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A Critical Review

Urban Solid Waste, Drainage Failure, and Flooding in a Changing Climate: Towards Integrated Waste and Water Resilience

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Abstract

Rapid urbanisation, changing consumption, and climate change are converging to make flooding one of the most damaging hazards in cities, particularly where solid waste management is weak. This review examines how uncollected and poorly disposed urban solid waste blocks drains, canals, and culverts, reduces hydraulic capacity, and transforms ordinary rainfall into damaging floods. It synthesises evidence on waste generation and composition, drainage hydraulics, flood exposure and vulnerability, public health consequences, and economic losses across cities in Africa, Asia, and Latin America, with lessons from high-income cities that have reduced risk through integrated planning. The review evaluates interventions across the waste hierarchy, drainage maintenance, green and grey infrastructure, recycling and circular economy models, community-based collection, and early warning systems, and shows that waste management is a flood management measure. It argues that resilient cities require coordinated governance that links waste, water, land use, and climate adaptation, with financing and participation that reach informal settlements and informal waste workers. The review concludes with a research and policy agenda centred on data, equity, and integrated urban systems that can reduce both waste and flood risk under future climate conditions.

Keywords: urban solid waste; flooding; drainage; climate resilience; circular economy; informal settlements; green infrastructure

1. Introduction

More than half of humanity now lives in urban areas, and urban populations are projected to grow by billions by mid-century, with most growth in Africa and Asia (United Nations, 2018; Hoornweg and Bhada-Tata, 2012). Cities concentrate people, assets, economic activity, and waste. Global municipal solid waste generation already exceeds two billion tonnes per year and is expected to rise substantially without decisive intervention (Hoornweg and Bhada-Tata, 2012; Kaza et al., 2018). At the same time, climate change is intensifying rainfall, raising sea levels, and increasing the frequency of extreme weather in many urban regions (Intergovernmental Panel on Climate Change, 2021; Intergovernmental Panel on Climate Change, 2022). The intersection of these trends creates a distinctive urban risk: waste that is not collected blocks the very drains that must convey heavier rainfall.

Flooding is already the most frequent and costly natural hazard in many cities (Jha et al., 2012; Intergovernmental Panel on Climate Change, 2022). While rivers, coasts, and topography shape flood hazard, human decisions shape exposure and vulnerability. Informal settlement on floodplains, loss of wetlands, expansion of impervious surfaces, and inadequate drainage all increase risk (Douglas et al., 2008; Jha et al., 2012). Among these drivers, solid waste is often overlooked in flood studies, treated as a sanitation issue rather than a hydrological one. Yet field

evidence from cities such as Accra, Lagos, Dhaka, Jakarta, and Mumbai consistently links waste-clogged drains to localised flooding even during moderate rainfall (Douglas et al., 2008; Lamond et al., 2012; Ahiablame and Shakya, 2016).

This review makes waste visible in flood science and policy. It asks four questions: (i) how do urban waste systems fail and how does that failure affect drainage; (ii) who is most exposed and why; (iii) what health, economic, and environmental consequences follow waste-related flooding; and (iv) which integrated interventions reduce both waste and flood risk. The review draws on peer-reviewed studies, assessments by international agencies, and city case studies, prioritising work that connects waste, drainage, and flooding rather than treating them in isolation. It is intended for students, researchers, planners, engineers, and policymakers who seek a systems view of urban resilience.

The argument is straightforward. Waste management is flood management. When waste is reduced, segregated, collected, recycled, and safely disposed, drains convey water, neighbourhoods stay drier, disease transmission falls, and cities save money on emergency response and infrastructure repair (Kaza et al., 2018; Lamond et al., 2012). Conversely, when waste accumulates in drains, even well-designed infrastructure underperforms. The review therefore treats waste, water, land, and climate as one integrated urban system, as illustrated in Figure 1.

