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Risk-Based Identification and Prioritisation of Plastic Waste Hotspots in Malawi Using a Transferable Decision Framework

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Abstract

Plastic waste presents a significant environmental and public health concern in Malawi, where rapid urban growth, limited waste collection services, and informal disposal practices contribute to persistent plastic waste hotspots. In Lilongwe City, the waste collection rate has been reported ranges from 10% to 30%. This means that out of the 500 to 600 tons of municipal solid waste produced each day, only about 50 to 150 tons are collected daily. These hotspots occur in settings such as drains, markets, settlement edges, riverbanks, and lakeshore environments. They intensify health-relevant exposure pathways by encouraging stagnant water, increasing flood risk, facilitating open burning, and supporting the formation of plastisphere biofilms that can contain pathogenic and antimicrobial resistant organisms. This research synthesises evidence on the main sources of plastic waste in Malawi, the mechanisms of leakage across different environments, and the associated health implications. It uses a scoping approach aligned with PRISMA-ScR guidance and is informed by the UK Research and Innovation (UKRI) funded Sustainable Plastic Attitudes to benefit Communities and their Environments (SPACES project), which highlights the influence of behavioural, governance, and environmental factors on plastic pollution. A two phase, risk-based decision framework to support targeted management of plastic waste hotspots is described. Phase 1 focuses on rapid harm reduction through the identification and ranking of hotspots according to risk severity, spatial extent, and feasibility, guiding timely interventions such as drain clearance, waste capture, and temporary stabilisation. Phase 2 addresses longer term prevention by tackling upstream drivers through policy measures, improved services, reuse and reduction schemes, and community engagement. The framework has been developed using evidence from Malawi; however, its methodology could be applied to other low- and middle-income countries that experience similar constraints and exposure pathways. The framework offers a transparent and practical tool for decision makers seeking to allocate limited resources effectively while reducing environmental and health risks associated with plastic waste.

Keywords: plastic waste; hotspot prioritisation; decision framework; risk assessment; low- and middle-income countries

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1. Introduction

Plastics are widely used because they are relatively inexpensive, lightweight, strong, and durable, enabling their application across a broad range of products and sectors with substantial societal benefit [1]. However, despite the benefits of plastics, unmanaged plastic waste is widely considered a major public health and environmental issue [2]. Malawi

provides a clear example where the plastic litter can accumulate across terrestrial and freshwater environments, including streets, drainage channels, rivers, and lake shorelines. These pressures are intensified by rapid urban growth, which can outpace waste collection capacity [3,4]. This situation is consistent with the plastic waste management framework, a white paper prepared by Roland Berger for the Alliance to End Plastic Waste, which classifies Malawi as a Category 1 "undeveloped system", indicating limited waste management regulation, infrastructure, and institutional capacity [5]. In Malawi's largest cities, solid waste services capture only a minority of generated waste; for example, reports for Lilongwe indicate that roughly 10–30% is collected, while approximately 500–600 tons per day are generated [6].

This research focuses on Malawi because it represents conditions shared across many low- and middle-income countries (LMIC): rapid urbanisation, limited waste collection coverage, and strong connection between streets, drains, rivers, and major freshwater bodies. These combined features can amplify exposure pathways (flooding, stagnant water, burning emissions) in ways that are not unique to Malawi. The hotspot approach and decision framework presented here could therefore be applied beyond Malawi to comparable settings. However, the framework is not meant to be used elsewhere without adaptation. Instead, Malawi is the main case study used to develop the hotspot and decision-support approach. Some parts may be relevant to similar settings, but any use in other places would need to be adjusted to local governance, infrastructure, environmental conditions, and waste management systems. Table 1 shows the Malawi-specific elements of the framework that may be adapted for use in compatible settings.

Table 1. Framework elements that are Malawi-specific and those that are transferable with local adaptation to comparable settings.

Variable	What It Means	Malawi-Specific Aspect	Transferable
Governance and enforcement capacity	The strength of institutions, regulation, and practical enforcement affecting plastic waste control	Role of MEPA, legal history of the plastic bag ban, and enforcement realities in Malawi	In any setting, governance and enforcement need to be assessed
Waste service capacity	How well the system can collect, clear, transport, and manage waste	Low collection coverage, service limitations, drain maintenance gaps, and city council resource constraints in Malawian cities	Interventions should match local service capacity and resources
Main leakage sources	The main sources of plastic entering the environment	Plastic bags, packaging, agrochemical containers, fishing gear, and tourism-related litter in Malawi	The same approach can be used to identify key waste sources elsewhere, but dominant plastic types and sectors will differ by place.
Environmental pathways	How waste moves from where it is produced to where it builds up	Strong links between streets, drains, rivers, flood pathways, and Lake Malawi	The same source-to-hotspot logic can be used in other places
Risk severity	How much waste builds up, how long it stays, and how risky it is	Particular hotspot conditions observed in Malawi's urban, riverine, and lakeshore environments	Hotspots can be identified and ranked elsewhere using accumulation, persistence, and exposure indicators
Exposure pathway	The ways waste may affect health, livelihoods, or ecosystems	Blocked drains, stagnant water, flooding, open burning, and local livelihood impacts in Malawi	The same principle can be used to assess local risks elsewhere

Table 1. *Cont.*

Variable	What It Means	Malawi-Specific Aspect	Transferable
Intervention feasibility	How practical and sustainable an intervention is under real local conditions	Feasibility shaped by Malawian institutions, access conditions, seasonal flooding, markets, and maintenance capacity	Can be used to compare options under local technical, financial, and governance limits
Prevention potential	How far upstream action can reduce future hotspot formation	Malawi-specific policy levers, stakeholder roles, and behaviour change opportunities	Cleanup should be combined with prevention and system improvement in any setting

Note: Transferability refers to comparable low- and middle-income country settings and requires adaptation to local governance, infrastructure, environmental conditions, and waste management systems.

The framework is not intended for direct transplantation to other settings. Its transferability depends on local adaptation and is most relevant where broadly comparable conditions exist, including limited waste collection systems, informal disposal practices, strong interactions between drainage and waste accumulation, open burning, and constrained governance or enforcement capacity. Even in such settings, the framework should be adapted to local institutions, infrastructure, environmental conditions, and waste management practices.

A national level overview of plastics in Malawi highlights the extensive use of thin plastic bags and plastic packaging across retail and households, underscoring how prominently plastics feature in the country's waste stream [7]. Beyond urban centres, plastic waste in Malawi is also associated with rural livelihoods and local economies. In agricultural areas, common sources include fertiliser and pesticide containers, especially empty pesticide containers including agrochemical packaging [8,9]. Additional agricultural plastics also result from routine practices, including plastic-based storage technologies (e.g., hermetic grain storage bags) and plastic sheeting used in crop management. These materials may add to rural plastic waste, particularly where waste collection and safe disposal options are limited [10,11].

In Malawi's inland waters, fishing activity can be a source of plastic pollution through lost or discarded fishing nets and gear [3,12]. Tourism may further increase waste generation at popular destinations, where shoreline surveys report common litter items linked to packaged food and drink (e.g., packaging materials, food wrappers, beverage bottles), and local evidence indicates that waste dumping is associated with tourism activity [3,13].

Plastic debris is mobilised, redistributed, and physically transformed by environmental processes and waste disposal practices. High-intensity rainfall and floods can carry plastics from urban areas through river networks and discharge them into Lake Malawi, spreading debris far from its original source. In some urban areas, accumulated waste is managed through open burning [14].

While this method can reduce the volume of visible litter in the immediate vicinity, it may also generate hazardous air emissions. Taken together, these processes can lead to the formation of "waste hotspots": distinct localities where waste concentrates at disproportionate levels, remains in place for long duration, and creates elevated risks for public health, livelihoods, and surrounding ecosystems.

The health relevance of plastic waste hotspots is multi-pathway rather than a single cause. Plastic waste should be understood primarily as a potential modifier of exposure environments rather than a primary disease driver, with current evidence suggesting that plastics may influence conditions that shape health risk rather than directly determine disease outcomes [15]. Where plastic litter accumulates in streets, informal dumps, and

critical drainage systems, it may worsen exposure conditions by promoting stagnant, contaminated water and reducing the ability of stormwater networks to flush waste away.

Malawi's National Waste Management Strategy (2019–2023) makes the linkage explicit: it states that accumulated waste and blocked drains can encourage vector breeding, contribute to infectious-disease-relevant exposure conditions (including those associated with malaria and cholera), and are a major contributing factor to flooding, while uncontrolled burning may produce harmful emissions [16]. Beyond drains, plastic items that trap water (e.g., bags, containers, and other litter) may also create persistent micro-habitats for mosquitoes, under certain conditions, potentially increasing opportunities for vector breeding where competent vectors and pathogens are present [17].

Recently, several studies, including research linked to the UK Research and Innovation (UKRI)—Sustainable Plastic Attitudes to benefit Communities and their Environments (SPACES) project have examined the impacts of plastic pollution on human health, including its possible role as a potential environmental reservoir for microbes of public health relevance.

Microbial communities, including potential human pathogens, can rapidly colonise plastic debris in natural environments. For example, plastisphere biofilms have been reported to harbour wastewater-associated pathogenic bacteria in surface waters, as well as human-pathogenic, fluconazole-resistant yeasts on beach plastics [18,19]. Studies have shown that pathogenic yeasts associated with plastic waste in aquatic habitats can be thermotolerant (capable of growth at human body temperature), exhibit virulence in infection models, and display resistance to at least one antifungal drug [20].

In addition, urban waste piles in Malawi have been shown to contain multiple pathogenic bacteria, indicating that such sites may represent pathogen-relevant waste environments [21]. These health linkages should be interpreted cautiously, because the current evidence base is stronger for indirect exposure conditions and plausible environmental pathways than for direct causal attribution of specific health outcomes to plastic accumulation itself.

Despite growing attention to plastics and municipal waste in Malawi, and despite the lifting of the injunction allowing MEPA to enforce the plastic bag ban, a practical decision gap remains. Under severe resource constraints, decision makers must still identify which hotspots to prioritise and which intervention packages are most feasible in local conditions. This requires a coordinated approach that takes account of service limitations, governance realities, exposure pathways, and the risk of recurrence. More broadly, evidence from Malawian cities highlights that available waste services are not sufficient to accommodate all residents, largely due to rapid urban population growth [4].

Because relevant evidence spans academic studies and grey literature across public health, waste systems, and environmental pathways, a scoping review is appropriate to map sources, leakage mechanisms, and intervention options; these findings are then structured into a practical prioritisation framework to support decision making under resource constraints. This research responds to that decision gap by proposing a risk-based assessment and decision framework designed to support targeted waste management in Malawi. The framework responds to two connected priorities. First, in the short term, it focuses on reducing harm at existing pollution hotspots through rapid measures targeting removal, containment, and treatment selected in line with local risk. Second, over the longer term, the focus is to stop hotspots from returning through addressing the sources of plastic waste leakage and how it occurs. That means using policy and economic levers, improving collection and treatment services, working with producers and retailers, and supporting sustained, community-based behaviour change. Accordingly, the framework is structured in two phases:

Phase 1 focuses on plastic removal and risk reduction through first identifying high-risk waste hotspots, then characterising the main waste types and exposure pathways, and finally selecting feasible management strategies using a decision matrix that is sensitive to local conditions.

