste burning and burying are recognized to the detachment of collection services and a lack of awareness of the environmental consequences [18–20]. According to the World Bank report [21], it stated that nearly half the urban centres cannot access reliable waste collection services, this observation was in most developing countries where 30 to 60% of the waste is uncollected from cities. In Africa, the waste collection rate for generated solid waste ranges from 25 to 70% according to UNEP [13]. In Sub-Saharan Africa specifically, the average collection rate is 57% as reported by CSE.

Some researchers have shown that irregular collection of waste in informal settlements causes environmental problems in the long term [22, 23], given that industrialization which is taking place in most developing countries [24, 25]. As Aidonojie et al. [26] postulate it seems that most of the environmental issues in the developing countries are caused by industrial activities. Developing countries have witnessed a high rate of urban expansion as a result of globalization, which is often associated with the emergence of informal settlements which puts constraints on existing services as these settlements are not planned [27] and therefore, exacerbate the social and environmental problems and impede sustainable development [5, 28–31]. Additionally, it may be important to develop a better understanding of informal development to ensure its effective management. Although some municipalities within South Africa try to provide waste collection services to informal settlements such as Dunoon in Cape Town the lack of spatial planning makes house-to-house collection very difficult [8, 22, 23, 32]. The nature of economic development in South Africa which is mainly concentrated in major cities such as Johannesburg, Pretoria, Durban and Cape Town, exacerbates the rural–urban migration from neighbouring countries [33]. Therefore, this caused the expansion of urban informal settlements as it was stated by Grangxabe et al. [1] post-apartheid era. South Africa has for past years faced challenges of waste management which looms large across the urban informal settlements, presenting a complex interplay of social, environmental, and public health implications. The generation of waste in the townships as marginalized communities are driven by several socioeconomic factors and are aggravated by the lack of proper infrastructure or poor spatial planning particularly in major cities in South Africa [34, 35]. This review study becomes important to delve into the critical issues surrounding waste generation and collection in South Africa's informal settlements, exploring the factors that influence disparities of inadequate waste management in informal settlements of urban areas. This review is highly relevant in the context of waste management challenges in the informal townships of South Africa. Given that informal settlements in South Africa continue to rise due to various factors such as immigration from rural areas and rural provinces in search of better

job opportunities and other expectations [36]. The influx of homeless migrants from other African countries also adds more challenges to the local municipalities [37].

2 Literature search method

The current study undertook a systematic evaluation to investigate the differentiation between solid waste creation and waste collection in informal urban settlements located in South Africa. Subsequently, papers were selected to inform the review by extensively searching the range of multiple scientific reputable databases. In these databases, key thematic search terms such as "waste collection," "waste management," "informal settlements," "slums," "solid waste challenges," "developing countries," and "municipality services." were used to narrow down the search within the relevant scope of waste generation and collection in urban informal settlements South Africa. This systematic search was designated to capture a broad range of academic papers and any other technical reports associated thereof with the waste generation and collection in urban informal settlements thus avoiding comprehensively capturing all studies that may not be directly related to the topic at hand. As such the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) reporting was fundamental to achieve this systematic search. Thus, in the current study PRISMA as depicted in Fig. 1 facilitated the identification and inclusion of pertinent literature. In this study, a comprehensive analysis was conducted on a total of 168 papers to fulfil the objectives of this research.

2.1 Data extraction and selection of studies

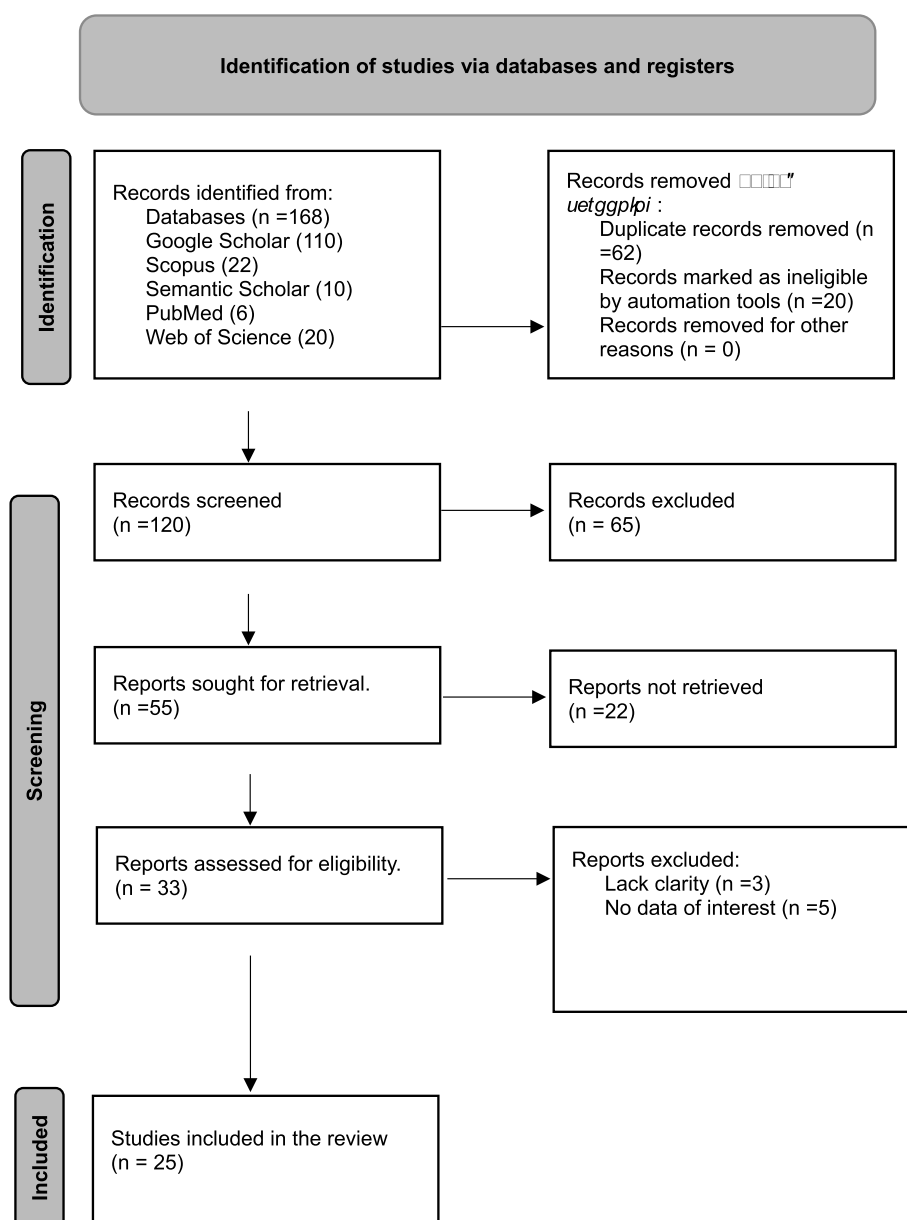
By utilising the global databases, the authors successfully identified records that could potentially be of relevance. As demonstrated in Fig. 1, a dataset was identified, and the database search produced 168 records. The authors opted to employ five distinct reputable databases, namely Semantic Scholar (110), Scopus (22), Google Scholar (10), PubMed (6) and Web of Science (20). Subsequently, the data was stratified and examined using the reference manager programme EndNote 21 throughout data processing as suggested by Grangxabe et al. [7]. EndNote 21 facilitated the elimination of duplicate papers, the categorization of articles through labelling, and the organisation of papers into subgroups [11]. During the duplication process, sixty-two duplicates were excluded before screening as shown in Fig. 1. Furthermore, post this bureaucratic process intended to maintain the objectivity, transparency, and reliability of research, the Creswell [38] methodology framework of reading, analysing, evaluating, and summarising scholarly materials related to the review was undertaken. To this end, an explanatory research approach was used to assess and explain the link between waste generation and collection in urban informal settlements of South Africa.