2. Urban Waste Generation, Composition, and Collection Gaps

Urban waste generation varies with income, consumption, population density, and economic structure. High-income cities generate more waste per capita, often more than one kilogram per person per day, while low-income cities generate less per capita but face greater collection and disposal challenges (Hoornweg and Bhada-Tata, 2012; Kaza et al., 2018). Globally, organic waste remains the largest fraction in many low- and middle-income cities, often exceeding half of municipal waste, followed by plastics, paper, glass, metals, and textiles (Kaza et al., 2018; Wilson et al., 2015). This composition matters for flooding because light plastics and films are easily carried by wind and runoff into drains, while dense organics decompose, produce leachate, and attract vectors when left in drains (Wilson et al., 2015; Lamond et al., 2012).

Collection coverage is uneven. In many high-income cities, collection approaches universality, while in low-income cities collection may reach only a fraction of households, with informal settlements disproportionately underserved (Kaza et al., 2018; Wilson et al., 2015). Even where collection exists, irregular schedules, inadequate vehicles, poor road access, and weak enforcement encourage dumping in open spaces, waterways, and drains (Douglas et al., 2008; Ahiablame and Shakya, 2016). The informal sector, including waste pickers, itinerant buyers, and small recyclers, often recovers a large share of recyclables and provides livelihoods, yet is rarely integrated into formal planning (Wilson et al., 2015; Gutberlet, 2008). Ignoring informal workers wastes expertise and undermines both recycling and flood prevention.

Open dumping and burning remain common where formal disposal is absent. Dumpsites located in low-lying areas, wetlands, or near drains are especially hazardous because they leach pollutants and are themselves flooded, spreading waste across neighbourhoods (Kaza et al., 2018; Douglas et al., 2008). Plastic waste is particularly persistent; bags, bottles, and packaging that enter drains can remain for years, fragmenting and contributing to downstream pollution (Jambeck et al., 2015; Borrelle et al., 2020). The growth of single-use plastics and e-commerce packaging has increased the volume of light, bulky waste that is most likely to block drains (Borrelle et al., 2020; Lau et al., 2020).

Seasonality amplifies collection gaps. During rainy seasons, waste generation may not change, but access for collection vehicles worsens, dumpsites become waterlogged, and residents may dispose of waste in drains to clear homes quickly (Lamond et al., 2012; Ahiablame and Shakya, 2016). Festivals, markets, and construction booms produce waste pulses that overwhelm collection. Understanding these temporal patterns is essential for scheduling collection, drain cleaning, and community clean-ups before peak rainfall (Jha et al., 2012).

3. How Waste Causes Drainage Failure and Flooding

Urban drainage is designed to convey a certain flow, assuming channels are clear and roughness is within design limits. Waste violates that assumption. Plastic bags and bottles accumulate at grates, culverts, and bridge piers, forming dams that raise water levels upstream (Lamond et al., 2012; Ahiablame and Shakya, 2016). Sediment, organics, and construction debris reduce channel cross-section and increase roughness, slowing flow and promoting ponding (Douglas et al., 2008; Jha et al., 2012). In combined sewers, waste can cause overflows that release sewage and waste onto streets, compounding health risks (Jha et al., 2012).

The mechanism is not only blockage of large channels. In many neighbourhoods, small tertiary drains, gullies, and household outlets are the first to clog. When these fail, water ponds in compounds, enters homes, damages floors and belongings, and creates breeding sites for mosquitoes (Lamond et al., 2012; Douglas et al., 2008). Residents may then clear drains by dumping waste downstream, shifting the problem rather than solving it. Over time, repeated clogging and manual clearing erode channel linings, increase maintenance costs, and reduce public trust in services (Ahiablame and Shakya, 2016). Figure 1 summarises this chain from waste to flooding and the climate drivers that intensify it.