Phase 2 focuses on mitigation and prevention; it maps the main sources of leakage and who is responsible; puts in place policy, systems, and incentives to prevent future releases; and builds in education and community participation so improvements are sustained.

2. Methods and Framework Development Approach (Plastic-Focused)

2.1. Review Design and Aims

This paper takes a scoping, narrative approach to synthesising the available evidence, and based on this, proposes an evidence-informed two-phase risk-based decision framework that supports Malawi plastic waste hotspot management strategies. Rather than producing a single pooled effect size, the paper focuses on four aims:

1. Identifying the main sources of plastic pollution and the leakage pathways most relevant to Malawi;
2. Synthesising evidence on health-related exposure routes and infection risks associated with hotspot areas;
3. Outlining the policy and implementation factors that determine what is practical;
4. Using these insights to develop a risk-based decision framework for prioritising hotspots and selecting interventions that fit local contexts.

The framework concept was developed in the context of the SPACES project; however, the specific decision variables and scoring criteria were derived from the evidence identified in this review. The review was informed by PRISMA-ScR guidance, which focuses on mapping the available evidence, clarifying key concepts, and highlighting gaps in what is currently known [22].

2.2. Search Strategy and Information Sources

The search strategy was designed to capture both peer-reviewed studies and relevant grey literature. Google Scholar, PubMed, and ScienceDirect were searched for academic literature. Google Scholar was used to capture broad interdisciplinary literature and citation-linked sources, while PubMed and ScienceDirect were used to improve coverage of public health and environmental studies relevant to plastic waste, exposure pathways, and hotspot risks. Searches combined Malawi-related location terms with topic terms linked to plastics, waste pathways, health relevance, and governance. Example search combinations included “Malawi plastic waste”, “drain blockage plastic flooding”, “Lake Malawi plastic debris”, “open burning plastic health”, “plastic regulations Malawi”, and “waste strategy Malawi”. Targeted searches were also carried out for specific hotspot settings (e.g., markets, riverbanks, and lakeshores) and key mechanisms (e.g., flood transport, open burning, and infection-relevant pathways). Backward reference searching was used to identify additional relevant sources. The final structured search was completed on 25 January 2026. Grey literature was included deliberately because feasibility constraints such as finance, enforcement, access, and maintenance capacity are often reported in planning documents rather than academic papers (Appendix A, Table A1). No publication year restrictions were applied because Malawi-relevant evidence spans older legal and policy materials as well as more recent empirical studies.

2.3. Screening and Study Selection

Screening was completed in two stages (title/abstract followed by full text) using Mendeley for reference management. Sources were included if they were relevant to

Malawi or clearly transferable to the Malawi context, focused on plastic waste or waste pathways, and provided enough conceptual, empirical, policy, or operational detail to support hotspot assessment or framework development. Sources were excluded if they were duplicates, not Malawi-relevant and not transferable, not focused on plastics or waste pathways, or did not provide enough operational detail to support hotspot assessment. Two reviewers made the full-text inclusion decisions, and any disagreements were resolved through discussion until consensus was reached. The PRISMA-ScR flow diagram and reasons for full-text exclusion are provided in Appendix A, Figure A1.

The search process resulted in 75 potentially relevant records being saved in Mendeley for screening. After removal of 3 duplicates, 72 records were assessed for eligibility. Following full-text review and relevance assessment, 64 sources met the inclusion criteria and were included in the final synthesis and framework development. The included sources comprised 38 peer-reviewed journal articles, 17 reports/strategy or policy/legal documents, and 9 web/online sources. Sources were excluded primarily because they were not Malawi-relevant, were not focused on plastics or waste pathways, or did not provide sufficient operational detail to inform hotspot assessment.

2.4. Evidence Charting and Synthesis

Evidence identification occurred in two stages. First, exploratory searching to support development of the initial mind map and to identify key concepts and hotspot settings was conducted from January 2025 onward. Second, a more structured evidence search to assemble the scoping evidence base for the framework was conducted in January 2026.

The included sources were organised by both source type and thematic relevance. To support consistency in interpretation, the same source-type and thematic grouping approach was applied across all included materials. Borderline cases or uncertainties in how evidence should be interpreted or grouped were discussed between the reviewers until a shared interpretation was reached, and the agreed thematic categories were then used consistently to organise narrative synthesis and framework development. Evidence charting was conducted manually. No formal qualitative analysis software was used. Instead, the included sources were reviewed and grouped by source type and by recurring thematic relevance to framework development. Source types comprised peer-reviewed journal articles, policy and legal documents, strategy and institutional reports, and relevant web-based materials. For synthesis, the evidence was grouped into three broad thematic categories: (1) plastic sources and leakage pathways; (2) health-related exposure pathways and hotspot risks; and (3) policy, governance, and implementation constraints affecting intervention feasibility. These themes were then used to organise the narrative synthesis and to support development of the decision framework. Unless otherwise stated, place-based examples, operational constraints, and hotspot settings discussed in this paper are drawn from Malawi-specific evidence, while wider literature is used primarily to support general framework logic and emerging mechanisms.

2.5. Framework Development and Decision Variables

Decision variables for the hotspot prioritisation framework were developed in stages to ensure that the pathway from sources to final criteria was clear and repeatable.

Candidate variables were generated using two main inputs: (i) an initial thematic mapping exercise (mind map Figure 1), which was used to organise key issues and practical considerations relevant to the hotspot decision making in the context of the SPACES project [23]; and (ii) the scoping review evidence base, including peer-reviewed studies and Malawi-relevant policy and planning documents, which provided the empirical and operational basis for defining pathways and feasibility constraints. Candidate variables

were then reviewed and refined by removing overlaps, combining similar ideas, and grouping the remaining variables into three blocks: risk severity, extent, and feasibility.

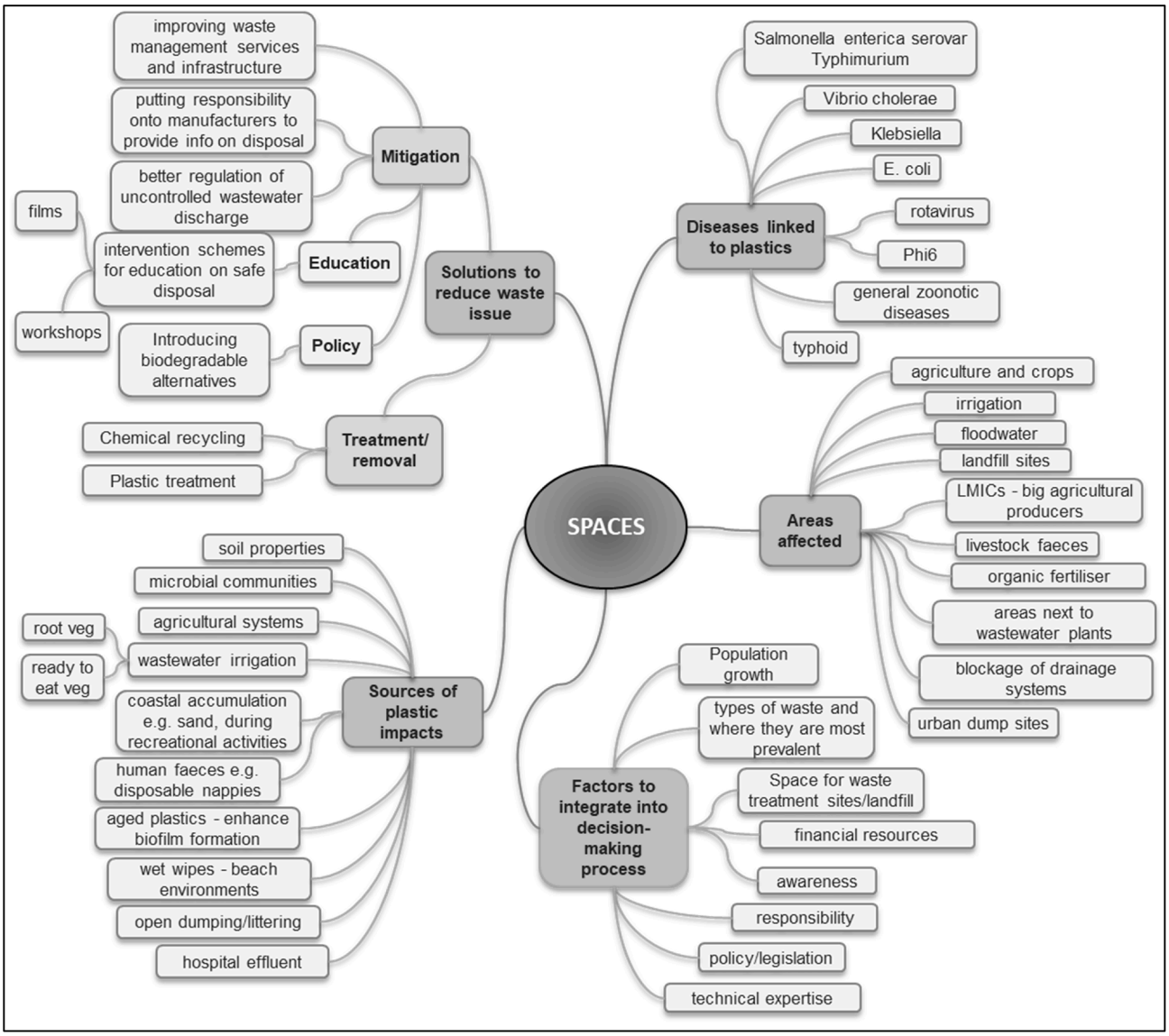


Figure 1. Literature-informed thematic mind map used to derive assessment variables and health-relevant pathways for the Malawi plastic hotspot framework.

In the present framework, feasibility also reflects real-world governance and policy conditions, including coordination capacity, enforcement realism, and the existence of workable operational and institutional pathways for implementation.

The three-part structure was used to distinguish between the seriousness of hotspot-related harms (risk severity), the scale or persistence of the hotspot (extent), and the practical realism of intervention under local operational constraints (feasibility). Each variable was scored on a 1–5 scale, supported by a short evidence-based justification and confidence tag, with lower scores used where evidence was more limited or borderline.

Some candidate variables were conceptually close to each other during framework development. To reduce redundancy and the risk of double counting, closely related variables were reviewed, combined, or separated according to whether they reflected risk severity, extent, or feasibility. The final set was retained because each variable was intended to capture a different aspect of hotspot priority or intervention selection, although limited

overlap may still remain because plastic hotspot systems are inherently multidimensional. This will be revisited in future calibration and validation work.

Variables were retained if they were supported by the reviewed literature and were useful for hotspot prioritisation and intervention selection in Malawi. The final set of variables was chosen to provide a clear and practical framework for decision making in data-limited settings.