2.2 Inclusion/exclusion criteria

Making use of the reference management program EndNote 21, a total of 168 identified records were exported to eliminate duplicates, while 62 duplicates were automatically deleted, and 8 duplicates were manually eliminated before screening as depicted in Fig. 1. Although 120 records had the keywords in their titles and/or abstracts, the same independent researchers conducted appropriateness assessments by reviewing the titles, abstracts, and subsequently the complete texts. Sixty-five records were excluded from the screening process as they were irrelevant to the research. Furthermore, several records contained crucial information that was inaccessible due to the paywall restriction. A third party was engaged to resolve the issues that arose throughout this procedure. Moreover, efforts were made to exclude papers that did not include urban informal settlements in South Africa. Only papers that conducted waste generation and collection within the urban informal settlements in South Africa. Likewise, only English-written papers published in scholarly journals were included in the current review. Each paper included in the database was analysed further by all authors to ensure each paper met the inclusion and exclusion criteria. A total of 55 publication reports were requested for retrieval; however, 22 were excluded due to the inability to access their full texts. Consequently, 33 reviews were included for evaluation against eligibility criteria, which encompassed the inclusion of pertinent data, high quality, and alignment with the study's scope. This study comprised 25 publications from the 33 reviewed which specifically documented the overview of vehicular air pollution in Sub-Saharan Africa.

Figure 2 shows the Connected Papers platform which utilises a specialised algorithm to identify pertinent research papers that are related to the topic at hand, sourced from the Semantic Scholar literature database. The primary source text serves as the foundation for constructing a literature graph that is organised according to shared

Fig. 1 The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines for waste generation vs waste collection in urban informal settlements in South Africa



characteristics. One method employed by researchers to ascertain pertinent material involves the identification of distinctive characteristics [39], such as "Prior" and "Derivatives." In this study, we have used this tool to strengthen the literature search of this study and also as a compliment to the PRISMA. The utilisation of a force-directed network in Connected Papers facilitates the visual categorisation of papers based on their similarity, while simultaneously distinguishing dissimilar papers [39]. When a node is picked inside the similarity space, the platform identifies the shortest path to the origin paper. Each node inside the graph symbolises an academic work that is associated with an original paper, and the papers are organised in accordance with their degree of similarity [40]. The magnitude of each node within the graph corresponds to the quantity of citations garnered by the journal article. The hue assigned to each node corresponds to the year of publication, while more vibrant colours signify more recent publications [39]. Research papers that exhibit similarities are interconnected by robust lines and tend to aggregate in clusters within the graph.

