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Plastic waste dynamics and governance challenges in urban Malawi

Gideon Gonthoka Gondwe[1*], Kambombo Mtonga[2] and Harold Wilson Tumwitike Mapoma[1]

*Correspondence: gideon_gondwe@yahoo.com; mepm23-ggondwe@mubas.ac.mw; kmtonga@mubas.ac.mw

[1] Physics and Biochemical Sciences Department, Malawi University of Business and Applied Sciences (MUBAS), Chichiri, Private Bag 303, Blantyre 3, Malawi

[2] Mathematical Sciences Department, Malawi University of Business and Applied Sciences (MUBAS), Chichiri, Private Bag 303, Blantyre 3, Malawi

Abstract

Plastic pollution in rapidly urbanising Sub-Saharan African cities remains poorly quantified in terms of its spatial distribution, behavioural drivers, and governance constraints. This study addresses this gap by integrating field-based waste quantification with socio-behavioural analysis across three major Malawian cities of Blantyre, Lilongwe, and Mzuzu. Specifically, the study, (1) quantifies plastic waste volume and spatial variation; (2) assesses public awareness, attitudes, and behaviours; and (3) evaluates institutional and infrastructural constraints in plastic waste management. A total of 27,574 plastic items (173.41 kg) were recorded across 30 sites. While localised high-accumulation areas were observed, there were no statistically significant differences across the cities ($F(2,27) = 1.43$, $p = 0.257$) or site types ($p = 0.693$), indicating system-wide distribution rather than spatially isolated hotspots. Waste composition was dominated by single-use plastics (bags: 42.6%; sachets: 34.1%). The survey results ($n = 1,101$) revealed high awareness (97.7%) and concern (> 90%), yet low recycling (4.5%) and limited policy awareness (29.3%), highlighting a pronounced awareness-behaviour gap. Regression analysis indicates that structural factors particularly location and infrastructure access outweigh socio-demographic variables in shaping behaviour. The low recycling rate is primarily constrained by limited infrastructure and access, rather than lack of willingness. These findings demonstrate that plastic pollution is systemically embedded, driven by interacting consumption patterns, infrastructural limitations, and governance constraints. The study provides novel mixed-methods evidence linking spatial measurements with behavioural and institutional dynamics, and identifies context-specific interventions, including decentralised recycling systems, market-based plastic reduction strategies, and Extended Producer Responsibility mechanisms tailored to informal urban economies.

Keywords: Plastic pollution, Urban Malawi, Spatial distribution, Consumer behaviour, Mixed-methods, Thin plastics ban, Recycling infrastructure, Extended producer responsibility (EPR)

1 Introduction

Plastic pollution has become one of the most pressing global environmental challenges, with recent estimates indicating that over 350 million tonnes of plastic waste are generated annually [35]. Earlier studies highlighted the scale and persistence of plastic production and waste [14], while more recent research emphasizes the

widespread presence of microplastics in water systems, food chains, and urban environments, raising concerns about ecological and human health impacts [48, 50].

Although plastic pollution is a global issue, its impacts are unevenly distributed. As of 2018, Africa produced 5% and consumed 4% of global plastics volumes, with lax regulation and improving economies contributing to the rising pollution (Sadan & [38]). Despite contributing a relatively small share to global plastic production, African cities experience disproportionate environmental impacts due to inadequate waste collection systems and high dependence on single-use plastics [47]. Most African countries have inadequate recycling capacities, which hinders proper waste management [2]. Microplastic pollution is also a significant concern in African water systems, leading to threats of ecological viability when combined with other stressors like climate change [30]. This disparity is particularly evident in sub-Saharan Africa, where rapid urbanization, population growth, and limited waste management infrastructure exacerbate plastic waste accumulation [20]. In many African urban centres, plastic waste streams are dominated by low-value, single-use materials such as plastic bags and sachets used for packaging water, food, and household goods [33, 36, 49]. These materials are difficult to recycle and are frequently found in drainage systems, open spaces, and informal settlements, contributing to flooding, environmental degradation, and public health risks [15, 39].

In Malawi, plastic pollution is increasingly evident in urban areas such as Lilongwe, Blantyre, and Mzuzu. Municipal solid waste management systems in these cities face significant challenges, including inadequate infrastructure, limited financial capacity, and low public participation [8]. Studies in Lilongwe (i.e., the capital city of Malawi) have further shown that socio-economic and institutional factors, including governance and policy enforcement, influence waste management practices and outcomes [25, 31]. Predicted that total municipal plastic waste production in Malawi will be 508,000 metric tons per year in 2060. The nature of consumption in Malawi has been shifting from reusable to more single-use and hard to recycle plastics. Malawi also has increasing water quality concerns, and many residents are using plastic water bottles for clean water as a result [45]. Estimates suggest that 75,000 tonnes of plastic is produced in Malawi each year, of which 80% is single-use plastic that cannot be recycled [46]. Based on population growth rates, it is estimated that by 2030 the amount of plastic waste generated in the capital city, Lilongwe, will be close to 32,000 tonnes more than double that in 2014 [46]. Although comparable projections for Blantyre and Mzuzu are limited, similar upward trends driven by urbanisation and increased reliance on single-use plastics are evident, consistent with patterns across Sub-Saharan African cities [44, 48].

The Government of Malawi introduced the Environmental Management (Plastics) Regulations in 2015 to regulate the production, importation, and use of thin plastics [26]. However, enforcement challenges and regulatory exemptions particularly for essential packaging materials such as sachets and food wrappers have limited the effectiveness of these measures. Consequently, plastic packaging materials continue to dominate the urban waste stream. Although previous studies in Malawi have examined waste management systems or public awareness separately [8, 16], there remains limited empirical evidence integrating quantitative assessments of plastic waste with analyses of public awareness, perceptions, and disposal behaviours. This lack of integrated

analysis constrains a comprehensive understanding of plastic pollution dynamics in the Malawian context.

Understanding the relationship between awareness and behaviour is critical, as high levels of environmental awareness do not necessarily translate into responsible waste management practices [12, 53]. Behavioural theories such as the Theory of Planned Behaviour suggest that individual actions are influenced by attitudes, social norms, and perceived behavioural control [3]. In Malawi, where infrastructural limitations and enforcement challenges persist, examining how demographic factors influence awareness and behaviour is particularly important for designing effective interventions. This study addresses these gaps by integrating plastic waste audits with household surveys, focus group discussions, and key informant interviews. The study combines environmental measurements with socio-behavioural analysis, thereby providing a comprehensive assessment of plastic waste dynamics in urban Malawi. Specifically, this study:

1. Quantifies the volume and spatial variation of plastic waste in urban Malawi, including the major cities of Lilongwe, Blantyre and Mzuzu.
2. Examines the correlation between demographic factors and awareness, perception, and attitudes of urban dwellers towards plastic use and disposal.
3. Analyses how plastic use and disposal practices relates to structural and governance factors.

The remainder of this paper is structured as follows: Sect. 2 presents a discussion of existing literature, highlighting global trends in plastic production and waste, plastic waste patterns, drivers, and structural constraints in Africa, and other relevant aspects. Section 3 presents the study methodology, including the study design, sampling framework, and data analysis plan. Section 4 outlines the major study findings. Section 5 presents a critical analysis of the study findings and their implication(s). Finally, Sect. 6 provides concluding remarks of the study and outlines possible future research directions.