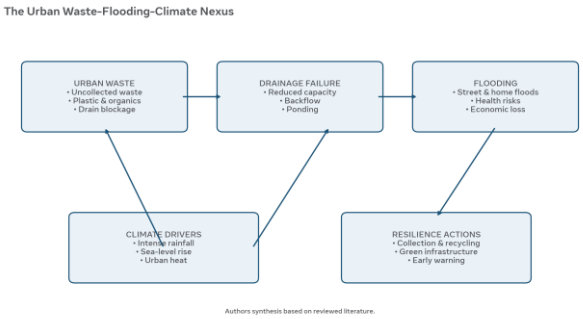


Figure 1. *The urban waste-flooding-climate nexus. Waste blocks drains, drainage failure creates flooding, and climate drivers intensify the cycle. Resilience actions break the cycle at multiple points.*

Hydrological modelling confirms the effect. Studies that simulate drainage with and without waste blockage find that

even partial blockage can substantially reduce capacity and increase flood depth and duration, especially for frequent, low-intensity storms that would otherwise be manageable (Ahiablame and Shakya, 2016; Lamond et al., 2012). Impervious surfaces compound the effect by increasing runoff volume and speed, leaving less time for drains to convey water (Jha et al., 2012; Intergovernmental Panel on Climate Change, 2022). Wetland loss removes natural storage that once buffered floods, while building on floodplains places more people directly in harm's way (Douglas et al., 2008).

Coastal cities face an additional interaction. Sea-level rise, storm surge, and high tides can prevent drainage outfalls from discharging, causing backflow that carries waste-laden water into neighbourhoods (Intergovernmental Panel on Climate Change, 2021; Jha et al., 2012). In such settings, waste in drains not only blocks flow but also contaminates floodwater with pathogens, chemicals, and sharp objects. The result is a flood that is both deeper and more hazardous than a clean-water flood of the same depth (Lamond et al., 2012).

4. Exposure, Vulnerability, and Inequality

Flood risk is not evenly distributed. Low-income households, informal settlements, and communities living near drains, canals, and low-lying land are most exposed and have fewest resources to cope (Douglas et al., 2008; Satterthwaite et al., 2020). These areas often receive the least waste collection, the least drainage maintenance, and the least investment in flood protection, creating a cycle of neglect and risk (Wilson et al., 2015; Satterthwaite et al., 2020). Women, children, older people, and people with disabilities face additional barriers to evacuation and recovery, while informal workers lose income when floods disrupt markets and transport (Intergovernmental Panel on Climate Change, 2022).

Figure 2 shows a comparative pattern across several flood-prone cities: where waste collection coverage is lower, flood vulnerability tends to be higher. The pattern is not deterministic, because topography, rainfall, and infrastructure also matter, but it reflects a consistent association reported in city studies (Douglas et al., 2008; Lamond et al., 2012; Kaza et al., 2018). Cities with strong collection, recycling, and drainage maintenance are better able to manage heavy rainfall, while cities with weak systems experience flooding even during ordinary storms.