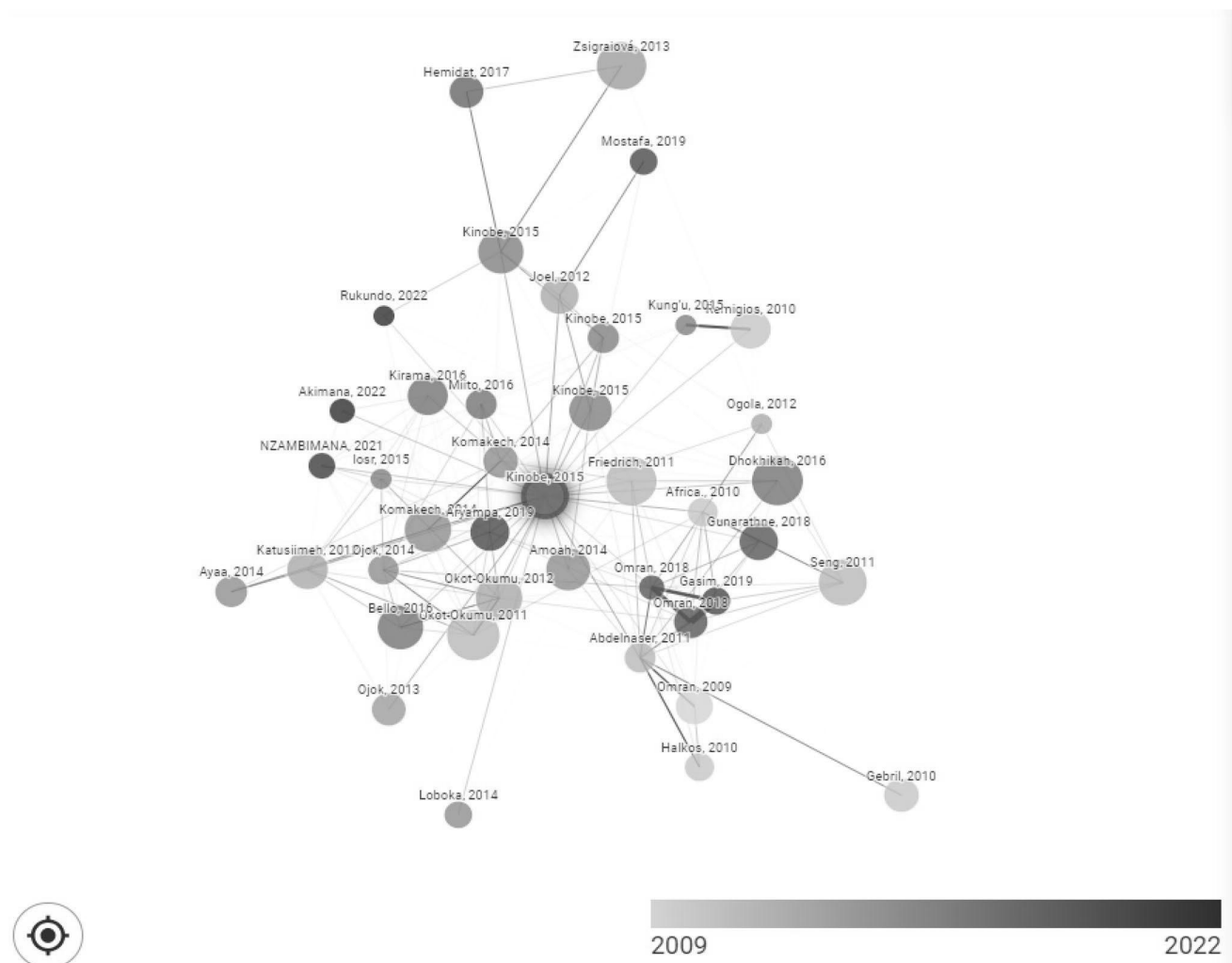


Fig. 2 Research papers related to waste generation and collection in urban informal settlements

2.3 Challenges of waste collection in urban informal settlements

According to the City of Cape Town reports it is estimated that approximately 18% of the total households in the metropolitan are informal dwellings and backyard dwellers have been estimated to have doubled from the 75 000 reported during the 2011 Census [41, 42]. This number might be higher than this given that there are several informal settlements that have been established during and post-COVID-19, mainly around Mfuleni township (planned settlement). The encroachment of informal settlements in these communities (Langa, Khayelitsha, Mfuleni, Delft, etc.) results in significant constraints in the provision of municipal services, including waste collection. Moreover, the metropolitan Cape Town serves as a prominent economic hub or centre within the province of the Western Cape, with an estimated population growth of a rate of 1.4% annually. According to DEA [43], the formal collection of waste accounted for an estimated 59% of the whole waste system. According to the South African National Garbage Information Baseline DEA [43], despite municipalities' efforts to ensure equitable waste collection services for all households, the provision of regular waste collection operations remains unattainable. The aforementioned phenomenon can be attributed to various variables, including migration and urbanisation, geographical distance, the generation of excessive trash, the emergence of new waste streams, and the associated costs of waste management DEA [44].

Notwithstanding the perception and environmental awareness, the lack of adequate waste collection systems which include waste bins, collection vehicles, and trained personnel, poses a significant challenge to efficient waste collection in informal settlements. The lack of proper infrastructure can result in irregular waste collection schedules

and accumulation of waste particularly in townships that have expended illegally without planning from the local municipality [32, 45]. A lack of effective and efficient waste management practices exacerbates poverty and social marginalisation, particularly in the townships that are close to informal settlements [8]. A growing number of urban areas are encountering difficulties in managing solid waste as a result of accelerated urbanisation, insufficient technical and financial resources, or inadequate policy emphasis. The interlinkage of environmental impact which is associated with uncollected waste in a city is important. For example, uncollected municipal solid waste can end up in drains resulting in the blockage of drainage systems which can lead to localized flooding during heavy rainfall. According to the City of Cape Town (CCT) By-laws waste collection happens weekly or bi-weekly to ensure that waste is collected effectively both in the suburbs and townships [41, 42].

Literature has shown that there might be irregular or inadequate waste collection services which could cause the resident to resort to illegal dumping [42, 46]. Overpopulation plays a role in the space in most of this township as they are encroached by informal settlements, as such a weekly waste collection might not be enough for one section of the township (Fig. 3). According to a study by Green [45], site C (Khayelitsha) is serviced by Masiqhame Trading 729 CC, which offers a wheelie bin service to formal areas (door-to-door collection) which is contrary to the informal section which means that is a central place for dumping. In the CCT report, it is stated that “The standard service level for informal settlements dwellings is a once-a-week, bagged door-to-door waste collection service provided to indigent families. In this category, each informal household will be provided weekly with Council refuse bags, of a size, number and design determined by the city.” The biggest challenge with such an approach is that it fails to include the socio-economic status of each informal settlement, such as when most people do their grocery shopping and also have an estimation of the population. Literature has shown that informal settlement is overpopulated, and this means that the waste generation might be above the estimated tons per City of Cape Town data. In its pursuit of achieving equitable access to waste collection services for all households, the city encounters ongoing challenges in effectively providing waste collection services to informal and backyard inhabitants. Navigating narrow pathways, steep terrains, and densely packed housing structures can make waste collection a logistical nightmare in urban informal settlements. Accessibility challenges often hinder waste collection services from reaching every household, exacerbating the issue of uncollected waste in these areas.



Fig. 3 Diagram depicting challenges of waste collection in the informal settlements

