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Linkages Between Solid Waste Management, Landfill Leachate, Wastewater, and Surface Water Pollution: An Integrated Review

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Abstract: Rapid urbanisation, population growth, and changing consumption patterns have resulted in a substantial increase in municipal solid waste generation worldwide. While solid waste management (SWM) has conventionally been addressed as a sector-specific urban service focused on collection, treatment, and disposal, growing scientific evidence suggests that improperly managed solid waste exerts far-reaching environmental impacts that extend well beyond disposal sites. In particular, interactions between solid waste, landfill leachate, urban wastewater systems, stormwater runoff, and surface water bodies create complex and often under-recognised pollution pathways. These interactions are especially pronounced in cities of developing regions, where inadequate waste segregation, poorly engineered landfills, limited wastewater treatment capacity, and dense drainage networks coexist. This integrated review synthesises existing literature on the formation and evolution of landfill leachate, its chemical and biological characteristics, and the mechanisms by which solid waste-derived contaminants are transferred into urban wastewater and surface water systems. The role of hydrological processes, including runoff, drainage connectivity, and seasonal rainfall, is examined as a critical driver of pollutant mobilisation and transport. The review further analyses the cumulative impacts of these interconnected pathways on surface water quality, aquatic ecosystems, and public health. By bridging disciplinary boundaries between solid waste management, wastewater engineering, hydrology, and urban environmental governance, this paper argues for a transition from sectoral waste management toward integrated urban environmental management frameworks. Key research gaps and policy implications are identified, highlighting the need for coordinated planning and governance to mitigate the growing burden of urban aquatic pollution.

***Index Terms* -** Solid waste management; landfill leachate; urban wastewater; runoff; surface water pollution; integrated environmental management.

I. INTRODUCTION

1. INTRODUCTION: BEYOND SECTORAL WASTE MANAGEMENT

Beyond Sectoral Waste Management Recent global assessments highlight the rapid growth of urban solid waste and the need for integrated waste–water governance frameworks (Kaza et al., 2018; UN-Habitat, 2020; Batool & Choudhary, 2009). Urban solid waste management has emerged as one of the most pressing environmental challenges of the twenty-first century. Accelerated urbanisation, economic development, and changing lifestyles have significantly increased the quantity and complexity of municipal solid waste streams. Historically, SWM has been conceptualised as a discrete service sector, primarily concerned with waste collection efficiency, disposal technologies, and compliance with public health regulations. This sectoral approach, while operationally convenient, has increasingly proven inadequate for addressing the broader environmental consequences of waste mismanagement.

Recent studies demonstrate that the impacts of solid waste extend well beyond land-based pollution, interacting dynamically with urban wastewater systems, drainage networks, and surface water bodies. In many cities, especially in low- and middle-income countries, waste is often stored in open areas, disposed of informally, or deposited in poorly engineered landfills. During rainfall events, contaminants from these waste sources are mobilised and transported into drains, sewers, and natural watercourses, contributing to widespread aquatic pollution (Naveen et al., 2018; Müller et al., 2020; Abubakar et al., 2022). The traditional separation of responsibilities between waste management agencies and water or sanitation departments has further exacerbated this problem. Solid waste policies often fail to account for downstream water quality impacts, while wastewater management strategies rarely consider solid waste as a significant diffuse pollution source. As a result, cumulative pollutant loads entering surface waters are underestimated, and mitigation measures remain fragmented.

This review adopts an integrated perspective to examine the linkages between solid waste management, landfill leachate generation, wastewater contamination, runoff processes, and surface water pollution. By synthesising insights from multiple disciplines, it aims to highlight the need for holistic urban environmental management approaches capable of addressing interconnected pollution pathways.