2 Literature review

2.1 Global trends in plastic production and waste

Global plastic production has increased dramatically from approximately 2 million tonnes in 1950 to over 400 million tonnes annually in recent years [37, 51]. While these figures are widely cited in the literature, they are largely derived from industry-based datasets and modelling approaches that depend on incomplete reporting, particularly from low-income countries. As a result, global estimates may underestimate the true scale of plastic leakage, especially in regions where waste monitoring systems are weak or non-existent [35].

A substantial proportion of plastics produced globally are designed for single use, with packaging accounting for nearly 40% of total plastic demand [14]. Despite increased policy attention and global awareness campaigns, recycling rates remain low, with only about 9% of all plastic waste recycled, while the majority accumulates in landfills or the natural environment [48]. However, these global aggregates mask significant regional disparities. High-income countries typically exhibit higher collection and recycling

rates, whereas low- and middle-income countries face systemic challenges that result in higher levels of mismanaged waste [20].

2.2 Plastic waste in Africa: patterns, drivers, and structural constraints

Plastic consumption in Africa has increased steadily due to rapid urbanisation, population growth, and changing consumption patterns associated with economic development [38]. Although per capita plastic use remains lower than in developed regions, waste management systems have not kept pace with rising consumption, resulting in significant levels of mismanaged plastic waste [20].

Urban centres are widely identified as critical intervention points for addressing plastic pollution. Empirical studies from cities such as Nairobi and Lagos demonstrate that high population density, expansion of informal settlements, and inadequate waste collection services significantly increase plastic leakage into drainage systems and water bodies [44]. However, many of these studies rely on aggregated data or limited sampling frameworks, which restrict their ability to capture intra-urban variability and localised hotspots of plastic accumulation.

Structural challenges across African countries further complicate plastic waste management. These include limited financial resources, weak institutional capacity, fragmented governance arrangements, and insufficient regulatory enforcement [47]. These constraints not only affect waste collection and recycling but also limit the availability and reliability of data, resulting in evidence gaps that undermine effective policy design.

2.3 Plastic waste in Malawi: data gaps and institutional dynamics

Plastic pollution in Malawi reflects broader regional trends but is characterised by significant empirical and institutional limitations. Existing estimates of plastic waste generation are often based on extrapolations rather than systematic field measurements, reducing their reliability for policy and planning purposes [45, 46].

The persistence of data gaps in Malawi is driven by a combination of institutional, methodological, and financial constraints. Responsibilities for waste management are distributed across multiple government agencies and local authorities, often resulting in weak coordination and unclear mandates [9]. Financial limitations restrict investment in environmental monitoring systems, while methodological challenges, including reliance on aggregated or outdated data, obscure spatial and temporal variations in plastic pollution.

Urban areas such as Lilongwe, Blantyre, and Mzuzu exhibit visible plastic accumulation in markets, drainage systems, and riverbanks. However, the absence of site-specific and longitudinal data makes it difficult to identify pollution hotspots or assess trends over time [16]. This limitation underscores the need for empirical studies that integrate environmental measurements with behavioural and institutional analysis.

2.4 Seasonal variation and environmental dynamics

Seasonal variation represents a critical yet often underexplored dimension of plastic pollution. During the rainy season, increased surface runoff and inadequate drainage systems mobilise accumulated plastic waste, transporting it into rivers, wetlands, and flood-prone areas [19]. This process results in temporal spikes in plastic pollution and

contributes to environmental degradation, including flooding and contamination of water bodies.

Failure to account for seasonal dynamics can lead to underestimation of pollution levels and misrepresentation of spatial distribution patterns. Consequently, studies that do not incorporate temporal variation may produce incomplete or misleading findings. Integrating seasonal analysis is therefore essential for accurately understanding plastic waste dynamics and designing effective interventions.

2.5 Public awareness, attitudes, and environmental behaviour

Global awareness of plastic pollution has increased significantly due to media exposure, policy interventions, and environmental advocacy [32]. Higher levels of environmental awareness are generally associated with increased concern about plastic pollution and greater willingness to adopt sustainable practices [42].

However, empirical evidence consistently demonstrates that awareness alone is insufficient to drive behaviour change. Studies indicate that while individuals may possess knowledge about environmental issues, their actions are often constrained by contextual factors such as convenience, availability of alternatives, and social norms [18].

In Malawi, a survey by [29] revealed that while most urban dwellers are aware of the environmental risks of plastic pollution, few actively participate in waste reduction practices. The waste management system and public awareness are inadequate to cope with the amount of waste generated in Malawi [45]. Similarly, [47] found that in Malawi, as is the case for many African countries in sub-Saharan Africa, there is a lack of knowledge about waste recycling and associated opportunities. This suggests that knowledge does not automatically translate into action, particularly in contexts where enabling conditions are lacking.

2.6 The attitude-behaviour gap in plastic waste management

The attitude-behaviour gap is a well-documented phenomenon in environmental research, referring to the disconnect between individuals' environmental values and their actual practices [23]. In the context of plastic pollution, individuals often express concern and willingness to reduce plastic use while continuing to engage in unsustainable behaviours.

The Theory of Planned Behaviour [3, 4] provides a useful framework for understanding this gap. While attitudes and social norms influence behavioural intentions, actual behaviour is also shaped by perceived behavioural control. In many developing-country contexts, limited access to waste management services, lack of affordable alternatives, and weak policy enforcement constrain individuals' ability to act on their intentions [47].

Empirical studies present contrasting findings. In some contexts, increased awareness leads to measurable reductions in plastic consumption, particularly when supported by policy interventions and accessible alternatives [27]. In other cases, awareness has little or no impact on behaviour, highlighting the importance of structural and contextual factors [18].

2.7 Behavioural, economic, and social drivers of plastic use

Plastic consumption and disposal practices are influenced by a complex interplay of behavioural, economic, and social factors. Convenience and affordability are key drivers of continued reliance on single-use plastics, particularly in low-income settings where alternatives may be unavailable or costly [20].

Socio-demographic characteristics such as age, education, gender, income level, and place of residence have been widely identified as important predictors of environmental awareness and behaviour [22]. However, the influence of these factors is neither uniform nor deterministic, as their effects are often mediated by contextual and structural conditions.

Informal economic activities often depend on plastic packaging due to its low cost, durability, and accessibility. Social norms and cultural practices also play a significant role, as individuals are more likely to adopt sustainable behaviours when they are widely accepted within their communities [41]. Conversely, in environments where improper waste disposal is common, behaviour change becomes more difficult.

These findings highlight the need for interventions that address not only awareness but also the broader socio-economic context in which behaviour occurs. This underscores the importance of integrating demographic analysis with behavioural and structural factors to better understand plastic waste practices in urban contexts such as Malawi.

2.8 Plastic waste management systems and ISWM

Plastic waste management systems differ significantly between high-income and low-income countries. High-income countries typically rely on formalised systems that include waste segregation, recycling infrastructure, sanitary landfills, and regulatory mechanisms such as Extended Producer Responsibility [35].

In contrast, waste management systems in Sub-Saharan Africa are characterised by limited collection coverage, inadequate infrastructure, and heavy reliance on informal systems [44]. Integrated Solid Waste Management (ISWM) has been proposed as a comprehensive approach that emphasises stakeholder participation, policy coherence, and sustainability [48].