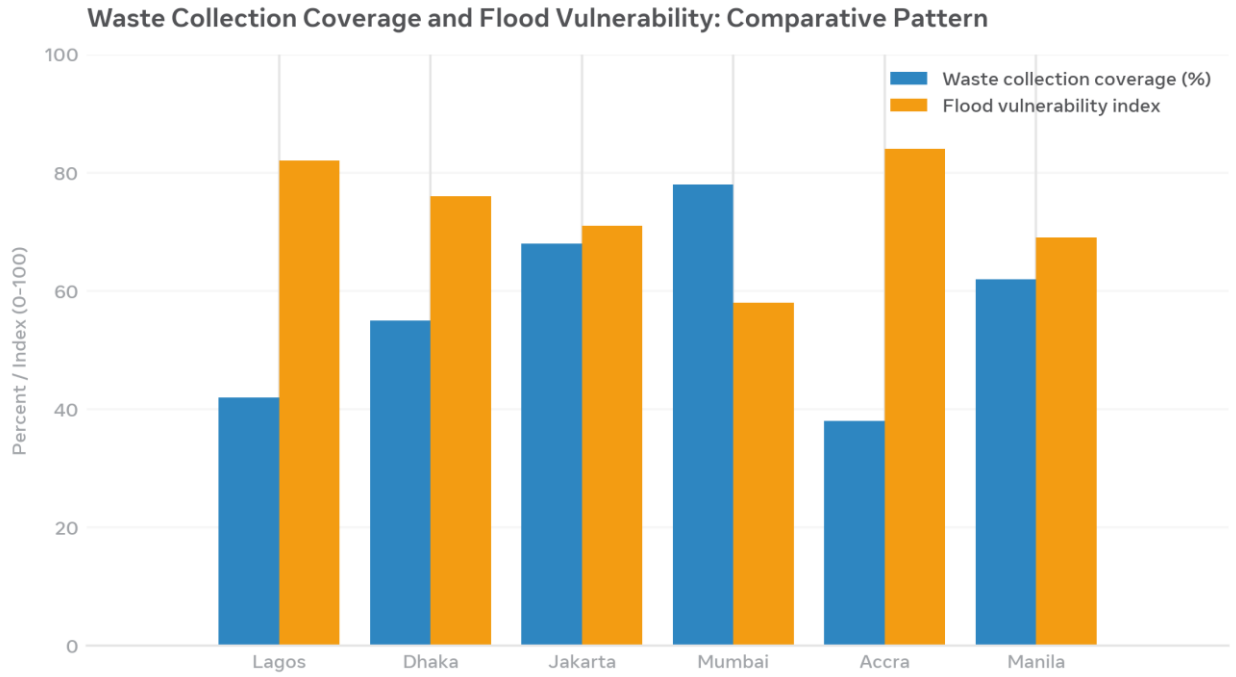


Figure 2. *Waste collection coverage and flood vulnerability: comparative pattern across selected flood-prone cities. Values summarise patterns reported in city studies and assessments reviewed in this article.*

Table 1. Flood drivers and waste contributions by city type. Authors synthesis.

City type	Dominant flood driver	Waste contribution	Priority action
Coastal megacity	Sea-level rise, storm surge, intense rain	Drain blockage, backflow of waste-laden water	Outfall protection, collection, early warning
Inland river city	River overflow, flash floods	Channel and culvert blockage	River clean-up, buffer zones, maintenance
Hillside / informal city	Flash floods, landslides	Dumping on slopes, blocked gullies	Community collection, slope stabilisation
Arid / semi-arid city	Infrequent intense storms	Sediment and waste in wadis and drains	Stormwater retention, waste control

Group	Exposure	Consequence	Support needed
Informal settlement residents	Homes near drains and floodplains	Property loss, displacement, disease	Secure tenure, services, early warning

Waste pickers / informal workers	Work in dumps and drains	Injury, infection, income loss	Protective equipment, integration, social protection
Market traders	Stalls near drains and roads	Stock loss, market closure	Drainage, storage, insurance
Children and older people	Limited mobility, school disruption	Health risks, missed schooling	Safe shelters, health services

Tenure insecurity deepens vulnerability. Residents without formal tenure may be reluctant to invest in home protection or to demand services, fearing eviction, while authorities may be reluctant to invest in areas deemed informal (Satterthwaite et al., 2020; Douglas et al., 2008). Migrants and newcomers, who often settle in the most affordable and flood-prone areas, may lack local knowledge of flood patterns and social networks that aid recovery (Jha et al., 2012). Addressing flood risk therefore requires addressing land, housing, and service rights, not only engineering (Satterthwaite et al., 2020).

Table 1 compares flood drivers and waste-related contributions across city types, while Table 2 summarises who is affected and how. Together they show that technical solutions must be paired with social inclusion if they are to reduce risk for those most in need.

Economic losses include damage to homes, roads, drains, and businesses, lost working days, and costs of clean-up and repair (Jha et al., 2012; Kaza et al., 2018). For low-income households, a single flood can destroy savings, force borrowing, and push families deeper into poverty (Satterthwaite et al., 2020). For cities, repeated small floods, often ignored in disaster statistics, can cumulatively exceed the cost of a single large flood because they erode infrastructure and deter investment (Douglas et al., 2008). Waste-related floods also increase municipal costs: emergency drain clearing, waste removal, and public health campaigns divert budgets from prevention (Kaza et al., 2018).