The management of this waste has therefore incurred an expense of R350 million for the city in recent years De Lille, [47]. Areas such as Bonteheuwel, Dunoon, and Khayelitsha, situated on the periphery of Cape Town, have encountered significant waste accumulation, leading to adverse effects on the stormwater system as a result of ongoing obstructions in stormwater pipes and natural watercourses. As a result, the health and well-being of the community have been significantly affected due to reported cases of diarrhoea and the presence of pests like rats and flies. To tackle the issue of waste management, the City of Cape Town has resorted to legislative interventions and spatial planning strategies to address the challenges of waste collection and municipal service delivery. The legislative frameworks are fundamental for regulating waste management, enforcing compliance, and providing equitable access to services for both formal and informal settlements [11, 17, 20]. Spatial planning is a fundamental mechanism that can improve the living conditions of rapidly expanding areas, ensuring that waste is properly managed while optimizing urban infrastructure for optimal performance CCT [48]. The National Environmental Management: Waste Act (No. 59 of 2008) establishes a legislative framework for waste management, mandating municipalities to comply with requirements on waste collection, recycling, and disposal. This Act emphasises the importance of a comprehensive waste management strategy that incorporates source reduction, reuse, and recycling, coupled with conventional waste management practices. Moreover, the City of Cape Town Waste By-Laws [41] have been revised to accommodate both the needs of the formal and informal settlements. These by-laws require waste to be collected once a week and prohibit any illegal dumping activities while emphasizing the penalties for non-compliance. In addition to this, the City of Cape Town has provided specific measures that have been implemented to tackle waste disposal issues within the informal settlements, including the establishment of designated dumping sites and the promotion of community-based waste management programs. Furthermore, to ensure verification and monitoring the City of Cape Town has launched public feedback mechanisms, enabling residents to report waste collection issues via mobile apps and municipal hotlines CCT, [49]. However, despite the available legal frameworks, the implementation of waste management laws in informal settlements remains a challenge due to problems with infrastructure, population density, and socioeconomic constraints that make implementation very difficult. To enhance enforcement the City of Cape Town has initiated several programs, including a collaboration known as the Green Zone Partnership Model (GZPM) with the Bonteheuwel community [50]. Additionally, there is an emphasis on environmental education within the Dunoon community to address waste management challenges in public open spaces. The South African government have made the integrated waste management strategy one of its priorities which sort to identify the national environmental strategy to reduce costs from environmental degradation. Waste collection and disposal are the most crucial parts or steps of any waste management system, which requires the utmost attention to avoid environmental pollution. Failure to execute the waste collection and disposal steps correctly may lead to or result in waste being scattered everywhere, as bins overflow and industrial wastewater polluting nearby water bodies [51]. One of the biggest problems for local authorities all over the world is how to provide services for waste collection and disposal in both efficient and effective ways. No matter which method of waste management is in use, waste has to be collected first. The planning of waste collection should ensure that its cost and time do not exceed acceptable levels while taking into account the prevailing socioeconomic, environmental and land use conditions [52]. The waste collection differs from markedly developed and developing nations [51], the quantity and nature of the waste produced differ with the level of development of a country. According to the study carried out by Macarthy et al. [53], one of the main reasons the townships have high incidences of dumping waste illegally is the absence of a well-planned and controlled waste management system in the townships. A certain informal settlement within Freetown has been found, as there are community bylaws forbidding dumping which are however, not implemented because waste is dumped mainly during the night and there is no one to stop the defaulters. However, Polasi [54], focused on the issues of management of wastes in the City of Johannesburg on the absence of irregular waste collection, which primarily explains why wastes are dumped illegally in the surrounding areas.

3 Results and discussion

3.1 Factors contributing to waste management challenges in the informal settlements of South African provinces

Available data from the urban area's informal settlements of six out of nine South African provinces are shown in Table 1. Overall, more than twenty informal settlements across South Africa that have formed part of the solid waste management investigations are featured in the current study as demonstrated in Table 1. These studies present the factors that

Table 1 Factors contributing to waste management challenges in the South African informal settlements

Province(s)	Informal settlement	Category	Description of factors affecting waste management	Author (s)
Gauteng	Alexandria Township	Infrastructure and Service Provision	Insufficient frequency of waste collection is a result of the incapacity of responsible and mandated authorities to efficiently generate waste	Kubanza [55]
		Infrastructure and Service Provision	There are challenges associated with the movement of waste. Uncollected solid waste spilt over the bins from uncollected containers	
		Infrastructure and Service Provision	Lack of solid waste management awareness and receptacles results in poor disposal and increased waste generation	
		Political and Governance factors	Inconsistency of municipal authorities and hired services, insufficient municipal assistance and a lack of service delivery on issues of waste collection and transportation	
	Kya sand and Mooiplaas	Social dynamics	Lack of community involvement and waste is regarded as the sole responsibility of the municipality. As such waste generation is viewed as an opportunity to create employment	Sibanda [56]
Ivory Park	Ivory Park	Infrastructure and Service Provision	Municipal failure to collect waste effectively and efficiently regularly	Rambuda [57]
		Infrastructure and Service Provision	The lack of disposal bins encourages waste littering and illegal dumping in these neighbourhoods	
	Ivory Park	Socio-economic factors	Lack of waste management practices due to lack of environmental awareness programs in the informal settlements	
		Demographic factors	Overcrowded settlements in Ivory Park produce more waste, which puts greater pressure on the waste collectors to collect as much waste as possible, damaging the assigned trucks within a short time	
		Infrastructure and Service Provision	The available bins aren't sufficient to handle overcrowding. As a result, householders resort to other methods of waste disposal, such as illegal dumping in open spaces, rivers, and street corners, burning of waste, and storing it in plastic bags	
Mpumalanga	Olivenhoutbosch	Infrastructure and Service Provision	Households in informal settlements do not receive waste disposal services from the municipality and use their methods instead	Mohale [58]
		Infrastructure and Service Provision	Although the department has many plans to address the issue, they do not have the funds to implement the plans. Funds are required to procure more resources as well as to provide enough capacity	
	Nyibe	Infrastructure	There were no facilities for storing residential solid waste	Ngema and Mbanga [59]
		Demographic factors	Due to urbanization, backyard dwellers and informal settlers are placing pressure on municipal solid waste collection services	
		Political and Governance factors	Lack of necessary waste disposal infrastructure Inaccessibility to households due to narrow roads Lack of punitive measures such as penalties or fines to deter waste littering behaviour within communities	
Msholoji	Msholoji	Infrastructure and Service Provision	There are no waste collection services provided by the local government	Yacim et al. [60]
		Infrastructure and Service Provision	There are no designated disposal facilities for waste disposal sites	
		Demographic factor	Msholoji is situated within the corridor that easily connects Mbombela city. Therefore, its proximity to the city attracts overcrowding which subsequently increases waste generation	

Table 1 (continued)