Similar studies in other countries, Nigeria for example, have also highlighted the impact of plastic contamination in low-income areas. Notably, the study by Chilote and Dhakal [24] presented an empirical study centred on awareness, stakeholder perceptions, and the potential for a deposit return scheme in Nigeria. They also proposed a framework for implementing waste collection services in Nigeria; however, the study is much narrower in scope and does not include a comprehensive risk assessment. Their findings add to the growing body of evidence suggesting the long-term health implications of plastic contamination, especially in poor urban and peri-urban areas.

The framework was informed not only by Malawi specific evidence, but also by relevant approaches developed in other contexts. In particular, it draws on guidance for plastic pollution hotspotting at country, regional, and city scales [25]; on approaches for removing legacy plastics from aquatic environments such as rivers, estuaries, harbours, and coastlines [26]; and on broader multi-criteria decision approaches for marine and terrestrial plastic waste management [27]. The framework proposed here adapts this broader logic into a practical Malawi-specific tool for hotspot prioritisation and intervention selection [25–27].

The novelty of the present framework is that it combines hotspot identification, public-health-relevant risk severity, spatial extent, and implementation feasibility within a single two-phase decision structure tailored to the Malawi context.

At this stage, the framework is evidence-informed and conceptually developed. It has not yet undergone pilot application, field testing, expert elicitation, stakeholder validation, or formal operational calibration, and these should be priorities for future research.

3. Plastic Pollution in Malawi: Sources, Leakage Pathways, and Hotspot Settings

3.1. Urban and Peri-Urban Consumption and Retail Packaging, Service Gaps, Agriculture, Irrigation, and Food Systems

A "plastic waste hotspot" refers to any place where plastic debris, or mixed waste that includes plastics, builds up and remains over time—for example, drains, dumpsites, market areas, rivers and streams, or lakeshores. Such sites can intensify exposure by concentrating pathways such as flood-driven redistribution, the creation of stagnant water, and open burning, and they can also increase the transfer of pollution to downstream environments.

Plastic pollution in Malawi arises from different sectors, and the main sources vary with geography and local activity patterns, including but not limited to urban and peri-urban consumption and retail packaging. In Malawi's main urban centres and peri-urban commercial corridors, consumer-related plastics, particularly thin carrier bags, wrappers, sachets, other lightweight packaging, and PET bottles, constitute a persistent component of the visible litter stream. In the public markets of Blantyre, solid waste is usually dealt with as a mix of refuse, operating within a combined formal and informal system. This method raises the risk of lighter packaging plastics from busy trading areas being scattered widely throughout the surrounding environment [28].

A composting-focused study from Blantyre provides further evidence that waste collected from markets is often highly contaminated with plastics, particularly bags and bottles, so it must be manually sorted out, increasing both labour time and operating costs.

This highlights how retail packaging becomes integrated into routine municipal waste handling, rather than remaining an easily separable fraction for recycling [29].

At the neighbourhood scale, a year-long field analysis in a densely populated informal settlement in Malawi highlights urban waste piles as health-relevant hotspots and notes that common urban plastic items (including sachets and bags) are present within waste accumulations and can contribute to the blockage of drains and sewage channels in poorly serviced areas [21]. Recent studies in Malawi highlight the extensive sale of sachet water in polyethylene packets, particularly in bustling market areas. This reveals a common consumer trend that contributes to the increasing presence of flexible plastics in urban environments [30].

Service gaps significantly contribute to the issue of plastic waste, leading to materials being discarded into streets and drainage systems. The Lilongwe Sanitation and Drainage Improvement Strategy states directly that poor solid waste collection efficiency worsens sanitation conditions and impedes drainage and flood management, and it frames improvements in solid waste management and urban drainage as measures that will improve public health and living conditions. The same document reports that Lilongwe's waste collection efficiency is only ~10–30% and notes that gaps in wastewater/faecal sludge management and solid waste disposal are intrinsically linked to urban drainage, reinforcing that waste and drainage must be treated as operationally connected systems [6]. Evidence from Blantyre also suggests that service gaps can shift plastics into drainage and water systems, reinforcing flood- and health-relevant hotspot formation [28].

A further pathway involves agriculture, irrigation, and food systems. In rural and peri-urban Malawi, plastics can enter the environment through agricultural supply chains and on-farm practices, particularly via agrochemical packaging and containers. Reviews of pesticide management in Malawi report substantial quantities of pesticide-related waste and highlight that empty pesticide containers may be improperly discarded or re-used within households, creating direct routes for plastic leakage and associated risks of chemical exposure [31]. Food production systems can also connect to health-relevant exposure pathways through irrigation of water and fresh produce. Evidence from Blantyre indicates that urban and peri-urban farmers increasingly rely on treated and untreated wastewater for vegetable cultivation, including irrigation using effluent from the Soche Wastewater Treatment Plant. The same study identifies wastewater irrigation as a mechanism by which contaminants may be transferred to soils and edible crops, thereby raising potential public health concerns [32]. This matters for targeted management because Malawi's livelihoods and exposure contexts differ sharply between urban consumers and rural producers: rural welfare and employment remain closely tied to smallholder farming, and dry-season irrigated farming is increasing in some areas [33], meaning agricultural communities may face plastic-related risks through field soils, on-farm wastes (containers/films), and irrigation-linked food pathways, not only street litter and drains.

Fisheries, shoreline activities, and recreational use represent important pathways for plastic waste. Lakeshore environments in Malawi may receive plastic litter both from local shoreline sources and from upstream transport through connected catchments. Along the Malawian margins of Lake Malawi, towns and beach sites associated with tourism, commerce and markets, transport hubs, and fisheries generate plastic waste locally through routine consumption and shore-based disposal practices [3]. At the same time, Lake Malawi is hydrologically linked to surrounding settlements via rivers, streams, and stormwater systems, providing a credible route by which land-based plastics generated inland or in urban areas can be transported and deposited along the shoreline. This dual-source interpretation is consistent with the largest published multi-year shoreline clean-up dataset for Lake Malawi: during annual clean-ups conducted between 2015 and 2018, volunteers

recorded almost 500,000 litter items, approximately 80% of which were plastics (with plastic carrier bags the most frequently collected item). These findings suggest that lakeshore environments function as persistent zones of plastic accumulation rather than being shaped by sporadic, isolated littering events (ibid).

Evidence from Blantyre further supports the role of rainfall, drainage channels, and river corridors in mobilising mismanaged plastics downstream [34–36]. More broadly, rivers and urban drains are widely recognised as major transport pathways for plastics from land into receiving waters, supporting the inclusion of hydrology and storm events in hotspot risk scoring [37].

3.2. Healthcare- and Wastewater-Adjacent Sources

For plastic-focused hotspot management, the most relevant health pathways can be grouped into:

1. Waterborne or enteric exposure, which occur through contact with contaminated water or floodwater in waste-affected environments [16,38];
2. Vector-borne risk conditions such as those caused by standing water and blocked drainage [6,16];
3. Airborne hazards from open burning, including smoke and toxic emissions [16];
4. Emerging "plastisphere" pathways where plastics may act as potential microbial substrates or retention surfaces within contaminated environments under certain conditions [39,40]. Infection-relevant organisms have been documented in Malawi water and wastewater contexts, and wider plastisphere evidence suggests plausible environmental health relevance; however, this does not in itself demonstrate that plastics directly cause human infection or disease [30,39–41]. The scale of Malawi's recent cholera emergency strengthens the rationale for infection-focused hotspot prioritisation. The WHO reported that from 3 March 2022 to 3 February 2023, Malawi recorded 36,943 cases and 1210 deaths across all 29 districts, describing it as the country's deadliest cholera outbreak and noting that it persisted beyond the typical rainy season pattern [42]. Cholera transmission is fundamentally driven by ingestion of contaminated food or water and is closely tied to access to safe water, sanitation, and hygiene [43].

In Malawi, wastewater infrastructure and sewage-impacted waterways may represent a distinct hotspot context because they can concentrate high microbial loads and receive mixed inputs (domestic sewage, industrial effluent, stormwater, and in some cases hospital-linked flows). In Blantyre, for example, the Soche wastewater treatment works serves the Queen Elizabeth Central Hospital (QECH) and is also a major reception point for latrine and septic tank emptying, illustrating how healthcare-associated and faecal wastes can enter municipal systems [44]. In addition, studies at the Soche WWTP report that treated effluent is used for irrigation in nearby gardens, highlighting a wastewater–food interface where environmental exposure pathways may extend beyond the treatment plant boundary [32].

Recent Malawi field evidence suggests that wastewater-adjacent surface waters can be pathogen-relevant: environmental surveillance in Blantyre's wastewater-contaminated rivers and ditches (linked to an informal sewage network) detected Salmonella Typhi presence across the year, demonstrating that sewage-impacted drainage/rivers may function as persistent microbial risk environments [41]. While Malawi-specific measurements of microplastics in wastewater and hospital effluent remain limited in the published literature, international wastewater research indicates that plastics in wastewater can develop biofilm "plastispheres" that contain potentially pathogenic bacteria and viruses, and that these organisms may persist through treatment and enter receiving waters or reuse pathways if controls are weak [40]. These findings suggest that plastics may contribute to environmen-

tally persistent exposure conditions, but they do not in themselves demonstrate a direct causal pathway from plastics to human disease.

A key hotspot mechanism is to capture lightweight plastics by roadside drains and stormwater channels, followed by progressive retention. Thin films and bags are easily displaced from disposal or storage points, and plastic films are widely recognised as among the items most prone to escaping containment as wind-blown debris [45]. Once plastics enter drains, they can accumulate at low-velocity sections, culverts, grates, and constrictions, especially where maintenance is limited. This mechanism is strongly supported by evidence from Lilongwe: the city's sanitation and drainage strategy documents that solid waste in drains reduces carrying capacity and is associated with localised flooding, stormwater overflow, and water stagnation, with a substantial fraction of surveyed culverts showing silting and/or solid waste presence [6].

During high-intensity rainfall and flood events, plastics stored on streets, in informal dumping points, and in partially blocked drains can be mobilised quickly and redistributed into rivers, floodplains, and low-lying settlement edges. Malawi's flood risk context makes this pathway operationally important: the 2019 Floods PDNA reports that approximately 975,600 people were affected (with reported fatalities), underscoring the scale at which flood processes can disrupt services and redistribute debris [46]. Flooding-linked evidence is particularly relevant for Malawi because hotspots often interact with heavy rains and floodwater. Experimental work simulating a peri-urban waste pile and flooding showed that toxigenic *Vibrio cholerae* can colonise and persist on plastic waste for at least 14 days and transfer to floodwater, at concentrations described in the study as potentially relevant to human exposure [47]. This supports plausibility for plastics acting as a persistence or transfer substrate in contaminated flood-affected hotspots, rather than as direct drivers of disease (ibid).