However, the implementation of ISWM in developing countries faces significant challenges. Financial constraints, weak institutional coordination, limited technical capacity, and low public participation hinder its effectiveness. As a result, ISWM often remains a theoretical framework rather than a fully operational system in many urban contexts.

2.9 Informal sector and circular economy potential

The informal waste sector plays a critical role in plastic waste management in developing countries. Informal waste pickers contribute significantly to material recovery and recycling, particularly in areas where formal systems are weak or absent [7].

In Malawi, informal waste pickers are commonly observed in urban centres such as Lilongwe and Blantyre, where they collect plastic bottles, containers, and other recyclable materials for resale [8, 31]. Despite their contributions, informal waste workers often operate under precarious conditions, with limited recognition, support, or integration

into formal systems. Integrating informal actors into formal waste management frameworks has been identified as a key opportunity for improving recycling rates, enhancing efficiency, and creating sustainable livelihoods.

2.10 Policy effectiveness and enforcement challenges

Policy interventions aimed at reducing plastic pollution have been implemented in many countries, including Malawi. The Environmental Management (Plastics) Regulations of 2015 represent a significant policy effort to control plastic use. However, evidence suggests that their effectiveness has been limited. Weak enforcement capacity, regulatory exemptions, and the persistence of informal and illegal plastic trade undermine policy outcomes [9, 46]. Studies from other contexts similarly show that plastic bans are often circumvented through smuggling, substitution, and informal markets [47]. These findings suggest that policy effectiveness depends not only on regulatory design but also on enforcement mechanisms, availability of alternatives, and public compliance.

2.11 Causal mechanisms of policy and behavioural failure

Behavioural research indicates that pro-environmental actions are constrained by both internal factors (such as motivation, awareness, and attitudes) and external conditions, including infrastructure, cost, and institutional support [13]. These constraints may inhibit pro-environmental goals while reinforcing competing behaviours, thereby limiting behavioural change. Furthermore, ecological models emphasise that behaviour is shaped by a complex interaction of individual, social, and environmental factors, suggesting that interventions focusing solely on awareness are unlikely to succeed [43]. The Theory of Planned Behaviour further explains that while individuals may hold positive attitudes towards environmental protection, actual behaviour is strongly influenced by perceived behavioural control, which is often limited in contexts with inadequate waste management systems [3, 4]. In addition, evidence shows that behaviour change is difficult to sustain over time, as intervention effects tend to diminish due to habit persistence, resource limitations, and environmental pressures [24]. Policy outcomes are therefore highly context-dependent, as the effectiveness of interventions is mediated by local barriers and enabling conditions [11, 28]. These findings highlight that both behavioural and systemic constraints must be addressed simultaneously to achieve effective and sustained plastic waste management.

It is clear from above that despite a growing body of global and regional literature on plastic pollution, significant gaps remain in the Malawian context. Specifically, there is a lack of integrative research that combines quantified assessments of plastic waste volume and spatial variations with behavioural and institutional analysis. Furthermore, limited attention has been given to the interaction between awareness, infrastructure, and policy effectiveness. These gaps limit the ability of policymakers to design targeted, evidence-based interventions and highlight the need for comprehensive, context-specific studies. Hence, this study addresses the identified gaps by adopting an integrated mixed-methods approach that combines field-based plastic waste quantification with behavioural and institutional analysis. Unlike previous studies that examine these elements in isolation, this research provides a comprehensive assessment of plastic pollution dynamics in urban Malawi. The study links environmental data with behavioural

insights, to advance understanding of the drivers of plastic pollution and offers practical, context-specific recommendations for improving waste management systems. The findings have direct implications for policy design, regulatory enforcement, infrastructure development, and behaviour change interventions.

3 Methodology

3.1 Study area

The study was conducted in Blantyre, Lilongwe, and Mzuzu, Malawi's three largest cities, representing the Southern, Central, and Northern regions, respectively. These cities were selected due to rapid urbanisation, high population densities, diverse socio-economic characteristics, and documented challenges with plastic waste accumulation. Lilongwe district, the capital and largest city of Malawi, has a population of 1,346,360. It is a cosmopolitan city with inhabitants from all over Malawi, Africa and the rest of the world. Blantyre City, located in the Southern Region, is Malawi's commercial and industrial capital with approximately 800,264 (2018 Census). Mzuzu City is the administrative and economic hub of Malawi's Northern Region, with a population of 221,272 as of the 2018 Census.

The Fig. 1 illustrates the spatial distribution and relative intensity of plastic waste accumulation across sampled sites in Blantyre, Lilongwe, and Mzuzu. Point symbols represent individual sampling locations, with symbol size proportional to the volume of plastic waste recorded (count per site). Waste volumes are classified into four categories (low, moderate, high, and hotspot) using a natural breaks (Jenks) classification scheme. Symbol shapes denote site types, including markets, streets, riverbanks, and residential areas. The inset show the location of Malawi within Africa, providing geographic context for the study area. Coordinates are approximate and used for spatial representation of sampling locations.

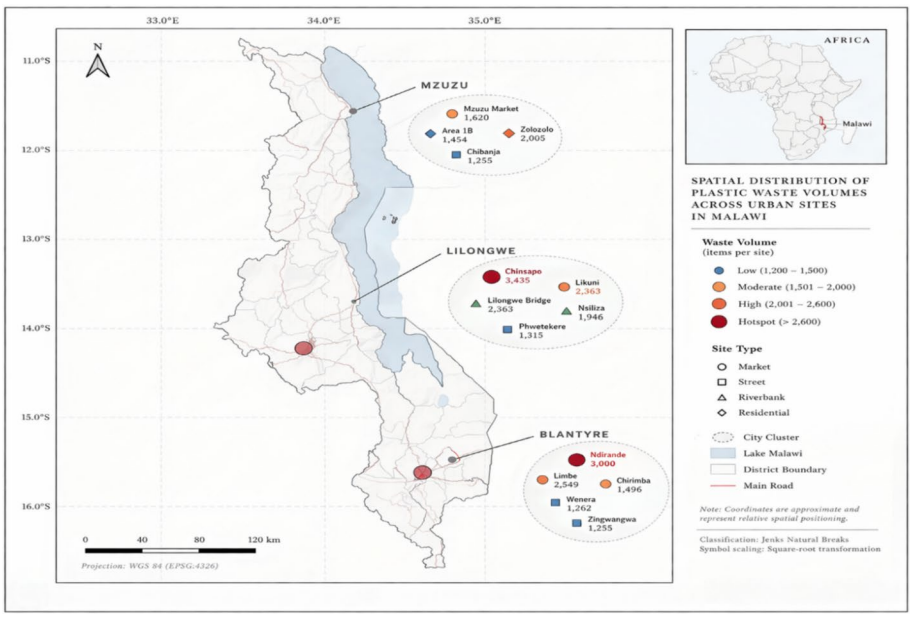

Fig. 1 Spatial distribution of plastic waste volumes across selected urban sites in Malawi

Across all three cities, solid waste management systems are characterised by limited collection coverage, inadequate infrastructure, and a reliance on informal disposal practices. These structural challenges, combined with rapid population growth and increasing consumption of plastic products, contribute to widespread environmental pollution. The spatial distribution of sampling sites within each city was designed to capture variation across key land-use types, including markets, streets, riverbanks, and residential areas. These environments represent critical points of plastic waste generation, accumulation, and transport within urban systems. By incorporating both formal and informal residential areas as well as high-activity commercial zones, the study captures the socio-spatial heterogeneity of urban waste dynamics. Importantly, the selection of these cities and sampling sites directly supports the study's objectives of analysing spatial variation in plastic waste volumes and examining the influence of socio-economic and environmental factors on waste distribution. The inclusion of diverse land-use types enables comparative analysis across urban contexts, while the multi-city design allows for broader generalisation of findings within Malawi's urban system.