Province(s)	Informal settlement	Category	Description of factors affecting waste management	Author (s)
KwaZulu-Natal	Shannon Drive informal settlement, in Durban	Infrastructure and Service Provision	Lack of access to waste disposal services as well as collection services	[61]
	Ekuphumleni Township	socioeconomic factors	Unwillingness to pay for waste management services due to affordability	Adeniran et al. [62]
	Edendale informal settlement	Environmental education	The importance of disposing of waste in municipal bins is not viewed and regarded as necessary within informal settlements	[63]
	Havelock informal settlement	Technological issues	While there is awareness of recycling in this informal settlement, the lack of such behaviour could be attributed to the fact that recycling facilities are not adequate. The settlement has been experiencing problems with recycling bottles with private recyclers not always coming to pick them up which results in piles of glass bottles being accumulated near the stream	Parikh et al. [64]
NTUZUMA TOWNSHIP				
North-West	Kosmos informal settlement Marikana informal settlement,	Infrastructure and Service Provision	There are proficient municipal waste management services in Ntuzuma Township, which are provided to the community in accordance with municipal regulations. Although the municipal truck does not collect waste punctually, some household members fail to pay attention to when and how their waste services are delivered, there are some noticeable deficiencies in service delivery	Ne and Du Plessis [65]
		Physical barriers	In the Madiheng Local Municipality, there are no accessible roads for waste collection	Kekana et al. [77]
		Infrastructure and Service Provision	Consistent with other informal communities, the Marikana-Soutpan lacks fundamental municipal services, such as garbage disposal	Malope et al. [66]
Western Cape	Joe Slovo	Infrastructure and Service Provision	Waste collection has become less regular, resulting in garbage overflowing and people dumping waste around them	Rodseth et al. [5]
		Infrastructure and Service Provision	Although the municipality provides waste management services across the informal services, some households are reported as lacking basic refuse removal services	
		Infrastructure and Service Provision	The municipality is having difficulties with implementing an efficient and effective waste collection system for Joe Slovo, with informal settlement exacerbating the issue as they lack adequate waste management services therefore leading to illegal dumping in the area	Jakeni et al. [46]
		Infrastructure and Service Provision	Due to the inaccessibility of the selected informal settlements and the lack of suitable infrastructure, illegally dumped waste is prevalent	Geyer and Van Lille [67]
Khayelitsha	Kayamandi	Political and Governance factors	The community participation in waste management is limited and this is coupled with weak law enforcement	Zonke and Matsiliza [68]
		Infrastructure and Service Provision	The residents claim insufficient waste disposal facilities	Cele and Pharoah [69]
		Socio-economic factors	Municipality skips are located near the dwellings but residents state that they are not enough and their attitude towards the area is otherwise as they feel no connection to the area	

Table 1 (continued)

Province(s)	Informal settlement	Category	Description of factors affecting waste management	Author (s)
Eastern Cape	Joe Slovo (Nelson Mandela Bay Municipality)	Technological factors	Inadequate access to recycling machines, the study reveals that most of the waste produced by the residents is recyclable	Adeniran et al. [70]
	Mlungisi, Newrest, Victoria Park and Aloevale	Infrastructure and Service Provision	Insufficient waste collection in these informal settlements leads to various disposal techniques, the study shows that more than half of the respondents disposed of household waste in undesignated sites or burnt it	Ngalo and Thondhlala [71]
	Mtata	Technological factors	The majority of the produced waste has the potential to be recycled, reused, or composted but to lack of proper machines makes it impossible	Tsheleza et al. [72]
	Mtata	Demographic factor	The growing population poses serious challenges for the municipality, and this is also complicated by the fact that service demands are sensitive to changes in the community setting	Poswa [73]
	Mdantsane	Demographic factor	The Buffalo City Metropolitan Municipality Mdantsane informal settlement struggles with access roads and proper sanitation services	Mshumpela [74]

exacerbate the waste management challenges within the informal settlements of the South African informal settlements. The available data in Table 1 indicate that in contrast to other provinces, KwaZulu-Natal and Eastern Cape have documented multiple informal settlements confronted with solid waste management challenges. These are informal settlements of urban areas characterised by job opportunities. For example, provinces such as Limpopo, Free State and Northern Cape do not form part of the current study given the lack of solid waste management studies documentation in the informal settlements of these areas. At the bottom of this is the lack of extensive economic activities in the vicinity of these provinces that attract multitudes of people across the country. Moreover, the current study indicates the variability of solid waste management factors and categories across the provinces. Reflecting on the complex relationship of demographic, socioeconomic, cultural, political, and technological influences amongst others. That is, provinces in South Africa encounter the challenges of waste management in the informal settlement at an individual level and peculiar to that setting. Table 1 below characterises these challenges and experiences at provincial levels.

3.2 Factors associated with waste challenges in Gauteng and North-West province

The factors that are associated with solid refuse challenges across the provinces' informal settlements of urban areas were derived from the available data from several studies (as illustrated in Table 1). In the Gauteng province (Fig. 4A) a total number of six factors that exacerbate waste challenges were identified, while in the North-West province, only half of these factors were identified (Fig. 4B). However, it is important to highlight that both provinces experience the scourge of waste collection factors. In the informal settlements of the North-West province insufficient waste collection (> 50%), whilst in the Gauteng province it is (< 40%). However, Gauteng experiences many more issues that breed waste challenges such as public participation, and inadequate municipal services which might be influenced by overpopulation. Overpopulation is generally associated with an increase in waste generation [75]. It is for this reason that Gauteng informal settlements also complain about insufficient infrastructure in the form of dustbins (Fig. 4). This is a cause for concern given that waste containers and dustbins are essential for the disposal of waste. To such an extent that many issues arise because of the insufficient availability of dustbins in the households [76]. This is a fundamental issue that can compromise public health, especially within informal settlements. In addition to a lack of disposal facilities, the North-West province is characterized by narrow roads this was reported in a study by Kekana et al. [77]. The narrow roads (25%) and disposal facilities (25%) are a challenge in the informal settlements given that they hinder waste collection. As corroborated by Guerrero et al. [78] poor route planning in the informal settlements compromises waste collection as well as transportation. Generally, in the North-West province, the waste management challenges belong to the broader category of infrastructure and service provision (67%) as demonstrated in Fig. 2B. The inaccessibility of waste collection is exacerbated by the narrow roads, as vehicles are unable to access these areas, resulting in the refuse remaining at its source of generation. Consequently, the absence of a suitable waste collection system disrupts the waste management flow, leading waste generators to engage in unlawful and undesirable practices such as illegal dumping [79].