3.3. Open Burning of Plastics: Major Health Hazard Alongside Infection Risk

Open burning is important because it can be a major exposure route even when the original problem appears to be "litter." Malawi's national strategy notes that uncontrolled burning generates particulate emission and persistent organic pollutant that may harm health locally and globally [16]. A systematic review focused on open burning of plastic waste synthesises evidence that large quantities of mismanaged plastic waste may threaten health and wellbeing, particularly in LMICs where waste management capacity is limited [48]. A global health perspective likewise emphasises that open burning of mixed wastes containing plastics is widespread, toxic, and often overlooked when plastic pollution is framed only as "litter" [49].

For hotspot planning, this means removal should not automatically be assumed to reduce risk unless the waste is transferred to safer treatment or disposal pathways than open burningl therefore, the likelihood of open burning and availability of controlled treatment and disposal should be included as explicit variables in the decision matrix.

4. Governance, Policy, and Implementation Context for Plastic Hotspot Management in Malawi

4.1. Institutional Landscape: Who Is Responsible for Action?

Plastic hotspot management in Malawi sits at the intersection of national regulation and local service delivery. At the national level, the Environment Management Act (Act No. 19 of 2017) establishes the Malawi Environment Protection Authority (MEPA) as the environmental regulator and sets the legal basis for environmental standards and enforcement [50]. The Act's date of commencement (1 November 2019) is also documented in legal summaries, signalling when the new institutional architecture became opera-

tional [51]. MEPA's stated mandate includes regulatory functions such as environmental assessments, coordination and oversight across stakeholders, and enforcement of environmental requirements—functions that are relevant to plastics regulation and compliance monitoring [50,52].

In cities, municipal solid waste management, including plastics, is primarily handled by city councils, which often face constraints in budgets, equipment availability, and service coverage. The African Clean Cities Platform city profile for Blantyre notes that solid waste management services are managed by the Department of Health and Social Services of the Blantyre City Council and reports that low-income areas often experience poor sanitary conditions due to dumping in open spaces, streams, roadsides, and drains [53].

Local government plays a central role in hotspot management, because many common plastic hotspot settings fall within city jurisdictions and require routine operational capacity, including collection, drain clearance, transfer, and disposal management.

In Lilongwe, the city's sanitation and drainage strategy explicitly treats solid waste management and drainage as linked systems and frames improvement through a mix of technical and non-technical actions, including communication/awareness, policy and regulation, institutional capacity, financing, private sector and non-government engagement, and monitoring [6]. This highlights a practical governance challenge: hotspot interventions typically require coordination among multiple actors, including regulators, city councils, communities, and private-sector service providers.

4.2. Core Legal and Policy Instruments Relevant to Plastics

Malawi's plastics governance includes both overarching environmental law and plastics-specific subsidiary regulation.

1. Environment Management Act (2017) [51]. The Act provides an overarching framework for environmental management and establishes the national regulator (MEPA) [50]. For plastic hotspot management, the importance of the Act is that it sets out the enabling legal basis for environmental compliance, enforcement, and the development and application of standards.
2. Environment Management (Plastics) Regulations (2015). Malawi's plastics-specific regulations prohibit the importation, manufacture, trade, and commercial distribution of plastic bags and plastic sheets below a specified thickness threshold (commonly described as 60 micrometres) while allowing exemptions for several categories of common packaging uses (e.g., certain food and medical/veterinary packaging and some waste storage applications) [54]. The regulations also include requirements such as marking/identification provisions (e.g., manufacturer name and bag thickness) and offences/penalties structures (ibid).
3. National Waste Management Strategy (2019–2023). Although not plastics-only, the strategy is highly relevant because it defines national priorities and acknowledges the mechanisms through which waste becomes a public health and infrastructure problem. It outlines priority areas such as reducing waste generation, promoting responsible behaviour, encouraging segregation at source, and supporting reuse/recycling and infrastructure development, and it clarifies that roles and responsibilities are shared across government bodies, the private sector, and the public. Crucially for hotspot management, the strategy explicitly links unmanaged waste and blocked drainage to flooding and disease risk—directly supporting prioritisation of drain- and flood-related plastic hotspots [16].
4. National environmental policy direction. Malawi's revised National Environmental Policy (2004) emphasises creating an enabling policy/legal framework for cross-sector coordination, strengthening enforcement machinery, and decentralising environmen-

tal management and governance [55]. This reinforces why hotspot management frameworks must be implementable within decentralised/local governance realities rather than assuming centrally delivered solutions.

4.3. Enforcement and Political Economy: The Plastics Ban in Practice

A major determinant of feasibility is whether regulations are consistently enforceable in practice. Malawi's thin plastics restrictions have experienced periods of legal contestation and uneven enforcement. A policy profile summarising Malawi's plastics regulation notes that the Plastics Manufacturers Association sought legal restraint against implementation and describes the regulatory exemptions that complicate enforcement in packaging markets [54].

More recent reporting describes enforcement strengthening in 2025, including inspections and penalties against firms producing or distributing banned thin plastics, and notes a court history that shaped the enforcement timeline [56]. Although media reports should be interpreted cautiously, the implication for the framework is clear: policy intent does not automatically translate into consistent compliance, and enforcement capacity can differ across places and over time. In hotspot planning, upstream prevention measures (such as plastic restrictions, producer responsibility, and market rules) should therefore be evaluated not only on whether they exist on paper, but on how enforceable they are in practice—considering inspection capacity, incentives for compliance, and the availability and affordability of substitutes.

5. Intervention Portfolio for Malawi: Matching Options to Hotspot Type and Feasibility

5.1. Using a Portfolio Approach

Addressing plastic hotspot management in Malawi requires multiple interventions because hotspot settings differ in dominant plastic forms, transport pathways, and operational constraints. What can be implemented in practice depends on factors such as funding, land availability, technical capacity, and enforcement realism. The interventions presented here are therefore not intended as universal or one-size-fits-all solutions. Rather, they are a portfolio of candidate options that should be matched to hotspot type, dominant risk profile, and feasibility under local conditions. Intervention selection depends explicitly on feasibility (F), including whether collection, maintenance, monitoring, and safe end pathways can be sustained in practice.

Malawi's National Waste Management Strategy calls for integrated waste actions and recognises drainage blockage and flooding as key mechanisms through which unmanaged waste creates harm, implying that a mixture of clearance, containment, and prevention is required rather than a single technology choice.

A practical intervention portfolio for Malawi should be guided by three main principles. First, it should reduce risks without simply shifting them elsewhere; for example, removing plastics from drains should not shift the end pathway to uncontrolled burning. Second, it should distinguish between immediate actions that rapidly reduce current exposure and longer-term measures that address upstream sources and prevent recurrence. Third, interventions should be chosen only where operation and maintenance are realistic and where the end pathway for collected material is clearly defined. Phase 2 measures become particularly important where hotspot recurrence is likely, where upstream leakage drivers remain unresolved, or where feasibility constraints identified in Phase 1 indicate that immediate harm reduction measures alone will not provide a durable solution.

Taken together, Sections 3, 5, and 6 form a single decision chain (Figure 2): hotspot types and dominant exposure conditions are identified first, feasible intervention classes are

then matched to those conditions, and final selection is guided by the scoring framework, including feasibility (F).

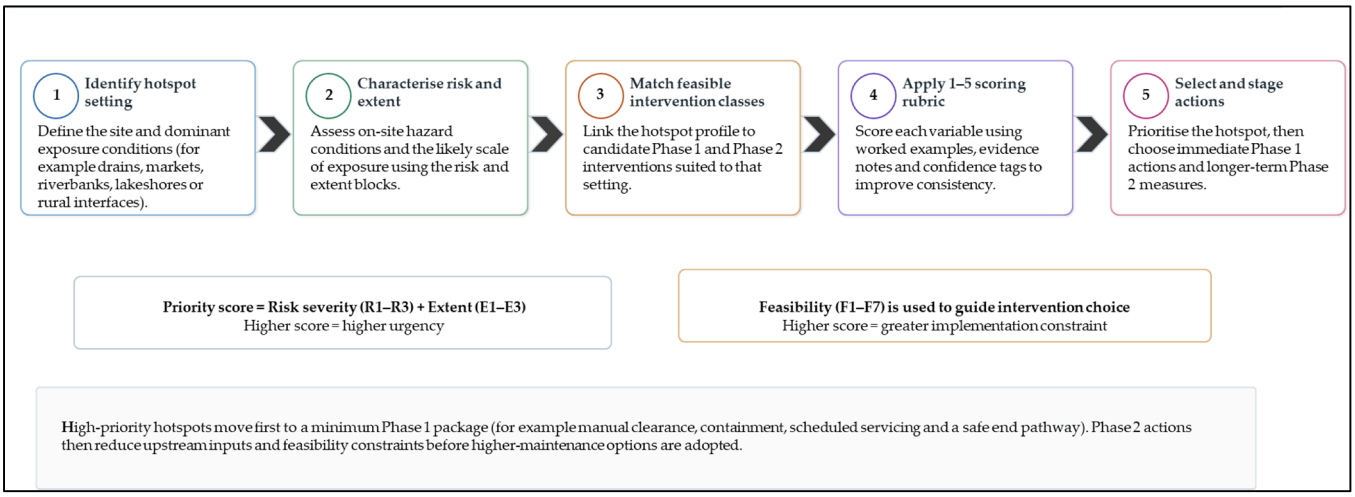


Figure 2. Decision pipeline for hotspot prioritisation and intervention selection.

5.2. Phase 1 Interventions: Rapid Removal and Capture at Hotspots

Phase 1 is the immediate response stage of the framework and is directed at reducing harm at existing hotspots. It emphasises rapid, feasible interventions that remove or contain accumulated plastics, restore drainage and flow conditions where relevant, and reduce direct human and environmental exposure. Actions in this phase may include targeted clean-up, drain clearance, temporary containment, and stabilised collection arrangements at hotspot locations.

(a) Targeted clean-up and drain clearance (manual + routine maintenance).

A proposed Phase 1 would focus on quick risk reduction in priority hotspots: removing accumulated plastics, restoring drainage function, and reducing direct contact with polluted environments. This usually involves a combination of (i) targeted clean-ups including manual removal from drains, riverbanks, and market edges; (ii) collection stabilisation, using temporary skips/containers and scheduled pick-ups at the hotspot perimeter; and (iii) routine maintenance to prevent re-accumulation, especially before and during the rainy season. There is a strong policy basis for prioritising drain-related hotspots in Malawi, particularly where blockage, recurrent accumulation, and direct exposure coincide [16].

Phase 1 implementation is more realistic when it recognises the existing labour and value chain around recyclables. Findings from Blantyre suggest that formalising recovery systems is not a simple switch; it relies on practical factors, income incentives, and local conditions. These factors should therefore be considered when designing rapid clean-up-to-recovery pathways (e.g., buy-back centres near hotspots, safe sorting points, and predictable off-take) [57].

(b) Trash traps, booms and screens in stormwater channels and waterways.

Trash interception devices such as mesh screens, floating booms, and river barriers can be used to capture plastics before they disperse downstream into riverbanks and lakeshore margins. These technologies range from basic, low-cost screens at drain outlets to larger booms and conveyor-based systems. Studies of stormwater litter control in southern Africa show that the performance of these devices depends on litter composition and flow conditions. Booms can retain smaller floating material, while screens can capture larger or partially submerged items such as bags and sheets. However, retention performance drops during high flows when litter is forced under or over booms [58].