Figure 1: Conceptual Framework of Pollution Pathways from Solid Waste to Surface Water

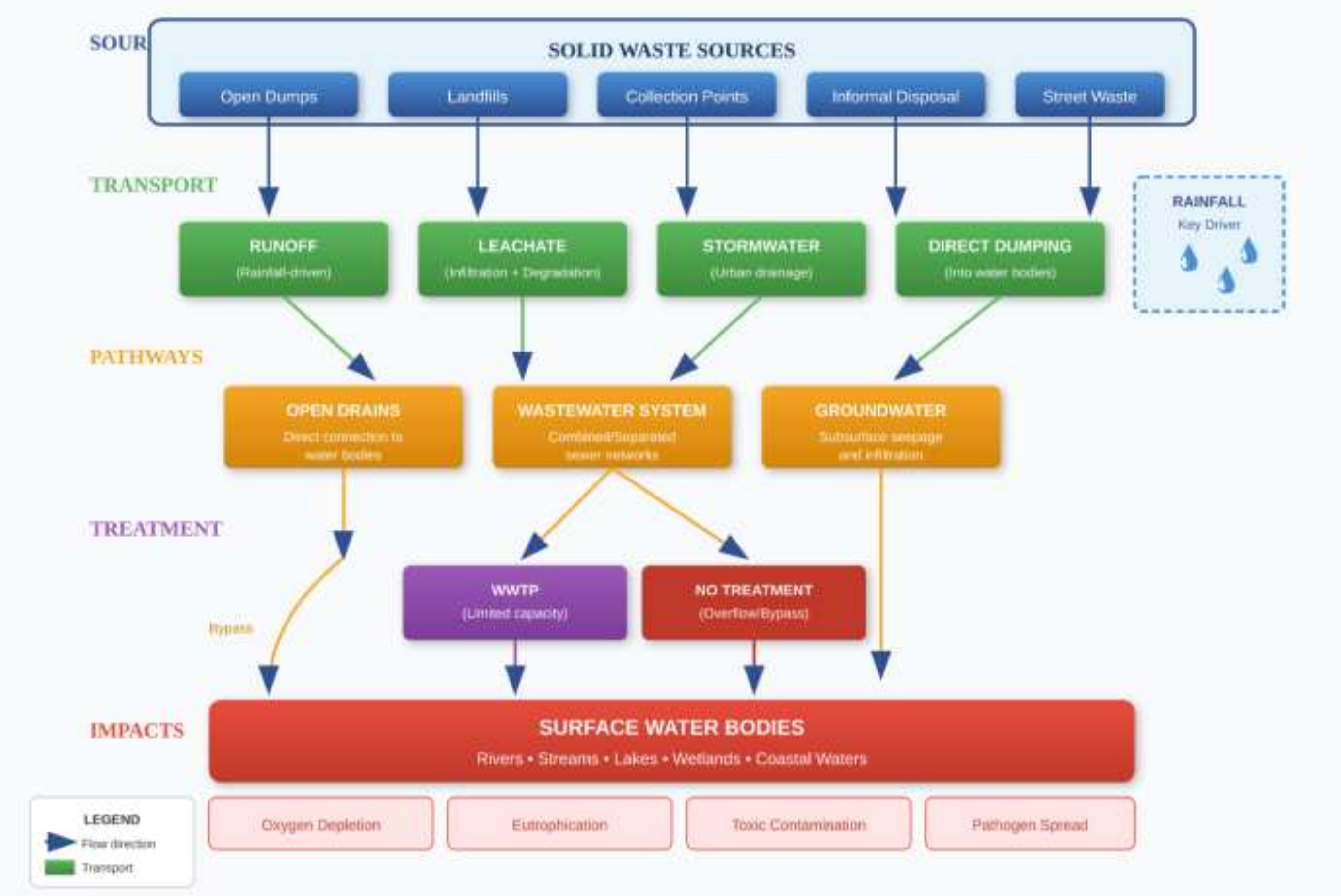

Figure 1 presents a conceptual framework illustrating the interconnected pollution pathways through which solid waste-derived contaminants reach surface water bodies. The diagram traces pollutant flows from primary waste sources (open dumps, landfills, collection points, informal disposal sites, and street waste) through various transport mechanisms (runoff, leachate, stormwater, and direct dumping) into intermediate pathways (open drains, wastewater systems, and groundwater). The framework highlights how these pathways converge at surface water bodies, with or without passing through treatment systems, ultimately causing impacts such as oxygen depletion, eutrophication, toxic contamination, and pathogen spread.