3.3 Factors associated with waste challenges in Kwazulu-Natal and Mpumalanga

Figure 5 shows that the number ($n = 4$) of factors that contribute to solid waste challenges between Kwazulu-Natal and Mpumalanga province were comparable. In both provinces of Kwazulu-Natal (40%) and Mpumalanga (60%) infrastructure and service provision are a challenge (Fig. 5A, B). Subsequently, this compromises the quality of waste collection in the informal settlements of these provinces, as indicated that insufficient waste collection in Kwazulu-Natal amounts to 40% (Fig. 5A), while in Mpumalanga province it equals 35% (Fig. 5B). Moreover, the Mpumalanga province experiences issues of waste management facilities (35%) as shown in Fig. 5A as well as the issues of overpopulation (16%) that are respectively associated with infrastructure and service provision as well as demographic factors. It is interesting to highlight that amongst other factors Mpumalanga also encounters issues of weakened law enforcement regarding waste management. That is, there is impunity associated with waste management practices that contravene the waste management practices such as littering as prescribed by the rule of law that governs solid waste within the informal settlements of Mpumalanga province. On the other hand, the Kwazulu-Natal informal settlements demonstrated a lack of knowledge (20%) regarding waste management which has to do with environmental education, limited access to waste technology (20%) which highlighted the insufficient of recycling technologies within the informal settlements as well as the issue of affordability (20%) as depicted in Fig. 5A. Affordability means they can't afford to pay for waste

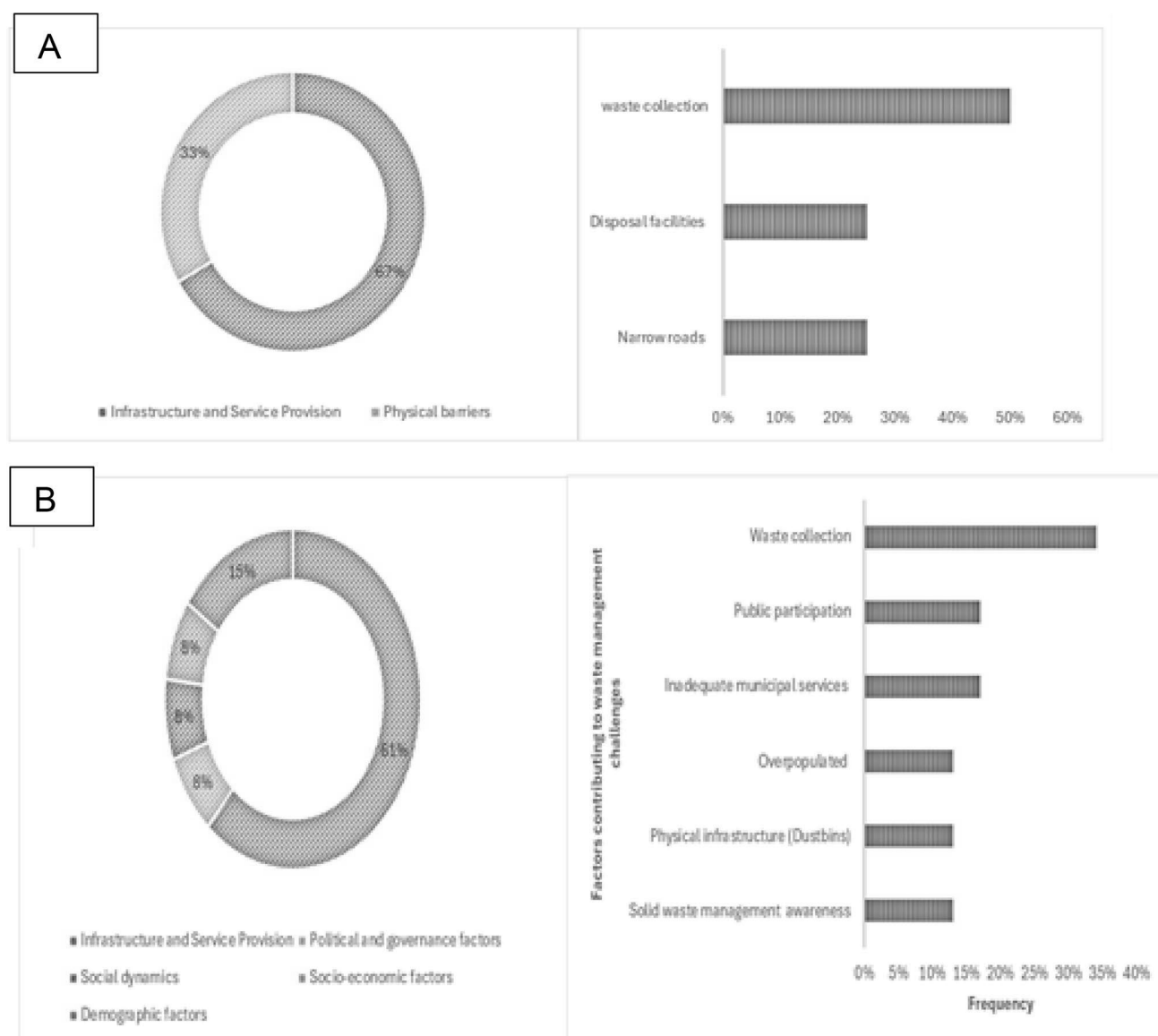


Fig. 4 **A** Factors connected to waste problems in North-West province and Gauteng. **B** Factors connected to waste problems in North-West province and Gauteng

collection services. This could be a reason why the lack of waste collection (40%) is the greatest contributing factor to the solid waste challenges experienced in this province. These observations are similar to those reported in the Keko Machungwa informal settlement in Der er Salaam [80]. In these informal settlements, Kasala [80] highlighted the lack of cooperation among the existing solid waste collection organs, inaccessibility in some places, low public participation, financial constraints and the unwillingness of the local community to pay for solid waste collection fees as the fundamental factors that impact waste management.