The Mr. Trash Wheel system was first installed in the Jones Falls stream in Baltimore, Maryland, and it illustrates a common design approach: capturing floating litter in waterways before it reaches larger water bodies and, ultimately, the ocean [59]. For Malawi, interception is particularly relevant where drains discharge into rivers or where river transport loads plastics toward lakeshore environments. The main challenge is not the device itself but ensuring that collected plastics are removed regularly and directed to an end pathway that avoids open dumping or uncontrolled burning.

5.3. Phase 2 Interventions: Prevention and Source Reduction

Phase 2 interventions are more appropriate where the main need is to reduce future plastic leakage and where longer-term institutional, market, or behavioural measures are feasible.

(a) Refill and reuse systems to reduce single-use packaging.

Refill and reuse approaches reduce plastic generation at the source by shifting consumption away from single-use bottles and sachets. Empirical evidence from a refill station intervention showed reductions in plastic bottle litter after installation, supporting refill as a credible source reduction measure in appropriate contexts [60]. For Malawi, refill stations are most plausible in dense urban areas where demand is steady and where water safety and affordability can be maintained. Because refill targets the upstream flow of plastics, it fits naturally into Phase 2 mitigation, but it is most effective when accompanied by local promotion, price incentives, and compatible container systems.

(b) Biodegradable or compostable alternatives (careful substitution).

Substitution strategies aim to replace certain plastic items (especially thin film bags and food packaging) with compostable alternatives (e.g., starch-based materials, plant fibres). In Malawi, substitution is attractive because it supports the intent of plastics restrictions, but it must be approached cautiously: biodegradable materials can still cause harm if they are littered, and some alternatives require specific composting conditions. As a result, alternatives are best treated as part of a broader prevention package (standards, procurement choices, consumer behaviour change), rather than a standalone fix.

(c) Producer responsibility and market controls (policy instruments).

Malawi already has plastics-specific regulation via the Environment Management (Plastics) Regulations (2015), which restrict certain thin plastics and includes compliance requirements. However, as discussed in Section 5, enforceability and exemptions matter. Phase 2 mitigation can therefore include strengthened enforcement realism (inspection capacity, clear guidance on exemptions), and—where politically feasible—extended producer responsibility (EPR)-style instruments to finance collection and support recycling markets. These measures do not remove plastics from existing hotspots immediately, but they reduce future flows into hotspots by shifting incentives upstream.

5.4. Phase 1–2 Bridge: Collection and Aggregation Systems That Make Plastics "Recoverable"

(a) Incentive-based collection and return systems (including reverse vending).

Where street litter and market waste dominate, incentive systems can convert "waste" into a recoverable commodity by paying small rewards for returned items. In South Africa, Pick n Pay's published programme describes reverse vending machines that provide customer rewards (via loyalty points) for returning recyclables, illustrating a scalable incentive mechanism in a regional context. While Malawi's retail landscape differs, the underlying idea can be adapted into lower-tech variants: buy-back centres, mobile collection days,

or deposit-style returns for specific high-value items (e.g., PET bottles), particularly in Blantyre and Lilongwe, where density supports regular collection routes.

(b) Community-scale collection and recycling hubs (low-tech shredding/extrusion).

Community or SME-led recycling hubs can improve recovery when they are designed around plastics that can be reliably sorted (e.g., HDPE/PP) and when there is a clear market for outputs. A case study on building a community-scale plastic recycling station demonstrates a low-tech chain (washing → shredding → extrusion) used to convert collected plastic into usable products, illustrating technical feasibility and the educational/community co-benefits of visible local recycling. At a systems level, community-based collection models such as Mr Green Africa's work in Kenya show how aggregation can be strengthened by linking informal collection networks to traceable supply for industrial buyers—an approach that may be informative for Malawi even if the institutional context differs. For Malawi, the main feasibility questions are: can consistent sorting be achieved, are energy and spare parts reliable enough for operation, and is there a stable offtake market for pellets or products?

5.5. Valorisation and Treatment: Converting Plastic Waste into Outputs

(a) Recycling plastics into construction materials (pavers, blocks, tiles).

Converting plastic waste into construction materials can create local demand for recovered plastics and reduce leakage by "locking" plastic into a product. Evidence from Ghana shows that plastic–sand pavement blocks can achieve usable mechanical performance and that converting plastic waste into pavement blocks is feasible as a waste-reduction pathway [61]. Studies from other contexts similarly report cement-free or low-cement plastic–sand paver blocks meeting light-traffic strength benchmarks and assessing water absorption and temperature effects, supporting feasibility beyond a single case study [62]. For Malawi, the approach is attractive where flood exposure and standing water are common, but it depends on feedstock consistency (mixed plastics), basic product standards (strength/water absorption/heat performance), and quality control across batches [61,62]. A key implementation risk is occupational and environmental exposure during melting/extrusion if controls are weak; a recent review of small-scale plastic brick production highlights likely emissions (e.g., particulates/VOCs/POPs) and elevated worker risk where safety measures are lacking [63].

(b) Plastic-to-fuel conversion (pyrolysis) for non-recyclable fractions.

Pyrolysis is often proposed for low-value or contaminated plastics that are difficult to recycle mechanically. A recent review focused on Africa discusses pyrolysis as a potential waste-to-energy route while emphasising the need to evaluate environmental impacts and operating conditions [64]. For Malawi, pyrolysis is only plausible where three conditions hold: consistent feedstock supply and pre-sorting (to avoid problematic plastics such as PVC), reliable energy/technical capacity for operation and maintenance, and emissions management to avoid creating air pollution burdens. Because Malawi's national strategy already flags uncontrolled burning as a pollution hazard, any thermal approach would need explicit safeguards to avoid replicating burning-related harms in a different form.

5.6. Matching Interventions to Hotspot Types in Malawi

The intervention portfolio becomes more useful when it is linked to the types of hotspots in which plastic waste accumulates, the main risks these settings create, and the practical constraints that affect what can actually be delivered. Table 2 brings these elements together to show how different intervention options align with different hotspot conditions in Malawi.

Table 2. Link between hotspot type, dominant risk profile, feasibility, and intervention options.

Hotspot Type	Dominant Risk Profile	Feasibility (F) Considerations	Likely Intervention Classes
Urban drains/stormwater channels	Blockage, stagnant water, flood redistribution	Access for clearance, maintenance capacity, safe disposal pathway	Drain clearance, routine maintenance, screens/booms
Markets/transport hubs	High litter generation, mixed packaging waste, rapid re-accumulation	Collection reliability, sorting space, off-take routes, local incentives	Buy-back systems, improved collection, community sorting/recycling
Riverbanks/lakeshores	Downstream transport, shoreline accumulation, tourism/fisheries impacts	Access, seasonal flows, community participation, removal logistics	Shoreline clean-up, upstream interception, refill or reuse measures
Peri-urban dumping areas	Mixed waste accumulation, burning risk, local exposure	Controlled end pathway, land, supervision, local demand for recovered material	Collection strengthening, controlled aggregation, safe valorisation
Rural/agricultural interfaces	Agrochemical packaging leakage, dispersed waste sources	Transport distance, return logistics, low-tech practicality	Collection days, return schemes, aggregation points, reuse/substitution

1. For urban drains and stormwater channels, Phase 1 prioritises drain clearance and, where maintenance capacity exists, interception screens or booms at key outlets; Phase 2 then focuses on reducing upstream inputs around markets and improving collection coverage to limit re-accumulation.
2. For markets and transport hubs, incentive or buy-back systems, combined with reliable collection routes, are often the fastest way to reduce litter; community recycling hubs become viable where sorting capacity and dependable off-take can be sustained.
3. For riverbanks and lakeshore margins (including Lake Malawi), interventions should combine upstream interception where feasible with shoreline collection and community engagement. Longer-term prevention can focus on tourism and vendor packaging controls, alongside refill or reuse options in high-footfall areas. Evidence of persistent lakeshore plastic accumulation supports treating these settings as priority areas for targeted management.
4. For peri-urban dumping zones, priorities include strengthening collection systems and ensuring controlled end pathways that avoid open burning. Valorisation options (e.g., construction products) may be appropriate where they create stable demand for recovered plastics and where production can be carried out safely under realistic operating conditions.
5. For rural and agricultural interfaces, practical options include targeted collection days, container return schemes, and locally appropriate aggregation points. Where energy supply and maintenance capacity are limited, substitution or reuse initiatives may be more realistic than high-tech recycling approaches.

6. Assessment Variables and Scoring System

Sections 3–5 establish that plastic hotspots in Malawi arise from recurring source–pathway setting combinations (for example, from markets into drains and then into rivers or lakes) and that health-relevant risk is strongly mediated by drainage blockage, flooding, standing water, and unsafe end pathways, such as open burning. Malawi's National Waste Management Strategy explicitly links accumulated waste and blocked drains to flooding and increased disease risk, supporting the need for a framework that prioritises hotspot

types where these mechanisms are strongest. The framework integrates behavioural, governance, and technical feasibility considerations with environmental processes.

The decision framework requires a transparent method to move from: (i) identifying a plastic hotspot, to (ii) assigning a priority level for action, and (iii) selecting interventions that are feasible in that setting. The framework therefore uses a small set of assessment variables designed for application in data-limited contexts. These variables aim to capture both the severity and extent of risk, and the practical constraints that affect whether interventions can be implemented and maintained. The variable set is intended to produce decisions that are transparent and auditable, so that an assessor can explain both why a hotspot was prioritised and why a particular intervention package was selected. Figure 2 summarises the decision pipeline used in this framework: hotspot settings and dominant exposure conditions are identified first, feasible intervention classes are then matched to those conditions, and final selection is guided by the scoring framework.

Table 3 presents the assessment variables and the scoring rubric used to evaluate plastic waste hotspots. Variables are grouped into three blocks: risk severity (R1–R3), extent (E1–E3), and feasibility (F1–F7). This structure separates hotspot priority from intervention deliverability: risk severity captures health-relevant hazard and exposure conditions at the site; extent captures the scale and likely distribution of impact; and feasibility captures the operational, institutional, and practical constraints that affect implementation. Higher scores indicate greater concern for risk and extent variables, and greater implementation constraint for feasibility variables.

6.1. Structure of the Assessment

The assessment variables are organised into three core blocks (Table 4): risk severity, extent, and feasibility. Risk severity variables describe the hazard and exposure conditions present at the hotspot itself, extent variables describe the likely scale and distribution of impact, and feasibility variables describe the practical constraints affecting implementation and maintenance. In the framework, risk severity and extent are combined to determine hotspot priority, whereas feasibility is considered separately to guide intervention selection under local constraints. Although R2 and E3 are conceptually distinct, with R2 capturing site-level vector-supporting conditions and E3 capturing the scale of exposure relevance through proximity to sensitive receptors, some overlap may arise in practice in densely exposed settings. This should be interpreted as a limitation of the framework and revisited during future empirical validation.