Environmental consequences extend beyond the flooded neighbourhood. Floods mobilise waste from drains and dumps into rivers, lakes, and coastal waters, spreading plastics, organics, and hazardous materials (Jambeck et al., 2015; Borrelle et al., 2020). This pollution harms aquatic ecosystems, fisheries, and drinking water sources, and undermines tourism and recreation (Jambeck et al., 2015). After floods, waste deposited on land can contaminate soils and groundwater, while open burning of flood waste releases air pollutants (Kaza et al., 2018). The waste-flood cycle thus connects urban sanitation to wider environmental quality.

6. Integrated Interventions: Waste, Drainage, and Green Infrastructure

Effective action follows the waste hierarchy: prevent waste, reuse, recycle, recover, and safely dispose of residuals (Kaza et al., 2018; Wilson et al., 2015). Prevention through reduced single-use plastics, product design, and consumer awareness reduces the volume of light waste most likely to block drains (Borrelle et al., 2020; Lau et al., 2020). Segregation at source, where households separate organics, recyclables, and residuals, improves recycling, reduces contamination, and makes collection more efficient (Wilson et al., 2015; Gutberlet, 2008). Composting of organics, which dominate waste in many cities, can reduce landfill burden and produce soil conditioner, while anaerobic digestion can generate energy (Kaza et al., 2018).

Collection must be regular, inclusive, and adapted to local conditions. In dense informal settlements, primary collection by community groups using handcarts, tricycles, or small vehicles can bridge the gap where large trucks cannot reach, transferring waste to secondary collection points (Wilson et al., 2015; Gutberlet, 2008). Integrating informal recyclers into formal systems, with fair pay, safety equipment, and recognition, improves recycling rates and livelihoods (Gutberlet, 2008; Wilson et al., 2015). Extended producer responsibility, deposit-return schemes, and pay-as-you-throw systems can shift costs and incentives toward waste reduction and recycling (Lau et al., 2020; Kaza et al., 2018).

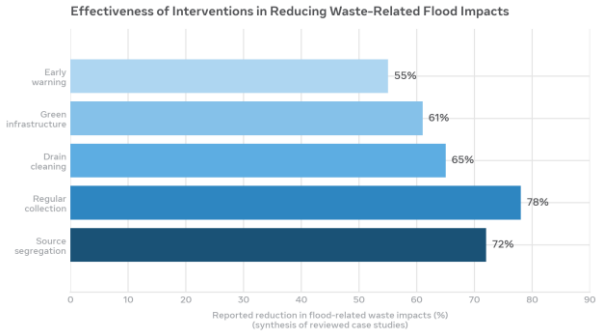
Drainage maintenance is a direct flood measure. Regular cleaning before rainy seasons, clearing of grates and culverts, and enforcement against dumping in drains can restore capacity at low cost relative to new construction (Ahiablame and Shakya, 2016; Lamond et al., 2012). Community drain cleaning programmes, when paired with collection so that removed waste is not dumped downstream, can be effective and build ownership (Douglas et al., 2008). Digital tools, including mobile reporting, geographic information systems, and sensors that monitor drain levels, can prioritise maintenance and warn of blockages (Jha et al., 2012).

Green infrastructure complements grey infrastructure by slowing, storing, and infiltrating runoff. Permeable pavements, bioswales, rain gardens, green roofs, urban wetlands, and restored floodplains reduce peak flows and trap waste before it enters drains (Ahiablame and Shakya, 2016; Fletcher et al., 2015). These measures also provide co-benefits: cooling, biodiversity, recreation, and improved air quality (Fletcher et al., 2015; Intergovernmental Panel on Climate Change, 2022). In dense cities, even small interventions, such as tree pits, planter boxes, and pocket parks, can help if maintained and protected from waste dumping (Fletcher et al., 2015).