3.4 Factors associated with waste challenges in Western Cape and Eastern Cape

The factors contributing to waste challenges in the Western Cape province are associated with infrastructure and service provision. The absence of formal waste management infrastructure in urban informal settlements often results in improper waste management practices, such as open dumping or burning of waste. Without designated collection points or recycling facilities, residents may resort to unsustainable methods of waste management. This is not startling especially since waste collection challenges in the informal settlement are at 50%. While the issue of negative

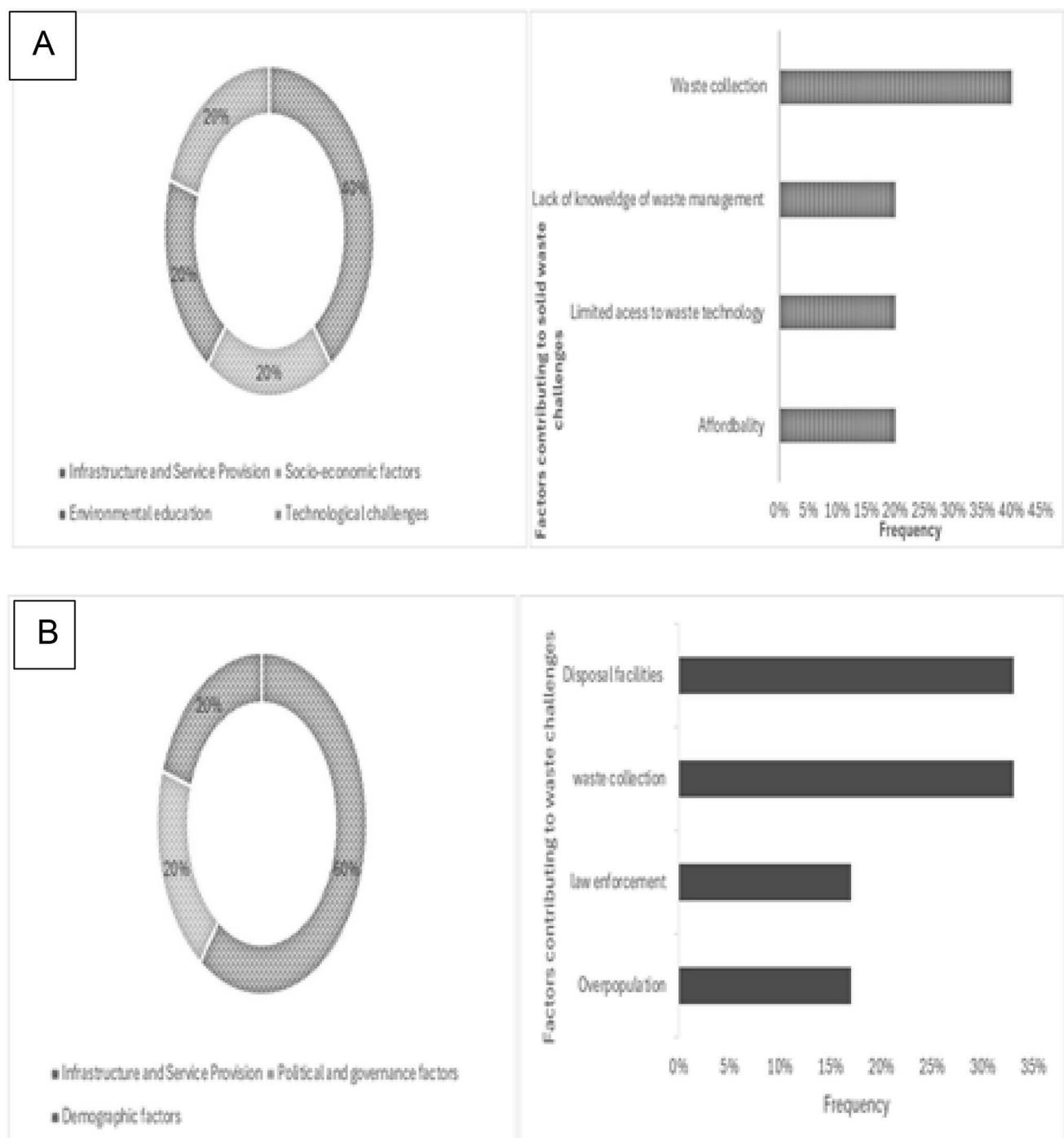


Fig. 5 **A** Determinants of waste management issues in Kwazulu-Natal and Mpumalanga. **B** Determinants of waste management issues in Kwazulu-Natal and Mpumalanga

attitudes, dustbins and the lack of law enforcement are at 20% each across Fig. 6A. In contrast to the Western Cape province, the Eastern Cape is infested with technological factors (40%) as well as demographic factors as depicted in Fig. 6B. As a result, access to waste management technology as well as overpopulation and waste collection (Fig. 6B) in that province compromise the concerted efforts of managing waste.