3.2 Study design

The study employed a convergent mixed-methods design, in which quantitative and qualitative data were collected concurrently, analysed separately, and integrated at the interpretation stage. Quantitative components included structured surveys and environmental plastic waste audits, while qualitative data were obtained through focus group discussions (FGDs) and key informant interviews (KIIs). This design enabled triangulation of behavioural data with observed environmental outcomes. This study involving human participants was reviewed and approved by the Malawi University of Business and Applied Sciences (MUBAS). All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its comparable ethical standards.

3.3 Data collection and tools

3.3.1 Plastic waste audit

Plastic waste was assessed using a field-based observational method adapted from Jambeck et al. (2015) and UNEP [47]. A purposive sampling strategy was used to select 5 sites per city (total = 15 sites), representing key urban land-use types (markets, riverbanks, and major streets). At each site, two replicate quadrats (5 m × 2 m) were established, resulting in 30 total transects across the study area. The quadrat size was selected based on its suitability for capturing representative micro-scale waste accumulation while maintaining feasibility for repeated measurements, consistent with similar environmental audit approaches. To reduce hotspot bias, site selection incorporated variation in land use, population density, and waste exposure levels, rather than focusing solely on visibly polluted areas. Plastic waste was assessed using direct observation within 5 m × 2 m quadrats. Items were counted, categorised (e.g., bottles, bags, packaging), and weighed. Each site was sampled twice over a two-month period, with visits conducted at similar times of day to minimise temporal variability.

3.3.2 Household survey

Structured questionnaires were administered to 1,101 urban residents across the three cities (Lilongwe: 385; Blantyre: 383; Mzuzu: 333) using stratified random sampling based on city, gender, age group, education level, and residential density. The survey assessed awareness of plastic pollution, attitudes toward plastic use and regulation, disposal practices, and access to waste services. Data were collected digitally using Kobo-Toolbox, and administered in English and Chichewa, with translation and back-translation procedures applied to ensure consistency. The sample size of 1,101 respondents was determined using Cochran's formula (1977) adjusted to finite population;

$$n_0 = \frac{N \times Z^2 \times P(1-P)}{e^2(N-1) + Z^2 \times P(1-P)}.$$

3.3.3 Qualitative data

A purposive sampling strategy was employed for the qualitative component of the study to ensure the selection of participants with direct experience, contextual knowledge, and practical involvement in plastic waste generation, management, and regulation in urban Malawi. Nine FGDs and nine KIIs were conducted with community leaders, market vendors, waste collectors, environmental officers, and civil society representatives. Interviews explored behavioural drivers, policy awareness, enforcement challenges, and practical waste management constraints.

3.4 Data processing and analysis

Quantitative and qualitative findings were integrated at both the analysis and interpretation stages, enabling comparison between reported behaviours and observed waste patterns.

3.4.1 Quantitative data

Quantitative data collected through questionnaire surveys and environmental observations were first exported from Kobo-Toolbox into Microsoft Excel for initial cleaning. Data cleaning involved checking for missing values, inconsistencies, outliers, and duplicate entries. Where necessary, incomplete or invalid responses were excluded from analysis to maintain data integrity. Variables were coded and labelled appropriately to facilitate statistical analysis. Descriptive statistics were generated to summarize key characteristics of the sample and to describe patterns in awareness, perceptions, attitudes, and plastic waste disposal practices. These statistics included frequencies, percentages, means, and standard deviations, presented through tables and graphical formats where appropriate. Inferential statistical analyses were then conducted to examine relationships between variables in line with the study objectives. Chi-square tests were used to assess associations between categorical variables, such as socio-demographic factors and awareness or disposal practices. Binary logistic regression analysis was applied to examine the influence of independent variables on dependent variables related to plastic use and disposal behaviour. These analyses enabled the identification of statistically significant predictors of plastic waste management behaviour in urban Malawi. Environmental sampling data was analysed through descriptive statistics. Environmental sampling

data, were analysed using descriptive statistics to assess volume and spatial variations across cities and site types. Comparative analysis was conducted to identify differences in plastic accumulation between markets, riverbanks, and street environments, as well as across the three study cities.

3.4.2 Qualitative data

Qualitative data obtained from focus group discussions and key informant interviews were transcribed verbatim and reviewed for accuracy and completeness. Transcripts were read repeatedly to achieve data familiarization before formal coding commenced. Thematic content analysis was employed to analyse qualitative data. An initial coding framework was developed based on the study objectives and themes emerging from the literature review. Open coding was first applied to identify recurring ideas, phrases, and concepts within the data. These codes were then grouped into broader categories and themes through axial coding. Key themes included perceptions of plastic pollution severity, behavioural drivers and barriers, institutional challenges, policy enforcement gaps, and community-based solutions. The qualitative analysis emphasized identifying patterns, similarities, and differences across participant groups and cities, thereby providing contextual explanations for trends observed in the quantitative data.

Data triangulation was employed by integrating results from survey questionnaires, environmental observations, focus group discussions, and key informant interviews to enhance validity. Quantitative findings were cross-checked against qualitative insights and field observations to confirm consistency or explain discrepancies.

3.5 Study limitations

The two-month sampling period limits the ability to capture long-term seasonal variation. Additionally, purposive environmental sampling may introduce bias; however, efforts were made to include diverse site types. These limitations are acknowledged when interpreting findings.

4 Results and discussion

4.1 Volume and variations of plastic waste

4.1.1 Magnitude and spatial distribution of plastic waste

Across the 30 surveyed sites, plastic waste accumulation was substantial, with a total of 27,574 plastic items counted, weighing 173.41 kg. The mean plastic count per site was 919.1 items (SD = 355.5), and the mean weight was 5.78 kg (SD = 1.54). However, accumulation was not evenly distributed as several sites recorded exceptionally high plastic counts compared to others. Sites such as Ndirande, Limbe, Chinsapo, Likuni, Zolozolo and Mzuzu market exhibited markedly elevated plastic counts relative to the overall average of 919 items per site (Skewness = +1.054), confirming the presence of extreme accumulation points. This suggests that plastic waste accumulation is concentrated in a limited number of high-intensity locations rather than being evenly distributed across urban areas. These high-accumulation sites can therefore be interpreted as spatial concentration points, consistent with the clustering patterns illustrated in Fig. 2.