Rainfall is identified as a key driver that intensifies pollutant mobilisation across all pathways. This integrated perspective forms the foundation for the subsequent detailed discussion of each component.

2. Formation and Evolution of Landfill Leachate

Previous studies demonstrate that climatic conditions, landfill design, and waste composition strongly influence leachate generation and evolution over time (El-Fadel et al., 1997; Renou et al., 2008). Landfill leachate is one of the most significant environmental by-products of solid waste disposal. It is generated when water percolates through waste layers and dissolves soluble components, entrains suspended solids, and undergoes biochemical interactions with decomposing organic matter. The sources of leachate include precipitation infiltration, surface runoff entering landfill cells, groundwater intrusion, moisture inherent in waste, and water produced during biochemical degradation processes (Kjeldsen et al., 2002).

2.1 Factors Influencing Leachate Generation

Several interrelated factors influence the quantity and quality of landfill leachate. Waste composition plays a central role, as organic-rich waste generates higher moisture and biochemical activity, leading to greater leachate volumes and pollutant concentrations. Climatic conditions, particularly rainfall intensity and duration, strongly affect leachate production, with humid and monsoon-dominated regions experiencing higher leachate generation rates. Landfill design and operational practices are equally critical. Engineered landfills equipped with liners, leachate collection systems, and covers can significantly reduce uncontrolled leachate migration. In contrast, open dumps and poorly managed landfills, common in many developing countries, allow leachate to infiltrate surrounding soils, groundwater, and drainage systems without treatment (Siddiqua et al., 2022).

Table 1: Leachate Characteristics Across Landfill Degradation Phases

Parameter	Acidogenic Phase (Young Landfill)	Methanogenic Phase (Intermediate)	Stable Phase (Mature Landfill)
pH	4.5–6.0	6.5–7.5	7.0–8.0
BOD (mg/L)	10,000–40,000	1,000–4,000	50–200
COD (mg/L)	20,000–60,000	3,000–15,000	500–3,000
BOD/COD Ratio	0.5–0.8	0.1–0.3	<0.1
Ammonia-N (mg/L)	500–1,500	500–2,000	100–500
Heavy Metals	High (mobile)	Moderate	Low (immobilised)
VFAs	High	Low	Very Low
Color	Dark Brown	Brown	Light Brown

Note: VFAs = Volatile Fatty Acids. Values are indicative ranges compiled from literature.

The temporal evolution of leachate composition across landfill phases has significant implications for environmental risk assessment and treatment system design. Table 1 summarises the characteristic ranges of key leachate parameters during the acidogenic (young), methanogenic (intermediate), and stable (mature) phases of landfill degradation. As evident from the table, young landfills generate highly acidic leachate (pH 4.5–6.0) with extremely high organic loads (BOD 10,000–40,000 mg/L), whereas mature landfills produce near-neutral leachate with substantially lower biodegradable content but persistent ammonia levels. The BOD/COD ratio serves as a useful indicator of biodegradability: ratios above 0.5 indicate readily biodegradable leachate amenable to biological treatment, while ratios below 0.1 suggest recalcitrant organic matter requiring advanced physico-chemical treatment approaches.

2.2 Temporal Evolution of Leachate

Leachate composition evolves as waste undergoes successive stages of decomposition. Young landfills typically produce acidic leachate with high concentrations of biodegradable organic matter, volatile fatty acids, and dissolved solids. As microbial processes advance toward methanogenesis, leachate pH increases, biodegradable organic matter declines, and refractory compounds such as humic and fulvic acids become dominant (Mohammad et al., 2022). This temporal evolution has important implications for environmental risk assessment and treatment system design. While older leachate may exhibit lower organic strength, it often contains high levels of ammoniacal nitrogen and persistent organic pollutants, posing long-term contamination risks.