This additive structure combines (i) risk severity, which reflects health-relevant exposure conditions, and (ii) extent, which reflects the scale of potential impact. It is used because it is transparent and monotonic: increasing any risk or extent component increases the priority score. Feasibility (F1–F7) is not added to priority because it reflects deliverability rather than urgency; instead, it is used to guide intervention choice. The feasibility block contains more variables than the risk block because the framework is intended for decision making in implementation-constrained settings, where access, service reliability, siting, coordination, and safe end pathways frequently determine whether a technically appropriate option can actually be delivered. If a hotspot ranks highly but feasibility constraints limit the intervention set, the framework applies a staged approach: (i) delivering a minimum Phase 1 package using low-tech actions that reduce exposure immediately, such as manual clearance, containment, scheduled servicing, and a safe end pathway; and (ii) prioritising Phase 2 measures that reduce upstream inputs and address feasibility constraints, including finance, siting, capacity, and coordination, before higher-maintenance or higher-capital interventions are adopted.

Table 3. Assessment variables and scoring rubric (1–5 scale).

Variable	Operational Definition	1 Very Low	2 Low	3 Moderate	4 High	5 Very High	Suggested Evidence/Examples
R1. Infection-relevant exposure intensity	Degree to which the hotspot is likely to bring people into contact with contaminated water, mixed waste, floodwater, or sewage-affected environments.	Dry or mainly inert littered site with little direct human contact.	Limited and infrequent contact possible.	Intermittent contact likely, especially after rainfall or through routine nearby activity.	Frequent contact likely in a regularly used public or domestic setting.	Frequent and direct contact likely in drain, floodwater, sewage-adjacent, food-handling, washing, or child play environments.	Site observation, sewage/wastewater presence, floodwater contact, food-selling or washing area nearby.
R2. Vector-breeding condition potential	Potential for the hotspot to create or maintain standing water and water-holding micro-habitats favourable to mosquitoes or other vectors.	No standing water and no water-holding litter observed.	Minor and short-lived pooling only after rainfall.	Some repeated pooling or scattered water-holding plas-tics/containers.	Standing water or blocked drainage is common.	Persistent standing water, repeated pooling, or many water-holding plastics/containers with clear blockage.	Visible stagnant water, blocked drains, trapped water in bags/containers, repeat observations after rain.
R3. Burning hazard	Likelihood that plastics at the hotspot are openly burned, or moved to an end pathway where burning is likely.	No evidence of burning and a plausible safer end pathway exists.	Rare signs or isolated reports of burning.	Occasional burning reported or some signs of previous burning.	Burning occurs regularly or is strongly likely where collection is weak.	Routine burning clearly observed, repeatedly reported, or highly likely because no safer end pathway exists.	Ash, charred plastics, smoke observations, multiple informant reports, absence of controlled disposal route.
E1. Population exposed	Approximate number of people regularly using, living beside, or passing through the hotspot area.	Very few people exposed.	Small local user group.	Moderate daily exposure.	Large exposed population or regular high footfall.	Very high exposure in dense settlement, market, school route, transport hub, or other heavily used public area.	Settlement density, housing adjacency, footfall, market activity, transport-node activity.

Table 3. *Cont.*

Variable	Operational Definition	1 Very Low	2 Low	3 Moderate	4 High	5 Very High	Suggested Evidence/Examples
E2. Foot-print/persistence	Spatial extent and persistence of the hotspot over time.	Very small and short-lived accumulation.	Localised site with limited persistence.	Moderate footprint or seasonal recurrence.	Large footprint or frequent recurrence.	Extensive, persistent, or recurrent accumulation that returns quickly without intervention.	Repeat site visits, photographs, local authority/community reports, length of affected drain/riverbank/shoreline.
E3. Proximity to sensitive receptors	Nearness of the hotspot to places or users more vulnerable to harm, such as schools, clinics, water points, play areas, or food-selling/washing areas.	No sensitive receptors nearby.	Distant from one receptor type.	Moderate proximity to one receptor type.	Very near one receptor or moderate proximity to several.	Directly adjacent to, or affecting, multiple sensitive receptors.	Simple mapcheck, GPS, site walk, photos, local knowledge of schools, clinics, water points, play/washing areas.
F1. Financial feasibility	Degree to which the intervention is affordable and can be funded and sustained under available budget, staffing, and operating conditions.	Funding is already available or the intervention is very low cost and readily affordable.	Costs are manageable with minor additional support.	Intervention is affordable only with some reallocation, partnership, or short-term support.	Costs are substantial relative to available resources and may limit implementation or continuity.	Intervention is unlikely to be affordable or financially sustainable under current conditions.	Indicative capital and operating costs; available municipal or project budget; likely need for external funding; staffing and fuel costs; expected maintenance cost; affordability relative to existing service levels; evidence of past funding gaps or failed continuation due to cost.
F2. Access for intervention	Ease with which workers, equipment, and collected waste can reach and leave the site safely.	Access is straightforward for routine intervention.	Minor access constraints.	Moderate access constraints or seasonal difficulty.	Difficult access due to narrow routes, flooding, unstable ground, or distance.	Very difficult or unsafe access that seriously limits intervention options.	Site walk, road/path access, slope, seasonal flooding, vehicle/manual access constraints.

Table 3. *Cont.*

Variable	Operational Definition	1 Very Low	2 Low	3 Moderate	4 High	5 Very High	Suggested Evidence/Examples
F3. Waste collection/service reliability	Reliability of local collection, transfer, or servicing arrangements needed to maintain the intervention.	Reliable service already exists or can be integrated easily.	Mostly reliable with occasional interruption.	Irregular or partial service.	Weak and inconsistent service with frequent gaps.	Very weak or absent service; maintenance likely to fail.	Collection schedules, missed pickups, council/service records, local reports.
F4. Space/siting suitability	Availability of physical space for bins, skips, sorting, barriers, booms, or temporary storage.	Adequate space and siting conditions available.	Minor siting limits but still workable.	Limited space requiring careful siting.	Very limited space or competing land use.	No practical space or major siting conflict.	Field observation, road width, land-use conflict, safe placement options, storage space.
F5. Institutional/coordination capacity	Degree to which responsible actors can organise, supervise, and sustain the intervention.	Clear lead actor and coordination path exists.	Minor coordination gaps.	Some uncertainty over roles or follow-up.	Weak coordination, unclear responsibility, or limited capacity.	Major coordination weakness or no actor realistically able to sustain the intervention.	City council role, community structure, private operator presence, prior maintenance history.
F6. Safe end pathway for collected plastics	Availability of a realistic route for collected material that avoids re-dumping or open burning.	Safe onward route clearly available.	Safe route available but somewhat limited.	Route exists but is inconsistent or fragile.	No dependable safe route; re-dumping or burning risk is high.	No credible safe route; collected plastics are very likely to be burned or dumped again.	Disposal/transfer/recycling options, off-take routes, transport arrangements, observed fate of collected waste.
F7. Community/stakeholder support	Likelihood that local users, traders, residents, or site managers will cooperate with and sustain the intervention in practice.	Strong support and low expected resistance.	Generally supportive with minor concerns.	Mixed or uncertain support.	Low support or likely resistance.	Strong resistance or very low participation likely to undermine implementation.	Short consultation; prior participation; trader/resident views; local willingness to maintain bins or barriers; evidence of past cooperation or resistance.

Table 4. Summary of variables grouped into three blocks used as inputs to the decision matrix.

Assessment Element	Meaning
Risk total/risk severity (R1 + R2 + R3)	Reflects the severity of potential harm and the degree to which the hotspot creates health-relevant exposure conditions, including floodwater contact, persistent standing water, and open burning
Extent total (E1 + E2 + E3)	Reflects the scale of likely impact, including the number of people exposed, the footprint and persistence of the hotspot, and its proximity to sensitive receptors such as water points, schools, clinics, markets, or lakeshore environments
Average feasibility ((F1 + F2 + F3 + F4 + F5 + F6 + F7)/7)	Reflects whether interventions can realistically be implemented and sustained, considering finance, access, service reliability, siting, institutional capacity, safe end pathways, and community support
Priority (risk total + extent total)	Indicates where urgent action is most needed

6.2. Scoring Scale and Evidence Grading

To make the variable set usable in practice, the framework applies a 1–5 scoring scale (Table 5). Each score is accompanied by a brief evidence note in the format "variable—score—evidence note" (see Table 3), indicating the main observation, document, or local information used to justify the score. If evidence is borderline between categories, the lower score is assigned unless at least two independent evidence sources support the higher score. Each score is also recorded with a confidence tag (high, medium, or low). Confidence does not affect the numeric score but indicates uncertainty and guides follow-up data collection.

Table 5. Scoring scale.

Scale	Meaning
1	Very low
2	Low
3	Moderate
4	High
5	Very high
R/E	Higher score = greater risk/extent
F	Higher score = greater implementation constraint

No formal pilot application, field testing, expert elicitation, stakeholder validation, inter-rater reliability testing, or operational calibration was undertaken in the present study. Accordingly, the scoring bands should be interpreted as preliminary decision-support categories rather than empirically validated operational thresholds. To improve consistency in future applications, the framework should first be applied to a small set of example hotspot cases, with scores compared and discussed among multiple assessors before independent scoring is undertaken. This calibration step would help align interpretation of the scoring thresholds across variables, identify ambiguous criteria, reduce score variability, and provide evidence for refining the decision bands.

To support interpretation of the assessment outputs, the framework groups raw scores into practical decision bands. Table 6 presents the priority bands derived from the combined risk severity and extent scores, indicating the level of urgency for action. Table 7 presents the feasibility average bands derived from F1–F7, indicating the degree of implementation

constraint. These bands are intended to support transparent and consistent interpretation of scores rather than to act as empirically validated thresholds.

Table 6. Priority bands (R + E).

Min	Max	Band	Meaning
6	10	Very Low	Monitor; routine surveillance
11	15	Low	Plan low-intensity action where practical
16	20	Moderate	Action required; schedule Phase 1
21	25	High	Priority hotspot for rapid Phase 1 action
26	30	Very High	Immediate priority, rapid Phase 1 and phased Phase 2

Table 7. Feasibility average bands.

Min	Max	Constraint Band	Meaning
1	1.49	Very Low	Few delivery constraints, interventions generally straightforward to implement and sustain
1.5	2.49	Low	Interventions generally deliverable
2.5	3.49	Moderate	Some delivery constraints
3.5	4.49	High	Staged response likely needed
4.5	5	Very High	Use basic Phase 1 risk-reduction package and address constraints in Phase 2

6.3. Framework Application: Illustrative Examples for Common Hotspot Types in Malawi

This section demonstrates how the two-phase framework can be applied to representative plastic hotspot types in Malawi. The examples (Tables 8–10) are designed as transferable templates: they show how hotspot identification, scoring, and intervention selection can be structured even when detailed quantitative datasets are limited. They also reflect mechanisms highlighted in Malawi's National Waste Management Strategy, particularly the links between waste accumulation, blocked drains, flooding, and disease risk.

Table 8. Case A: Urban drain and market-adjacent hotspot (high flood interaction).