In contrast, plastic weight measurements showed moderate variability across sites, with no extreme clustering (Kurtosis = 0.006), suggesting that while counts varied

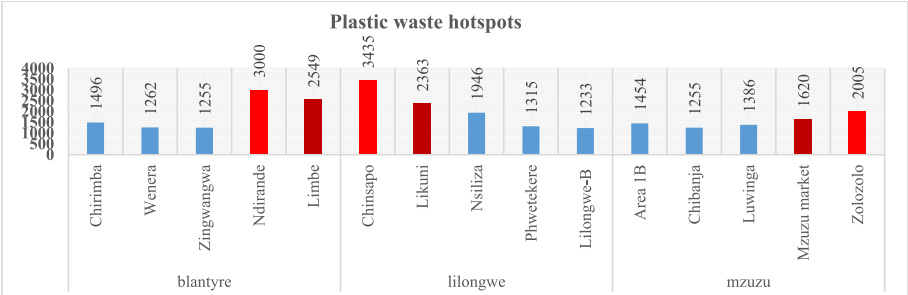

Fig. 2 Plastic waste hotspots sites

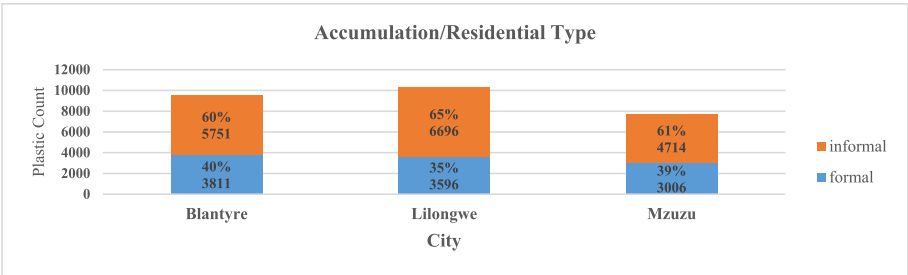

Fig. 3 Formal VS Informal settlement plastic accumulation

sharply, overall weight distribution remained relatively stable. These findings demonstrate spatial concentration of plastic waste in specific urban locations, implying localised waste management inefficiencies rather than uniform city-wide accumulation.

At the city level, Lilongwe recorded the highest total plastic load (10,292 items; M = 1029.2, SD = 431.9), followed by Blantyre (9,562 items; M = 956.2, SD = 403.0), while Mzuzu recorded the lowest totals (7,720 items; M = 772.0, SD = 138.9). Although numerical differences were observed between cities, these variations were not statistically significant ($F(2, 27) = 1.43$, $p = 0.257$, $\eta^2 \approx 0.10$). This suggests that plastic waste accumulation does not differ substantially across cities, indicating that the problem is widespread and driven by common urban factors rather than location-specific conditions.

Plastic waste accumulation also varied across site types. Markets recorded the highest total waste (13,640 items; M = 974.3, SD = 388.0), accounting for approximately 49% of all collected waste. Riverbanks followed (5,488 items; M = 914.7, SD = 455.8), while streets recorded lower totals (8,446 items; M = 844.6, SD = 251.9). However, these differences were not statistically significant ($p = 0.693$). This suggests that although certain environments appear to accumulate more waste, the differences are not strong enough to confirm systematic variation across site types.

Informal settlements recorded higher mean plastic accumulation compared to formal residential areas, accounting for 62.2% of total waste. However, this difference was not statistically significant ($t = -0.64$, $p = 0.528$). Figure 3, shows plastic waste accumulation on the settlement types.

This indicates that the observed differences may be due to random variation rather than structural disparities in waste management. Nonetheless, the higher absolute

contribution of informal areas may reflect population density and activity levels rather than statistically distinct waste generation patterns.

4.1.2 Plastic type composition

Plastic bags (42.6%) and sachets (34.1%) dominated the waste stream, together accounting for over 77% of observed plastics. This suggests a strong dependence on low-cost, single-use plastic packaging, particularly in informal retail and consumption systems. The persistence of these materials despite existing regulatory restrictions highlights potential gaps in enforcement and the continued availability of affordable alternatives. Other plastic categories contributed relatively small proportions (each less than 11%), indicating that the waste stream is heavily concentrated in a few dominant product types as shown in Fig. 4.

4.2 Public awareness, attitude and perceptions vs demographic factors

4.2.1 Demographics summary

The survey sample size of 1,101 respondents comprised 51.4% male and 47.8% female respondents, indicating a relatively balanced gender representation. The dominant age group was 25–34 years (338, 30.70%), followed closely by 35–44 years (317, 28.79%), Younger adults (18–24) represented 16.53%, while older populations (55+) comprised only 5.54%. Employed individuals dominated at 36.78% (405 participants), reflecting formal sector engagement. Students represented 19.16% (211 participants), indicating youth engagement with environmental issues. The majority of respondents had completed secondary education (54.4%), followed by tertiary education (27.7%), only 4.90% had no formal education, suggesting survey participation skewed toward educated urban populations. Traders comprised 16.53% (182 participants), representing informal sector commerce. Farmers accounted for only 8.08% (89 participants), reflecting Malawi's rapid urbanization. These demographics indicated the survey captured primarily urban, employed, and relatively educated populations in Malawi's three largest cities, where solid waste generation is most concentrated.

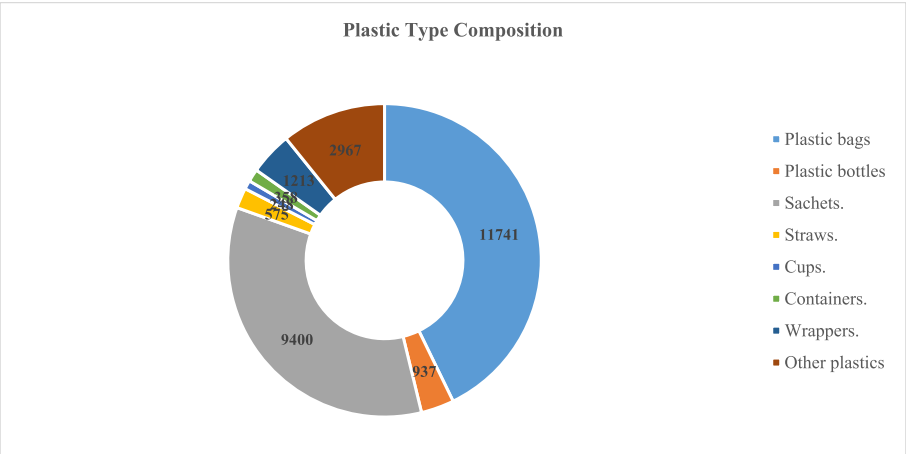

Fig. 4 Plastic waste composition by Type

4.2.2 Awareness and knowledge

An overwhelming majority of respondents (97.73%, n = 1,076) reported having heard about single-use plastics, with only 25 respondents (2.27%) indicating no prior awareness. Only 29.34% of respondents stated being aware of existing government policies. This reveals a substantial gap between general environmental awareness and policy-specific knowledge. Chi-square analysis revealed a highly significant relationship between district and policy awareness ($\chi^2 = 106.532$, $p < 0.001$), indicating geographic variation in policy communication effectiveness. Regarding awareness of negative environmental effects; 68% (n = 749) of respondents demonstrated awareness, 22.0% (n = 242) of respondents demonstrated unawareness, and a substantial proportion 110 (10%) indicated uncertainty. Remarkably, 89.92% of respondents rated their knowledge as "high" or "very high." On self-assessment of their knowledge about plastic pollution. This suggests a potential overestimation of knowledge, where perceived understanding does not fully align with actual awareness of environmental consequences or policy frameworks. Education level was significantly associated with knowledge ($\chi^2 = 87.201$, $p < 0.001$), indicating that formal education plays a key role in shaping environmental awareness.