3. Chemical and Biological Characteristics of Leachate

The complexity of leachate chemistry and microbiology has been widely documented, including heavy metal mobility, emerging contaminants, and diverse microbial consortia (Christensen et al., 2001; Li et al., 2021; Sekhohola-Dlamini & Tekere, 2020). Landfill leachate is a chemically complex and highly variable effluent. Its composition reflects the heterogeneity of municipal solid waste, encompassing organic, inorganic, and biological constituents with diverse environmental impacts.

3.1 Chemical Characteristics

Key chemical parameters commonly reported in leachate include biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), ammonia-nitrogen, chloride, sulfate, and electrical conductivity. High BOD and COD values indicate the presence of oxygen-demanding organic matter, which can severely degrade receiving water quality if discharged untreated. Heavy metals such as iron, zinc, lead, copper, cadmium, and chromium are frequently detected in leachate. Their concentrations depend on waste composition, pH, redox conditions, and landfill age. Acidic conditions enhance metal solubility, increasing the likelihood of leaching and transport into aquatic systems (Li et al., 2021). In addition to conventional pollutants, leachate may contain a wide range of xenobiotic organic compounds, including pharmaceuticals, pesticides, plastic additives, and industrial chemicals. These emerging contaminants raise particular concern due to their persistence, toxicity, and potential to disrupt endocrine systems.

3.2 Biological Characteristics

Biological processes within landfills play a crucial role in shaping leachate composition. Microbial consortia comprising bacteria, archaea, and fungi drive the sequential breakdown of organic matter through hydrolysis, fermentation, acetogenesis, and methanogenesis. Syntrophic interactions between microbial groups enable the degradation of complex substrates that individual organisms cannot metabolise alone (Sekhohola-Dlamini and Tekere, 2020).

Leachate may also contain pathogenic microorganisms and antibiotic-resistant genes, originating from household, healthcare, and animal waste. When leachate enters wastewater systems or surface waters without adequate treatment, these biological contaminants pose significant public health risks.

4. Interaction of Solid Waste with Urban Wastewater Systems

Urban drainage connectivity and combined sewer systems have been shown to intensify the transfer of waste-derived contaminants into wastewater networks (Butler & Davies, 2011; Mekonnen & Hoekstra, 2020). Urban wastewater systems frequently act as secondary transport pathways for solid waste-derived contaminants. In many cities, wastewater consists of a mixture of domestic sewage, industrial effluents, stormwater runoff, and drainage flows that intersect with waste handling and disposal sites.

Table 2 summarises the principal pathways through which solid waste-derived contaminants are transferred into surface water bodies. As the table illustrates, each waste source is associated with distinct transport mechanisms and intermediate media before reaching receiving waters. Open dumps, which lack containment infrastructure, release pollutants primarily through surface runoff that enters open drains and ultimately reaches rivers. Landfills, even when partially engineered, generate leachate that may seep into wastewater networks or groundwater before emerging in streams. Waste collection points, often located near roadways and drainage infrastructure, contribute contaminants via stormwater flows that can cause sewer overflows during heavy rainfall, impacting lakes and other standing water bodies. Understanding these pathway-specific dynamics is essential for designing targeted interventions at critical transfer points.

Table 2. Major Pathways Linking Solid Waste to Surface Water Pollution

Waste Source	Transport Mechanism	Intermediate Medium	Receiving Water
Open dumps	Runoff	Drains	Rivers
Landfills	Leachate seepage	Wastewater	Streams
Collection points	Stormwater	Sewer overflow	Lakes

4.1 Waste-Derived Contaminants in Wastewater

Unsegregated waste storage, roadside dumping, open collection points, and informal disposal practices allow organic matter, nutrients, suspended solids, and metals to be mobilised into wastewater during rainfall events. Studies have reported significantly higher pollutant concentrations in wastewater collected downstream of waste disposal zones compared to background urban wastewater (Naveen et al., 2018; Mekonnen et al., 2020). In combined sewer systems, stormwater and sewage are conveyed together, increasing the likelihood of untreated discharges during high-flow events. Even in separated systems, illegal connections and poorly maintained drains can introduce waste-derived pollutants into sewage networks.