Priority Scoring (R + E) Variable	Score	Confidence	Short Justification
R1. Infection-relevant exposure intensity	5	High	Frequent and direct contact is likely because the hotspot is drain-adjacent, flood-affected, and close to food-use and public activity.
R2. Vector-breeding condition potential	5	High	Blocked drainage and stagnant water create persistent vector-supporting conditions.
R3. Burning hazard	3	Medium	Burning may not occur at the drain itself but is plausible where collection is weak and waste is re-disposed nearby.
E1. Population exposed	5	High	Dense urban setting with heavy market footfall and frequent daily use.
E2. Footprint/persistence	5	High	Recurring accumulation and blockage are likely without repeated maintenance.

Table 8. *Cont.*

Priority Scoring (R + E)			
Variable	**Score**	**Confidence**	**Short Justification**
E3. Proximity to sensitive receptors	4	Medium	Likely to be close to food areas, water-use points, schools, or clinics in a dense urban setting.
Priority total	27		
Priority band	Very High		
Feasibility Scoring (F1–F7 Average)			
Variable	**Score**	**Confidence**	**Short Justification**
F1. Financial feasibility	3	Medium	Intervention is feasible but may need budget reallocation or short-term support for repeat servicing and staff time.
F2. Access for intervention	2	High	Access is generally possible, though congestion and narrow market-edge routes may slow operations.
F3. Waste collection/service reliability	4	Medium	Collection and servicing are often weak or irregular, creating a high risk of recurrence.
F4. Space/siting suitability	3	Medium	Space for skips, barriers, or temporary storage may be limited in crowded market-edge settings.
F5. Institutional/coordination capacity	3	Medium	Delivery depends on council–community coordination and sustained supervision, which may be uneven.
F6. Safe end pathway for collected plastics	4	Medium	A dependable route safer than re-dumping or open burning may not be consistently available.
F7. Community/stakeholder support	3	Medium	Support is possible but likely to be mixed without engagement and visible follow-through.
Feasibility avg	3.14		
Constraint band	Moderate		
Likely Phase 1 response			
Targeted drain clearance, temporary containment/collection stabilisation, scheduled repeat servicing before and during the rainy season, and confirmation of safe onward handling of removed plastics.			
Likely Phase 2 response			
Improve regular collection around market edges, reduce upstream litter leakage, strengthen local coordination and maintenance responsibility, and support trader/community engagement to reduce recurrence.			

To illustrate how the scoring system translates into practical decisions, the framework is applied below to three contrasting hotspot settings in Malawi: Case A (Table 8), Case B (Table 9), and Case C (Table 10). Case A, representing an urban drain and market-adjacent hotspot with high flood interaction, produced a risk score of 13 and an extent score of 14, giving a combined priority score of 27 and placing it in the Very High priority category (Table 6). Its separate feasibility average was 3.14, indicating moderate feasibility constraint (Table 7). This suggests that the hotspot is highly urgent, while the main intervention barriers are manageable enough to allow a substantial Phase 1 response focused on immediate harm reduction. Case B, representing a river outfall and lakeshore accumulation hotspot at the Lake Malawi interface, produced a risk score of 7 and an extent score of 13, giving a combined priority score of 20 and placing it in the Moderate priority category. Its feasibility average was 3.29, also indicating moderate feasibility constraint. Although both cases fall within the same overall feasibility category, the practical barriers arise from different sources. In Case B, the importance of Phase 2 is not because feasibility is worse, but because

shoreline accumulation is strongly shaped by upstream inputs and repeated redeposition, meaning that Phase 1 clean-up alone is less likely to prevent recurrence.

Table 9. Case B: River outfall and lakeshore accumulation hotspot (Lake Malawi interface).

Priority Scoring (R + E) **Variable**	**Score**	**Confidence**	**Short Justification**
R1. Infection-relevant exposure intensity	3	Medium	Moderate infection-relevant exposure is possible where people wash, fish, or collect water, or where children play near the shore.
R2. Vector-breeding condition potential	2	Medium	Less important than in blocked urban drains, though local pooling or trapped water may still occur.
R3. Burning hazard	2	Medium	Burning may occur near informal dumping or sorting points but is not the main hotspot mechanism.
E1. Population exposed	3	Medium	Exposure is moderate overall, though it can be higher in fishing, tourism, or busy shoreline areas.
E2. Footprint/persistence	5	High	Accumulation can be extensive and recurrent due to redeposition and shoreline transport.
E3. Proximity to sensitive receptors	5	High	The hotspot is directly connected to a sensitive freshwater receptor with implications for water use, livelihoods, and ecosystem health.
Priority total	20		
Priority band	Moderate		
Feasibility Scoring (F1–F7 Average) **Variable**	**Score**	**Confidence**	**Short Justification**
F1. Financial feasibility	3	Medium	Repeated shoreline removal and transport can create moderate cost pressure without external support.
F2. Access for intervention	4	Medium	Shoreline access, distance, terrain, and seasonal conditions can make removal difficult.
F3. Waste collection/service reliability	4	Medium	Servicing is often weak at river-entry points and shoreline margins.
F4. Space/siting suitability	2	Medium	Some shoreline areas may have temporary staging space, though this varies by site.
F5. Institutional/coordination capacity	3	Medium	Action often requires coordination across local authority, community, fisheries, tourism, or shoreline users.
F6. Safe end pathway for collected plastics	4	Medium	Safe onward management may be limited, raising the risk of re-dumping or burning after removal.
F7. Community/stakeholder support	3	Medium	Community participation is important, but support may vary depending on site and perceived benefit.
Feasibility avg	3.29		
Constraint band	Moderate		
Likely Phase 1 response			
Targeted shoreline clean-up at accumulation zones, temporary storage or staging where feasible, transport of collected waste through a safe onward route, and focused action at river-entry accumulation points.			
Likely Phase 2 response			
Upstream interception and source reduction, improved management at river/drain entry points, coordination across shoreline actors, and community engagement and prevention measures to reduce repeat deposition.			

Table 10. Case C: Roadside culvert blockage in a dense informal settlement.

Priority Scoring (R + E)			
Variable	**Score**	**Confidence**	**Short Justification**
R1. Infection-relevant exposure intensity	5	High	Frequent direct contact is likely because contaminated runoff, blocked drainage, and waste-affected surfaces occur within a densely used settlement environment.
R2. Vector-breeding condition potential	5	High	Culvert blockage, stagnant water, and trapped plastics create persistent vector-supporting conditions, especially during and after rainfall.
R3. Burning hazard	4	Medium	Open burning is plausible where waste accumulates repeatedly and regular collection is weak, even if it is not constant at the culvert itself.
E1. Population exposed	5	High	The hotspot affects a densely populated informal settlement with high daily exposure.
E2. Footprint/persistence	5	High	The blockage is likely to recur quickly without repeated servicing and upstream control.
E3. Proximity to sensitive receptors	5	High	Such hotspots are often close to homes, footpaths, water-use points, and play areas, increasing exposure concern.
Priority total	29		
Priority band	Very High		
Feasibility Scoring (F1–F7 Average)			
Variable	**Score**	**Confidence**	**Short Justification**
F1. Financial feasibility	4	Medium	Repeated clearance, labour, transport, and servicing create a substantial cost burden relative to available resources.
F2. Access for intervention	5	High	Access may be very difficult because of narrow paths, unstable ground, congestion, and flood conditions.
F3. Waste collection/service reliability	5	High	Collection and follow-up servicing are likely to be very weak or absent in this setting.
F4. Space/siting suitability	4	Medium	Space for skips, barriers, or temporary storage is likely to be very limited in a dense settlement edge.
F5. Institutional/coordination capacity	4	Medium	Sustained action may be difficult because responsibility, supervision, and coordination are likely to be weak or fragmented.
F6. Safe end pathway for collected plastics	5	High	A credible onward route for removed waste may be absent, creating a high risk of re-dumping or burning.
F7. Community/stakeholder support	5	Medium	Support may be difficult to sustain where trust is low, servicing is inconsistent, and space is contested.
Feasibility average	4.57		
Constraint band	Very High		
Likely Phase 1 response			
A basic immediate Phase 1 package focused on essential harm reduction: manual clearance of the worst blockage, temporary containment where possible, scheduled repeat servicing, safe onward handling of removed waste, and local communication to reduce re-blockage.			
Likely Phase 2 response			
Improve collection coverage in the surrounding settlement, reduce dumping into drains, strengthen local authority and community coordination, identify a reliable safe end pathway, and develop longer-term drainage and hotspot-prevention measures.			

Case C represents a roadside culvert blockage in a dense informal settlement and produces a very high priority score because it combines intense exposure, persistent standing water, recurrent blockage, and a large, exposed population. It also produces a Very High feasibility constraint score, indicating that, although the hotspot is highly urgent, implementation barriers are severe. These barriers arise from difficult site access, weak service reliability, limited siting space, uncertain coordination, and the absence of a dependable safe end pathway for collected plastics. The assessment therefore suggests that this hotspot should receive a minimum immediate Phase 1 risk-reduction package focused on essential harm reduction, while Phase 2 addresses the structural barriers that prevent fuller implementation.

A summary visualisation (Figure 3) is provided to complement Tables 3–10 by showing the assessment variables, decision logic, intervention summary, and illustrative case applications in simplified visual form.

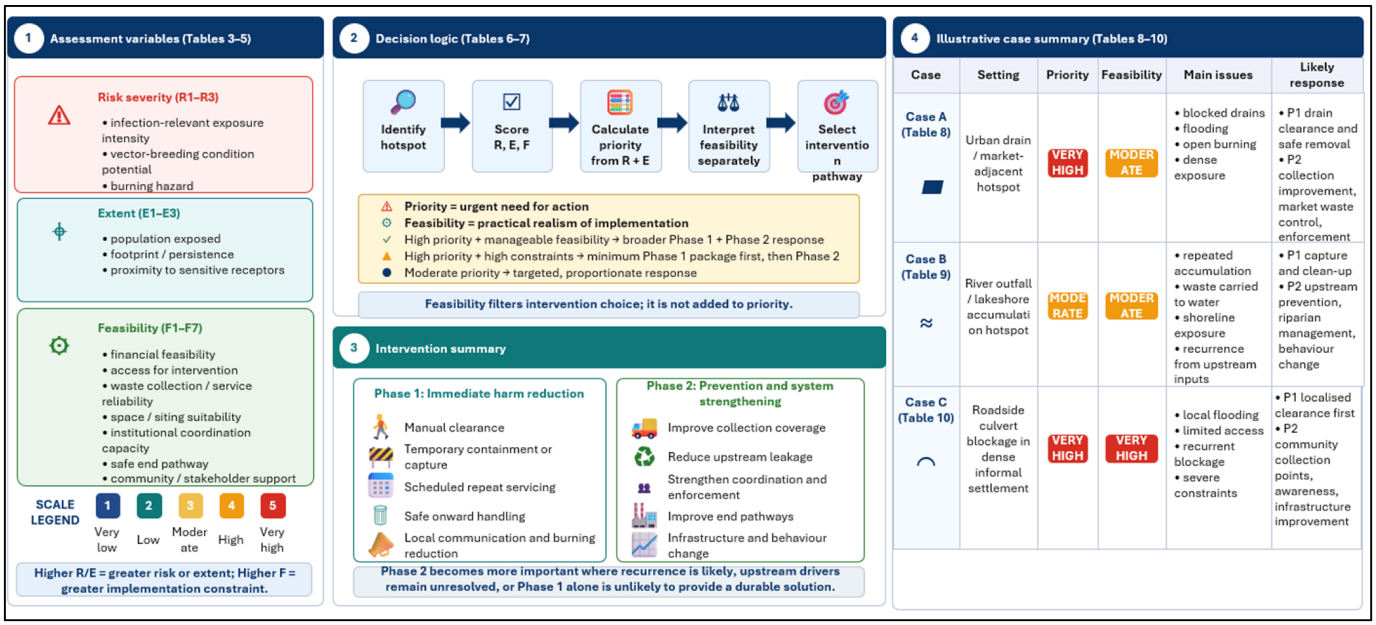


Figure 3. Visual summary of framework, scoring, and illustrative cases.