4.2.3 Attitude and perception towards plastic pollution

Respondents' views on whether plastic pollution is a serious problem was ranked using 5-likert scale. Combined, 90.37% of respondents agree or strongly agree that plastic pollution is a serious problem. The high proportion expressed strong concern (78%) suggested that the issue had emotional salience for most respondents, which is a positive indicator for potential behavioural change. The high willingness rate (87%) is particularly significant as it indicates behavioural intention. A clear majority (66.12%) believe the government is not doing enough, while only 19.16% are satisfied with government efforts. City-level analysis reveals significant variations, dissatisfaction was particularly pronounced in Blantyre and Mzuzu, while Lilongwe recorded comparatively lower levels of dissatisfaction and a higher proportion of uncertainty as shown in Table 1. This suggests that public trust in institutional effectiveness is limited, which may reduce compliance with waste management policies and interventions.

4.3 Plastic use/practices and behaviours

The data reveals that Plastic bag use remains widespread among respondents. Combined, 94.6% reported using plastic bags at least occasionally, with only 5.4% indicating rare or no use. Use of cloth or reusable bags was also reported, though at lower levels. plastic bag use remains more prevalent, suggesting that many respondents alternate between plastic and reusable options depending on context. Plastic bottle use was

Table 1 Perception towards government action in reducing plastic pollution

City	No%	Not sure%	Yes%	Total%
Blantyre	69.5	6.3	24.3	100.0
Lilongwe	59.2	21.0	19.7	100.0
Mzuzu	70.3	17.1	12.6	100.0
Total	66.1	14.7	19.2	100.0

similarly widespread. Approximately 90.5% reported frequent use, and 98.8% reported at least occasional use. This reflects the continued reliance on bottled beverages and limited access to consistent alternative water sources. Table 2 shows that while some respondents report using reusable alternatives, these are often used inconsistently. This suggests that plastic reduction behaviours are situational rather than habitual, influenced by convenience and availability.

4.4 Qualitative insight

The qualitative component sought to explore perceptions, behavioural drivers, institutional constraints, and governance dynamics shaping plastic use and disposal practices in urban Malawi. The findings are presented thematically, with emphasis on convergence and divergence between community level perspective and institution viewpoint.

4.4.1 Awareness of plastic pollution

Participants across the all FGDs demonstrated general awareness of plastic pollution as an environmental problem. Single-use plastics particularly thin carrying bags and sachets were frequently identified as primary contributors to blocked drainage systems and urban litter accumulation. Many respondents associated plastic pollution with visible environmental degradation.

Awareness was largely attributed to radio and television programs, as well as school-based environmental messaging. However, discussions revealed that while participants recognized plastics as problematic, understanding of long-term ecological and health impacts was often limited. Environmental responsibility was frequently framed in terms of personal cleanliness rather than systemic waste management.

These insights align with the quantitative findings indicating high levels of environmental concern but persistent harmful disposal behaviours. The qualitative data suggest that awareness exists at a general level but lacks sufficient depth to drive sustained behavioural transformation in the absence of structure support.

Table 2 Description of plastic use frequency

Practice	Response	Frequency	Percentage
Plastic bag use	Always	651	59.13
	Sometimes	320	29.06
	Often	71	6.45
	Rarely	40	3.63
	Never	19	1.73
Cloth/reusable bag	Always	514	46.68
	Sometimes	352	31.97
	Often	78	7.08
	Rarely	115	10.45
	Never	42	3.81
Plastic bottle use	Always	537	48.77
	Sometimes	314	28.52
	Often	145	13.17
	Rarely	92	8.36
	Never	13	1.18

4.4.2 Driver of plastic use

Affordability and convenience emerged as dominant drivers of plastic use. Market vendors consistently emphasized the economic logic underpinning their reliance on thin plastic bags. Participants highlighted that plastics are inexpensive, readily available, lightweight, and expected by customers.

These statements illustrate the embeddedness of plastic use within informal market systems. Thin plastics function not merely as packaging but as integral components of everyday commercial transactions. In contexts characterized by price sensitivity and thin profit margins, vendors prioritize cost efficiency and customer satisfaction. This dynamic reflects broader informal economy characteristics, where regulatory compliance is strongly influenced by economic feasibility and market availability. The findings suggest that plastic dependence is not solely behavioural but structurally embedded within urban commercial systems.

4.4.3 Waste disposal practices and service delivery constrains

Across all study locations (Mzuzu, Blantyre and Lilongwe city), irregular waste collection services were cited as a primary factor contributing to improper disposal practices, including burning, open dumping, and drainage disposal. Participants described inconsistencies in municipal service delivery and limited availability of public waste bins.

Typical comments from the participants included, "The waste collecting trucks come once in a long time and sometimes months pass, and there are no bins in the market. Where do you expect people to throw the waste?". Such narratives indicate that harmful disposal behaviours are often responses to infrastructural deficiencies rather than deliberate environmental neglect. Participants frequently expressed frustration with limited access to official dumpsites and the long distances required to reach designated disposal areas.

Key informants confirmed institutional limitations affecting waste management systems. Reported challenges included; Limited financial resources, Inadequate collection vehicles and personnel, Weak inter-agency coordination, Insufficient monitoring and enforcement mechanism. A municipal official stated, "The law exists, but enforcement is difficult because we lack resources and manpower."

These findings point to institutional capacity constraints as a central determinant of waste management outcomes. The persistence of open burning and dumping appears closely linked to service delivery gaps rather than purely attitudinal resistance.

4.4.4 Policy awareness, enforcement and government challenges

Awareness of Malawi's thin plastics ban emerged as inconsistent and, in some cases, ambiguous. Several FGD participants questioned whether the ban was still operational, citing the continued widespread availability of thin plastics in markets.

One participant remarked, "If the ban is there, why are plastics still being sold everywhere?". This perception reflects weakened regulatory legitimacy and limited visibility of enforcement efforts. Participants overwhelmingly expressed the view that government action on plastic pollution was insufficient.

Key informants identified multiple challenges from the government including; weak enforcement capacity, political interference in regulatory processes, limited coordination between local councils and central government, absence of strong local by-laws, inconsistent monitoring of manufacturers and distributors.

Stakeholders also emphasized the need for incentive-based approaches, such as recycling buy-back centres, to complement regulatory measures. One civil society representative stated, "Bans alone will not work unless people have affordable alternatives and incentives."

These insights highlight that regulatory framework, while formally established, face implementation challenges rooted in institutional capacity, political dynamics, and market realities.

4.5 Regression analysis on plastic use and disposal behaviour

To examine the socio-demographic factors influencing plastic use and disposal behaviours, three binary logistic regression models were estimated for: (1) likelihood of reducing plastic use, (2) support for a plastic ban, and (3) likelihood of recycling plastic waste. The results are summarised in Table 3.