4.2 Wastewater Treatment Limitations

Wastewater treatment plants are typically designed to handle domestic sewage and predictable industrial loads. The influx of solid waste-derived contaminants—particularly high-strength organic matter, ammonia, and toxic substances—can overwhelm treatment capacity and reduce removal efficiency. As a result, partially treated or untreated wastewater may be discharged into surface waters, amplifying pollution impacts.

5. Role of Runoff, Drainage, and Seasonal Rainfall

Runoff processes, stormwater infrastructure, and climate extremes significantly influence pollutant mobilisation and transport in urban environments (Fletcher et al., 2015; IPCC, 2022). Hydrological processes play a central role in linking solid waste, leachate, wastewater, and surface water pollution. Rainfall acts as a mobilising force, transforming solid waste into a diffuse pollution source.

5.1 Runoff and Drainage Connectivity

Surface runoff generated during rainfall events washes waste-derived contaminants from streets, dumpsites, and landfill surfaces into drainage channels. Open drains, common in many cities, provide direct pathways to rivers and lakes. Where drainage systems are poorly designed or maintained, pollutants bypass wastewater treatment entirely.

5.2 Seasonal Rainfall and Extreme Events

Seasonal rainfall patterns, particularly monsoon precipitation, significantly influence wastewater interactions. Increased rainfall enhances leachate generation, dilutes some pollutants, but increases overall contaminant loads due to greater volumes. Siddiqi et al. (2022) demonstrated that rainfall alters leachate pollution indices, highlighting the dynamic nature of contamination. Hill towns and mountainous regions are especially vulnerable due to steep slopes and short hydrological pathways that rapidly convey pollutants into surface waters (Parvin et al., 2021). Figure 2 illustrates the dramatic seasonal variation in pollutant loading from waste sources, comparing relative concentrations during dry and wet (monsoon) seasons. The bar chart reveals that pollutant mobilisation increases by 3–6 fold during monsoon periods across all major parameters. Total suspended solids (TSS) show the most pronounced increase (approximately 6.5 times), reflecting the enhanced erosion and particulate transport during heavy rainfall events. Similarly, pathogen loads increase substantially (over 6 times) due to the washing of faecal contamination from waste deposits