Early warning and emergency preparedness save lives. Forecasts, flood maps, and community warning systems that reach residents in local languages and through trusted channels enable evacuation and protection of belongings (Jha et al., 2012; Intergovernmental Panel on Climate Change, 2022). Pre-positioned clean-up equipment, safe shelters, and health services reduce post-flood disease. After floods, rapid waste removal and disinfection prevent secondary health crises (Lamond et al., 2012). Figure 3 summarises the relative effectiveness of interventions reported across reviewed case studies, with regular collection

and source segregation showing the strongest reductions in waste-related flood impacts.

Figure 3. Effectiveness of interventions in reducing waste-related flood impacts. Values summarise patterns across reviewed case studies; effectiveness varies by city context and implementation quality.



Fragmented governance is a major barrier. Waste is often managed by one agency, drainage by another, land use by a third, and climate adaptation by a fourth, with little coordination (Jha et al., 2012; Satterthwaite et al., 2020). Integrated planning requires shared data, joint budgets, and clear accountability for drains, collection, and flood protection (Kaza et al., 2018). Cities that have reduced waste-related flooding, such as through integrated solid waste and stormwater programmes, typically have strong mayoral leadership, inter-agency coordination, and community partnerships (Lamond et al., 2012; Wilson et al., 2015).

Finance must shift from emergency response to prevention. Investing in collection,

8. Future Research and Policy Agenda

recycling, drainage maintenance, and green infrastructure is often cheaper than repeated flood repair, yet prevention is harder to fund because benefits are diffuse and long-term (Jha et al., 2012; Kaza et al., 2018). Climate finance, development assistance, and private investment can help if projects demonstrate both waste and flood benefits (Intergovernmental Panel on Climate Change, 2022). Cost recovery through user fees must be designed equitably, so that low-income households are not excluded from services (Satterthwaite et al., 2020).

Community participation is essential. Residents know where drains clog, where waste accumulates, and where floods occur first (Douglas et al., 2008). Participatory mapping, citizen reporting, and community clean-ups generate data and ownership, while education in schools and markets can change disposal behaviour (Gutberlet, 2008; Lamond et al., 2012). However, participation must not become a substitute for state responsibility; communities should not be expected to clean drains indefinitely without collection, equipment, and payment (Satterthwaite et al., 2020). Table 3 summarises interventions, strengths, and limitations.

Table 3. Interventions for waste-related flooding: strengths and limitations.

Intervention	Strengths	Limitations / needs
Source segregation & recycling	Reduces drain waste, creates jobs	Requires awareness, markets for recyclables
Regular inclusive collection	Prevents accumulation, protects drains	Cost, access in informal areas
Drain cleaning & maintenance	Restores capacity quickly	Needs collection for removed waste, repeat effort
Green infrastructure	Slows runoff, multiple co-benefits	Land, maintenance, waste protection
Early warning & preparedness	Saves lives, reduces losses	Needs trust, reach, and safe shelters
Circular economy policies	Reduces waste at source	Requires regulation, industry cooperation

9. Conclusion

Urban waste and flooding are not separate problems. Uncollected waste blocks drains, blocked drains create floods, and floods spread waste, disease, and economic loss, with climate change intensifying the cycle (Douglas et al., 2008; Lamond et al., 2012; Intergovernmental Panel on Climate Change, 2022). The evidence reviewed here shows that integrated action works: reducing waste, improving collection and recycling, maintaining drains, investing in green infrastructure, and strengthening early warning can substantially reduce flood risk, especially for vulnerable communities (Kaza et al., 2018; Fletcher et al., 2015; Wilson et al., 2015). The challenge is not lack of knowledge but lack of coordination, finance, and inclusion. Cities that treat waste management as flood management, and that govern waste, water, land, and climate together, will be better prepared for a wetter, more urban future. Protecting drains from waste is a simple, powerful step toward safer, cleaner, and more resilient cities.

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