Table 3 Logistic regression results for plastic use and disposal behaviours

Predictor	Reduce plastic use (OR [95% CI])	Support plastic ban (OR [95% CI])	Recycle plastic (OR [95% CI])
Age (Ref: 18–24)			
25–34	1.88* [1.02, 3.47]	0.87 [0.56, 1.35]	1.97 [0.74, 5.25]
35–44	1.52 [0.80, 2.89]	0.68 [0.44, 1.07]	1.09 [0.37, 3.24]
45–54	1.73 [0.75, 3.99]	0.52* [0.31, 0.87]	1.43 [0.45, 4.55]
55+	1.30 [0.41, 4.12]	0.56 [0.27, 1.14]	0.74 [0.13, 4.33]
Gender (Ref: Female)			
Male	0.95 [0.61, 1.48]	1.12 [0.86, 1.46]	1.48 [0.82, 2.67]
Education (Ref: None)			
Primary	3.01 [0.94, 9.67]	2.12 [0.94, 4.79]	1.32 [0.26, 6.73]
Secondary	3.65** [1.50, 8.85]	1.65 [0.90, 3.03]	0.91 [0.24, 3.41]
Tertiary	2.45 [0.96, 6.25]	2.00* [1.06, 3.77]	0.77 [0.19, 3.08]
Postgraduate	1.37 [0.45, 4.22]	2.48* [1.13, 5.47]	2.00 [0.42, 9.43]
Income (Ref: 100–200 k)			
< 50 k	1.13 [0.47, 2.70]	1.93 [0.98, 3.78]	0.53 [0.15, 1.87]
50–100 k	0.68 [0.31, 1.52]	1.17 [0.68, 2.03]	1.27 [0.49, 3.26]
200 k +	1.03 [0.47, 2.25]	1.04 [0.67, 1.63]	0.60 [0.24, 1.52]
Prefer not to say	1.52 [0.74, 3.14]	0.89 [0.59, 1.34]	0.30** [0.13, 0.72]
City (Ref: Blantyre)			
Lilongwe	0.16*** [0.08, 0.29]	0.85 [0.61, 1.19]	2.73* [1.12, 6.63]
Mzuzu	1.18 [0.48, 2.90]	1.22 [0.82, 1.81]	6.05*** [2.35, 15.57]

Odds Ratios (OR) reported with 95% Confidence Intervals

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***

Reference categories: Age (18–24), Gender (Female), Education (None), Income (100–200 k), City (Blantyre)

"Prefer not to say" (gender) excluded due to small sample size

4.5.1 Likelihood to reduce plastic use

The model predicting the likelihood of reducing plastic use was statistically significant ($p < 0.001$) and demonstrated a moderate explanatory power (Pseudo-$R^2 = 0.14$), indicating a reasonable model fit.

Education emerged as a key predictor. Respondents with secondary education were significantly more likely to reduce plastic use compared to those with no formal education (OR = 3.65, 95% CI [1.50, 8.85], $p < 0.01$). This highlights the role of education in enabling pro-environmental behaviour.

Geographic location had a strong influence. Residents of Lilongwe were significantly less likely to reduce plastic use compared to those in Blantyre (OR = 0.16, 95% CI [0.08, 0.29], $p < 0.001$), suggesting that contextual urban factors—such as infrastructure, availability of alternatives, and consumption patterns—shape behavioural outcomes.

Age showed limited effects, with respondents aged 25–34 more likely to reduce plastic use than those aged 18–24 (OR = 1.88, $p < 0.05$), while other age categories were not statistically significant. Gender and income were also not significant predictors ($p > 0.05$).

Overall, plastic reduction behaviour appears to be influenced more by education and location-specific conditions than by demographic characteristics such as gender or income.

4.5.2 Likelihood to support a plastic ban

The model predicting support for a plastic ban was statistically significant ($p = 0.03$), but explained a relatively small proportion of variance (Pseudo-$R^2 = 0.02$), indicating limited explanatory power.

Education was a significant predictor. Respondents with tertiary (OR = 2.00, 95% CI [1.06, 3.77], $p < 0.05$) and postgraduate education (OR = 2.48, 95% CI [1.13, 5.47], $p < 0.05$) were more likely to support a plastic ban compared to those with no formal education. This reinforces the role of higher education in shaping pro-policy attitudes.

Age showed a negative association among older respondents. Individuals aged 45–54 were significantly less likely to support a plastic ban compared to those aged 18–24 (OR = 0.52, 95% CI [0.31, 0.87], $p < 0.05$), suggesting generational differences in environmental attitudes. Other variables, including gender, income, and city, were not statistically significant predictors. These findings indicate that support for regulatory measures is primarily shaped by education and generational factors rather than economic or geographic differences.

4.5.3 Likelihood to recycle plastic waste

The regression model for recycling behaviour was statistically significant ($p = 0.01$) and explained a moderate proportion of variance (Pseudo-$R^2 = 0.08$).

City of residence was the strongest predictor. Respondents in Lilongwe (OR = 2.73, 95% CI [1.12, 6.63], $p < 0.05$) and Mzuzu (OR = 6.05, 95% CI [2.35, 15.57], $p < 0.001$) were significantly more likely to recycle compared to those in Blantyre. This suggests that recycling behaviour is strongly shaped by local infrastructure, service availability, and urban systems.

Income also showed a significant effect. Respondents who preferred not to disclose their income were less likely to recycle (OR = 0.30, 95% CI [0.13, 0.72], $p < 0.01$), potentially reflecting socio-economic uncertainty or disengagement from formal waste systems.

In contrast, age, gender, and education were not significant predictors.

Overall, recycling behaviour appears to be driven more by structural and contextual factors than by individual socio-demographic characteristics.

The logistic regression models showed varying levels of explanatory power. The model predicting reduction in plastic use demonstrated moderate explanatory capacity (Pseudo-$R^2 = 0.14$, $p < 0.001$), while the recycling model showed modest explanatory power (Pseudo-$R^2 = 0.08$, $p = 0.01$). In contrast, the model predicting support for a plastic ban had limited explanatory power (Pseudo-$R^2 = 0.02$, $p = 0.03$), indicating that additional unobserved factors may influence policy support.

5 Discussion

5.1 Persistence of plastic waste accumulation in urban systems

The consistently high plastic waste loads observed across sites, cities, and sampling rounds indicate sustained accumulation within the study period rather than short-term or episodic fluctuations. While the absence of significant temporal variation suggests stability over the sampling window, caution is required in characterizing this pattern as "chronic" in the absence of longitudinal evidence. Instead, the findings point to a persistent imbalance between waste generation and removal capacity, a condition widely reported in rapidly urbanising cities across Sub-Saharan Africa [44, 48].

The lack of statistically significant variation across cities and site types further suggests that plastic pollution is systemically distributed rather than spatially isolated. This indicates that underlying drivers such as consumption patterns, waste collection inefficiencies, and infrastructure deficits are broadly similar across urban contexts in Malawi. Comparable patterns have been documented in cities such as Accra, Kampala, and Lusaka, where waste accumulation reflects shared structural constraints rather than localized anomalies [1]. At the same time, the coexistence of localized high-accumulation sites (hotspots) with statistically comparable city-level averages indicates that plastic waste is heterogeneous at micro-scales but structurally consistent at broader scales. This reinforces the need for interventions that address systemic inefficiencies while also targeting high-risk locations.