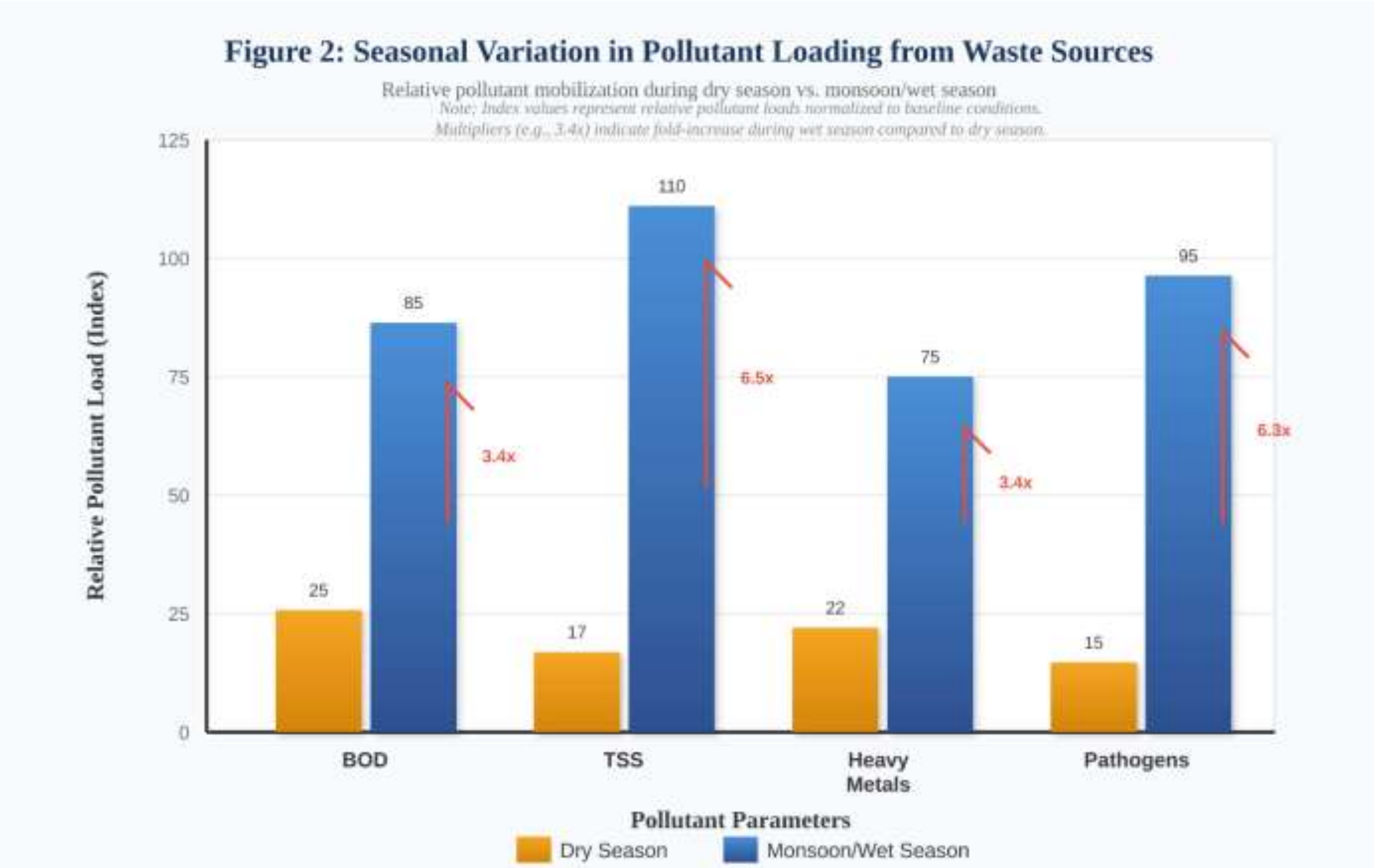

Figure 2: Seasonal Variation in Pollutant Loading from Waste Sources

into drainage systems. BOD and heavy metal concentrations also exhibit significant seasonal amplification (3–4 times), underscoring the critical importance of monsoon-specific management strategies. These findings have direct implications for the design of treatment systems, which must accommodate not only higher volumes but also substantially elevated pollutant concentrations during wet seasons.

6. Impacts on Surface Water Quality

Diffuse pollution from solid waste and urban runoff represents a major driver of surface water degradation and ecological stress (Carpenter et al., 1998; Igwegbe et al., 2024). The cumulative discharge of landfill leachate, contaminated wastewater, and runoff exerts severe pressure on surface water systems. Organic pollution increases biochemical oxygen demand, leading to oxygen depletion and fish mortality. Nutrient enrichment promotes eutrophication, algal blooms, and subsequent hypoxic conditions. Table 3 highlights the dominant pollutants originating from solid waste and their effects on surface water quality and aquatic ecosystems. The table reveals distinct source-impact relationships: organic waste drives oxygen depletion through elevated COD and BOD loads, while food waste decomposition releases ammonia that exhibits direct aquatic toxicity. Electronic waste (e-waste) contributes to heavy metals that bioaccumulate through food chains, posing long-term ecological and human health risks. Mixed municipal waste, containing organic matter, healthcare waste, and animal waste, serves as a reservoir for pathogens that cause waterborne disease transmission. Recognising these specific source-pollutant-impact chains is essential for designing targeted source reduction and treatment strategies.

Table 3. Key Pollutants Associated with Solid Waste–Water Interactions

Pollutant	Primary Source	Environmental Impact
COD/BOD	Organic waste	Oxygen depletion
Ammonia	Food waste	Aquatic toxicity
Heavy metals	E-waste	Bioaccumulation
Pathogens	Mixed waste	Disease transmission

Table 3 highlights dominant pollutants originating from solid waste and their effects on surface water quality and aquatic ecosystems.