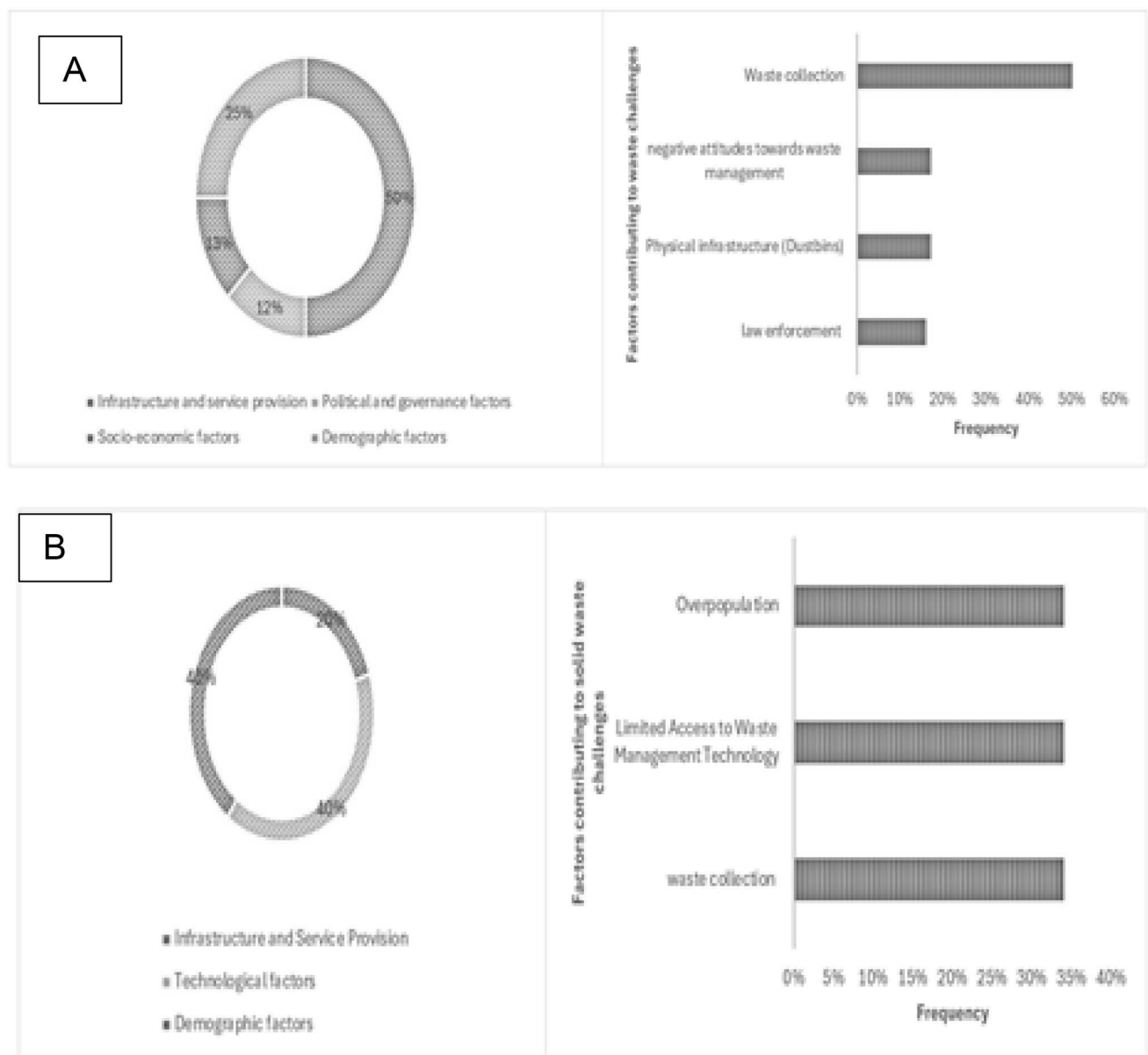


Fig. 6 **A** Contributors of waste challenges in Western Cape and Eastern Cape. **B** Contributors of waste challenges in Western Cape and Eastern Cape



Fig. 7 National outlook of factors contributing to solid waste challenges in the informal settlements

3.5 National outlook of factors contributing to waste challenges across the country

The amalgamated solid waste challenges of South Africa indicate that within the broader context of the waste challenges are infrastructure and service provision > 60% as highlighted in Fig. 7A below. This discovery in essence accentuates that within the informal settlements of the country, solid waste generation as well as poor waste management practices are because of lacking infrastructure and provision of reliable service. It is for this reason that across the informal settlements of the country factors contributing to poor waste management and generation are associated with insufficient waste collection (45%) and physical infrastructure (25%) as depicted in Fig. 7B. This discovery is not startling given that waste collection around the urban areas is less than 55% [81]. The lack of infrastructure generally impacts service provision negatively. In essence, most urban areas in the country in addition to setbacks of collection and adequate disposal are devoid of well-designed municipal treatment. This observation contrasts with that of one of their counterparts within developed countries [82]. For example, it is widely recognised that urban municipalities in developing nations face significant challenges in the effective and efficient management of waste services [78, 83]. The core issue lies in inadequate infrastructure combined with limited service coverage, along with improper disposal and treatment methods, which are fundamental aspects of traditional waste management practices [84, 85]. Subsequently, this impedes the waste management service delivery. To this end, Parrot et al. [86] posit that disposal, or dustbins are systematically mentioned as the primary infrastructure needed by the population in all quarters, whether it's an affluent or informal settlement. This has cumulative impacts, as the poor collection threatens sanitation and public health. For African states, this is the norm, as Jambeck et al. [87] highlight that waste mismanagement is associated with a lack of infrastructure in many African countries. Moreover, the lack of infrastructure compromises the prospects of solid waste recycling initiatives that advance the circular economy. Thus, it is reiterated that infrastructural challenges amongst other issues include the lack of waste recycling activities and the opportunities associated thereof [88]. This unfortunately aggravates waste generation and exerts pressure on inefficient service delivery that is already stretched. Consequently, the lack of recycling facilities as well as the knowledge prompts 75% of waste into the landfills (Operation [89]).

4 Conclusion

Ineffective waste management in South Africa's informal settlements poses a significant challenge to environmental sustainability and public health. Despite constitutional mandates ensuring a clean and healthy environment, inadequate waste collection persists. In light of this view, the current review study has discovered that the primary factors contributing to South Africa's solid waste challenges are inadequate infrastructure and limited service provision, particularly in informal settlements. These challenges not only interfere with waste collection efficiency but also impacts negatively the proper disposal and recycling efforts, ultimately exacerbating environmental and public health concerns. The hierarchical and technical approach to waste management posed numerous environmental, social, and economic issues. The arrangement of houses into high-density settlements, along with insufficient waste management services, intensifies the problem of indiscriminate dumping in several emerging towns. Addressing these issues requires a multi-faceted approach that integrates policy reforms, infrastructural development, and community engagement to enhance waste management efficiency. Post-apartheid South Africa illustrates a notable trend characterised by accelerated rural-to-urban migration since the advent of democracy in 1994, as previously marginalised populations are increasingly assimilated into fully serviced mainstream communities. The South African government should consider developing the less developed provinces this will reduce the rural-urban migration which will also reduce the informal settlements. Moreover, have a proactive human settlement department to address issues of spatial planning and monitor the development of settlements. There is a lack of efficiency and sustainability in waste management as a result of the national solid waste legislation policies and strategies that do not align with local government practices and procedures. The fundamental conclusion of this study is that the South African government should develop other provinces economically to reduce emigration. Cater to migrants with low-cost housing in the cities, by investing again in the cities after having invested a great deal in them. Continue (or expand) investment in rural areas for jobs/incomes to poor rural households that would otherwise migrate into cities. Increase education and employment opportunities in rural areas to restore rural economies and urban-to-rural migration flow. Lastly, there is a general need for investments in waste management infrastructure, which comprises recycling facilities. The successful establishment of contemporary waste treatment systems, such as the waste-to-energy initiative, can fundamentally be facilitated by partnerships between the government and the private

sector. To this effect, the implementation of waste-to-energy initiatives can offer alternative energy sources and reduce landfill dependence while providing an alternative source for energy production, especially for a country battling with load-shedding.

5 Recommendations

- Prioritise the expansion and maintenance of roads in informal settlements to facilitate waste collection vehicles.
- Ensure that a sufficient number of public waste containers are deployed, particularly in high-density areas, and that they are regularly maintained and emptied.
- Develop waste disposal sites in informal settlements that are strategically located and more easily accessible.
- Create community-based campaigns that emphasise the significance of waste disposal, recycling, and appropriate waste sorting.
- Facilitate the integration of informal waste collectors into the formal waste management system by providing training and equipment.

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Declarations

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Consent for publication Not applicable.

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