5.2 Dominance of single-use plastics

The predominance of plastic bags and sachets (77% of observed waste) underscores the continued reliance on low-cost, single-use packaging within urban consumption systems. Despite Malawi's 2015 ban on thin plastics, the persistence of these materials suggests implementation constraints rather than policy absence. Similar outcomes have been reported across Sub-Saharan Africa, where plastic bans have achieved mixed results due to enforcement challenges and market dynamics [47].

These findings indicate that regulatory measures alone are insufficient in the absence of supporting systems. The continued circulation of banned plastics reflects gaps in enforcement, availability of alternatives, and monitoring of supply chains. This dynamic

also contributes to the observed disconnect between high public awareness and persistent environmental outcomes, highlighting the importance of aligning policy instruments with institutional capacity and market realities.

5.3 The awareness-behavioural gap

Despite high levels of awareness and concern about plastic pollution, behavioural change remains limited. This disconnect reflects the well-established attitude–behaviour gap in environmental research [21, 23]. While respondents expressed strong concern, this did not consistently translate into reduced plastic use or improved disposal practices. This pattern can be interpreted through the Theory of Planned Behaviour, which posits that behaviour is shaped not only by attitudes but also by perceived behavioural control and social norms [3] In this study, constraints such as affordability, convenience, and limited access to alternatives appear to limit individuals' capacity to act on pro-environmental intentions.

Qualitative findings reinforce this interpretation, showing that plastic use is embedded in everyday economic practices, particularly within informal markets. Similar patterns have been observed in other Global South contexts, where structural constraints limit the effectiveness of awareness-based interventions [6, 34].

5.4 Structural versus social-demographic drivers

The regression analysis indicates that education is associated with increased likelihood of reducing plastic use and supporting regulatory measures, suggesting that knowledge contributes to pro-environmental intentions [17]. However, education did not significantly predict recycling behaviour, and variables such as gender and income were largely insignificant.

In contrast, location (city of residence) emerged as a stronger predictor, particularly for recycling behaviour. This finding highlights the importance of contextual and structural factors, including infrastructure availability, service delivery systems, and local governance. Similar evidence from other developing urban contexts suggests that waste-related behaviours are more strongly influenced by access and opportunity than by individual characteristics [20, 52].

5.5 Governance and implementation constraints

The study identifies a gap between the existence of plastic waste policies and their implementation. While regulatory frameworks such as plastic bans are in place, awareness of these policies remains limited, and enforcement is inconsistent. These findings point to implementation constraints, including limited institutional capacity, resource shortages, and weak coordination [44, 47]. The continued availability of restricted plastic products in markets reflects challenges related to regulatory enforcement and credibility. The finding that a majority of respondents (66.1%) perceive government efforts as insufficient further suggests broader concerns regarding institutional effectiveness. Qualitative insights highlight issues including weak enforcement, limited resources, and coordination challenges between local and national authorities. Similar patterns have been documented across Global South cities [40].

At the same time, the distribution of responsibility across individuals, government, and producers indicates openness to multi-stakeholder governance approaches, consistent with collaborative governance frameworks [5]. In this context, Extended Producer Responsibility (EPR) represents a relevant policy mechanism. By shifting responsibility upstream to producers, EPR can contribute to reducing plastic leakage and financing waste management systems. However, its effectiveness will depend on regulatory enforcement, monitoring capacity, and integration with existing informal sector practices.

5.6 Recycling infrastructure as a system constraint

Limited access to recycling facilities (20%) represents a critical bottleneck in the waste management system. The high proportion of respondents uncertain about the existence of such facilities (42%) further indicates low visibility and accessibility of recycling pathways. These findings suggest that low recycling rates are primarily structural rather than behavioural, reflecting gaps in collection, sorting, and processing systems [44]. From a circular economy perspective, plastic waste management in Malawi is therefore constrained by systemic limitations rather than individual behaviour alone. Without accessible and functional recycling systems, behaviour change initiatives are unlikely to produce substantial improvements in waste outcomes.

5.7 Policy implications

The findings highlight the need for targeted and context-specific interventions: Strengthening waste collection systems through expanded coverage and improved service reliability, particularly in high-density urban areas [20], Introducing economic instruments, including recycling incentives and subsidies for reusable alternatives, to address affordability constraints [6], Enhancing policy communication and enforcement to ensure that existing regulations are visible, credible, and consistently applied [48], and Implementing Extended Producer Responsibility (EPR) schemes to shift responsibility to producers and support financing of waste management systems [35]. Effective implementation will require coordination between local governments, national authorities, and private sector actors.

5.8 Integration of mixed-methods evidence

A key strength of this study lies in the integration of quantitative and qualitative data. Survey results identified high awareness alongside limited behavioural change, while qualitative findings provided insight into the structural and institutional constraints shaping these outcomes. This triangulation demonstrates that plastic waste dynamics are influenced by the interaction of behavioural, economic, and governance factors, reinforcing the value of mixed-methods approaches in environmental research [10].

Overall, the findings indicate that plastic pollution in Malawi's major cities arises from a combination of behavioural, economic, infrastructural, and regulatory factors. While awareness is high, structural constraints including inadequate waste collection, limited recycling infrastructure, and weak enforcement significantly limit effective waste management. Addressing plastic pollution will therefore require not only behavioural change

but also system-level reforms that improve infrastructure, strengthen governance, and align policy with local socio-economic realities.

6 Conclusion

This study demonstrates that plastic pollution in Malawi's major cities is substantial and systemically distributed. A total of 27,574 plastic items (173.41 kg) were recorded across 30 sites, with single-use plastics (77% bags and sachets) dominating the waste stream. Despite visible hotspots, there were no statistically significant differences across cities or site types, indicating that plastic pollution is driven by shared structural conditions rather than location-specific factors. A clear awareness–behaviour gap was observed. While awareness and concern were high (97.7% awareness; > 90% perceive seriousness), plastic use remained widespread (94.6%) and recycling low (4.5%). With only 20.1% reporting access to recycling facilities, the findings suggest that low recycling rates are primarily infrastructure-driven, although limited demand may also contribute. These results indicate that plastic pollution is shaped by interacting behavioural, economic, and institutional constraints rather than individual attitudes alone. Targeted interventions should prioritise: (1) market-based plastic reduction strategies in high-accumulation areas; (2) decentralised recycling systems to improve access and visibility; and (3) strengthened enforcement and producer responsibility mechanisms across supply chains. The cross-sectional design limits long-term inference. Our future work will explore adoption of longitudinal and spatial approaches. Overall, effective plastic waste management in Malawi requires a shift from awareness-based approaches toward coordinated, system-level interventions.

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Author contributions
GG: conceptualization, methodology, data collection, formal analysis, writing and original draft preparation. KM, HWTM: supervision, methodology support, statistical analysis guidance, and critical review of the manuscript.

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Data availability
The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study involving human participants was reviewed and approved by the Malawi University of Business and Applied Sciences (MUBAS) Research Ethics Committee. All procedures performed in this study were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants prior to their inclusion in the study. Participation was voluntary, and respondents were informed of their right to withdraw at any time without penalty. Confidentiality and anonymity were strictly maintained. Minors (individuals below 18 years of age) were not included, only individuals aged 18 years and above were included in the study to ensure their capacity to provide informed consent and independent perspectives.

Consent for publication
Not applicable. The manuscript does not contain any individual person's data in any form (including images, videos, or personal identifiers.

Competing interests
The authors declare no competing interests.

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