The provided cases are illustrative Malawi applications grounded in hotspot settings discussed in the evidence base, rather than formal scored assessments of individually surveyed named sites. They are used to demonstrate how R, E, and F scores can be assigned and how these scores guide hotspot prioritisation and intervention selection.

7. Conclusions

Plastic pollution in Malawi is not distributed evenly across the landscape. Instead, it accumulates in hotspots such as urban drains and stormwater channels, dumping areas near markets, peri-urban settlement edges, riverbanks and outfalls, and along lakeshores.

These hotspots are significant because plastics interact with Malawi's environment and public services, particularly drainage performance, seasonal rainfall and flooding, and informal disposal practices, creating conditions that can increase health risks and environmental harm. Malawi's National Waste Management Strategy explicitly recognises that accumulated waste and blocked drains contribute to flooding and disease risk, and it identifies uncontrolled burning as a serious hazard, reinforcing the need for targeted, risk-informed hotspot management rather than generic interventions.

This research proposes a two-phase, risk-based decision framework for targeted plastic hotspot management in Malawi. Phase 1 prioritises immediate harm reduction by identifying and ranking hotspots based on health-relevant risk severity and extent, then selecting context-appropriate intervention bundles that address the dominant mechanism (e.g., drain retention and blockage, flood redistribution, lakeshore deposition) while ensuring a safe end pathway for collected material. Phase 2 focuses on preventing recurrence by tracing dominant plastic sources and responsible actors and applying mitigation packages that combine governance tools, service improvements, incentives, alternatives/reuse options, and education/participation. The framework integrates behavioural, governance, technical, and environmental considerations relevant to plastic waste hotspots in Malawi, and these are reflected in the assessment variables used to support realistic and context-sensitive intervention selection.

The practical value of the framework is that it clarifies the trade-offs by showing what should be prioritised (risk and exposure) from what can be delivered now (feasibility constraints). This lowers the chance of common mistakes such as selecting technologies that cannot be maintained, clearing hotspots without preventing rapid re-accumulation, or displacing risk by shifting plastics into open burning.

In practical terms, the framework can support municipal prioritisation under constrained budgets by identifying which hotspots require the most urgent action and which intervention options are most feasible in context. It can also support hotspot monitoring over time; help sequence immediate Phase 1 actions and longer-term Phase 2 measures; and support integrated planning across waste, drainage, public health, and governance systems by identifying hotspots where plastic accumulation, flood risk, health-relevant exposure, and implementation constraints intersect, thereby helping decision makers coordinate responses across sectors rather than addressing these issues separately.

The illustrative examples show that using the same set of variables helps keep decision making consistent for different hotspot types, while still allowing site-specific adaptation.

Future work should focus on validating the framework by applying it to different local settings. Next steps include pilot testing across different hotspot types (urban drains, peri-urban dumping/burning zones, and lakeshore interfaces), stakeholder workshops to refine variable weighting, and monitoring systems that capture seasonality in hotspot formation.

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Appendix A

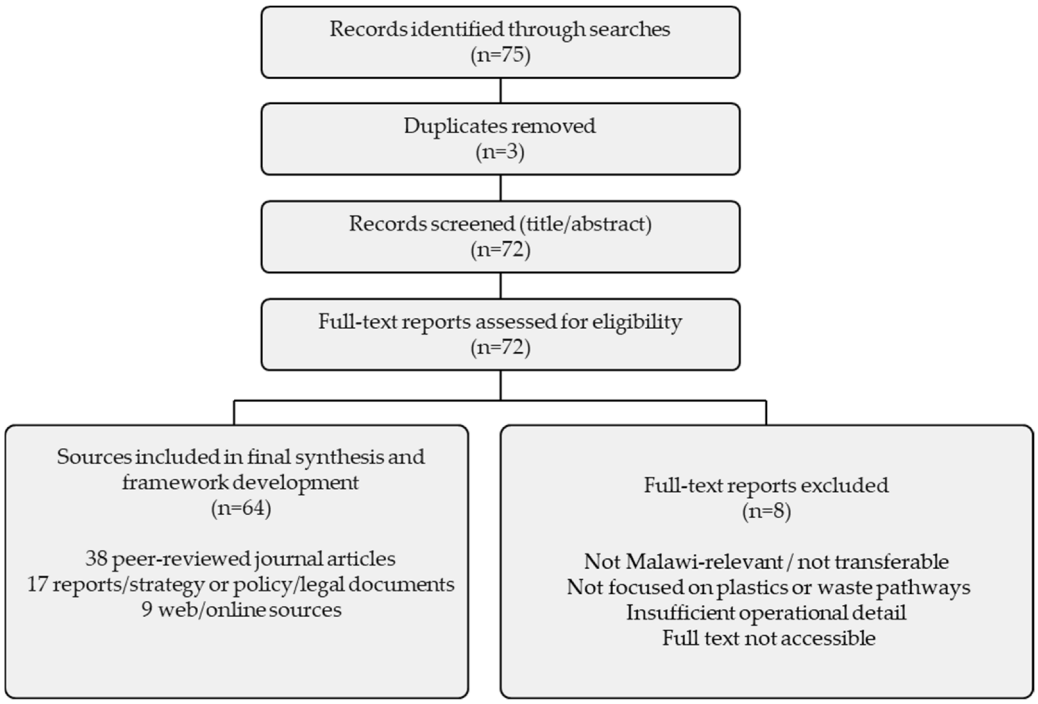


Figure A1. PRISMA-ScR flow diagram and reasons for full-text exclusion.

Table A1. Grey literature sources searched/used. Grey literature was included because it often provides implementation details (e.g., costs, service coverage, and enforcement) that are not reported in journal articles.

Source/Site (As Used in This Paper)	Ref(s).	Type of Material	Why It Was Used (What It Contributed to the Framework)
Alliance to End Plastic Waste	[5]	Grey literature/white paper	Malawi is listed as an "Undeveloped system", corresponding to Category 1 in the framework's plastic recycling maturity categories.
Lilongwe City Council/LWSP	[6]	City strategy/planning document	City-level service delivery context (solid waste–drainage linkage, operational constraints relevant to feasibility and Phase 1 actions).
Malawi Government (national policy/strategy documents)	[16,55]	National strategy/policy	National priorities and mechanisms (e.g., drain blockage, flooding, waste governance) used to justify hotspot pathways and decision variables.
The SPACES Project—Sustainable Plastic Attitudes to benefit Communities and their Environments	[23]	Project website	Used to describe the SPACES project context and its relevance to framework development, including behavioural, governance, and environmental considerations.
Malawi Government (post-disaster assessment)	[46]	Post-disaster needs assessment report (PDNA)	Evidence on flood impacts and disaster context informing seasonality and flood redistribution as hotspot mechanisms.

Table A1. *Cont.*

Source/Site (As Used in This Paper)	Ref(s).	Type of Material	Why It Was Used (What It Contributed to the Framework)
Malawi Government Gazette/legal notice	[50]	Gazette supplement/Act notice	Legal foundation for national environmental governance referenced in the institutional context section.
Blackhall's Laws of Malawi (MalawiLaws portal)	[51]	Legal summary/bulletin entry	Used to document Act details (including commencement date information) and provide accessible legal referencing.
MEPA official website	[52]	Regulator mandate web page	Used for MEPA mandate/roles (coordination, enforcement, oversight) relevant to compliance monitoring.
Overview of the Situation of Plastics (Malawi and Zimbabwe project)	[7]	Project report/overview	Background synthesis on plastics situation; used to inform Malawi-specific problem framing and intervention context.
African Clean Cities Platform (Data Book entry for Blantyre/Malawi)	[53]	City waste profile/data book	Comparable municipal waste system context and descriptors supporting governance/service feasibility discussion.
Plastic Pollution Policy Country Profile: Malawi (NI PB)	[54]	Policy brief/country profile	Summary of plastics policy context and implementation considerations used in governance/policy discussion.
MW Nation (media report on enforcement action)	[56]	News article	Used as illustrative evidence of enforcement activity (treated cautiously; informs "enforcement realism" discussion).
WHO Disease Outbreak News (Cholera—Malawi)	[42]	Outbreak report web page	Used for cholera outbreak scale/timeline to justify health relevance of hotspot risk pathways.
WHO Cholera fact sheet	[43]	Public health fact sheet	Used for general cholera transmission framing (water/sanitation link) supporting infection-relevant pathways.
FAO news release (container management scheme)	[9]	News release web page	Used for agriculture-related container return/management initiatives relevant to rural/agricultural interface interventions.
Integrated Pest Management Plan—Malawi Floods Emergency Recovery Project (MFERP)	[8]	Project plan/report	Used for pesticide/agricultural waste management context and operational considerations relevant to rural interface constraints.
Training guide for vegetable production (manual)	[11]	Training manual (PDF)	Used for agricultural/food system context (practical rural practices and settings relevant to exposure pathways).
WRC Report TT 95/98 (stormwater litter removal)	[58]	Technical report	Evidence on interception devices (booms/screens) and performance constraints informing Phase 1 interception options and feasibility.
Mr Trash Wheel website	[59]	Technology description web page	Illustrative example of interception system design logic for waterways (used as a non-peer-reviewed technical description).

Table A1. *Cont.*

Source/Site (As Used in This Paper)	Ref(s).	Type of Material	Why It Was Used (What It Contributed to the Framework)
Additional non-Malawi grey literature used to inform the conceptual design of the framework			
UNEP/Life Cycle Initiative, National Guidance for Plastic Pollution Hotspotting and Shaping Action	[25]	Intergovernmental guidance report/institutional grey literature	Used to inform the conceptual logic of plastic hotspot identification and the linking of hotspot assessment to action planning and intervention selection.
The Royal Society, Legacy Plastics: Interventions to Remove Existing Plastic from Aquatic Environments	[26]	Institutional summary report/grey literature	Used to inform clean-up prioritisation logic for existing plastics in aquatic environments, especially the consideration of feasibility, likely effectiveness, environmental impacts, and trade-offs in intervention choice.

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