Heavy metals and persistent organic pollutants pose chronic toxicity risks, bioaccumulating in aquatic organisms and entering the human food chain. Pathogens introduced through wastewater and leachate contamination increase the incidence of waterborne diseases, particularly in communities reliant on untreated surface water for domestic use. Importantly, studies increasingly recognise that diffuse waste-derived inputs can rival or exceed point-source discharges in terms of total pollutant load, particularly in rapidly urbanising regions (Igwegbe et al., 2024).

7. Integrated Urban Environmental Management Approaches

Integrated urban environmental management, supported by circular economy principles and life-cycle thinking, is increasingly recognised as essential for sustainable waste–water systems (Brown et al., 2009; Kirchherr et al., 2017; Zaman et al., 2022). Addressing the interconnected impacts of solid waste, leachate, wastewater, and surface water pollution requires integrated urban environmental management frameworks. Such approaches move beyond isolated sectoral interventions to consider material flows, hydrological pathways, and institutional coordination.

7.1 Infrastructure Integration

Key measures include source segregation to reduce leachate toxicity, engineered landfills with effective leachate collection and treatment systems, and the separation of stormwater and sewage networks. Coordinated planning of waste facilities and drainage infrastructure can significantly reduce pollutant mobilisation.

7.2 Circular Economy and Life-Cycle Thinking

Circular economy principles emphasise waste reduction, material recovery, and resource efficiency, reducing the volume and toxicity of waste entering disposal sites. Life-cycle assessment provides a valuable tool for evaluating environmental trade-offs across waste management options (Zaman et al., 2022).

7.3 Governance and Public Participation

Effective governance is essential for integration. This includes cross-sectoral coordination, clear regulatory frameworks, and robust monitoring systems. Public participation and behavioural change, supported by education and incentives, further enhance system effectiveness. Drawing together the insights from the preceding discussion, Table 4 presents a comprehensive framework for integrated urban environmental management addressing the wastewater nexus. The framework identifies six key domains of intervention—infrastructure, monitoring, policy, technology, governance, and community—each with specific actions and expected outcomes. This multi-dimensional approach recognises that technical solutions alone are insufficient; effective management requires concurrent attention to institutional coordination, regulatory coherence, and public engagement. The framework is intended to guide policymakers and practitioners in developing context-specific strategies that address the interconnected nature of waste and water challenges.

Implementation of this framework requires prioritisation based on local conditions. In cities with severe infrastructure deficits, investments in engineered landfills and separated drainage systems may yield the greatest immediate benefits. In contexts where physical infrastructure exists but coordination is lacking, governance reforms and cross-sectoral monitoring may be more impactful. Community engagement is universally important, as source-level waste segregation reduces pollutant loads throughout the downstream chain. The expected outcomes listed in the table provide measurable targets against which progress can be evaluated.

Table 4: Framework for Integrated Urban Environmental Management

Domain	Key Actions	Expected Outcomes
Infrastructure	Integrate waste, drainage, and wastewater systems	Reduced pollutant bypass; improved treatment efficiency
Monitoring	Establish cross-sectoral monitoring networks	Real-time data for early warning and response
Policy	Develop unified environmental regulations	Coherent standards across wastewater domains
Technology	Adopt nature-based solutions and advanced treatment	Enhanced removal of emerging contaminants
Governance	Create inter-departmental coordination bodies	Break down institutional silos
Community	Promote waste segregation and public awareness	Reduced waste loads at source

8. Research Gaps and Policy Implications

Recent policy-oriented literature emphasises the need for coordinated governance, long-term monitoring, and climate-resilient planning (OECD, 2020; IPCC, 2022). Despite growing recognition of SWM–water linkages, significant research gaps remain that warrant urgent attention from the scientific community and policymakers alike.

8.1 Critical Research Gaps

8.1.1 Limitations in Integrated Monitoring Systems

Long-term, integrated monitoring of waste, leachate, wastewater, and surface water systems remains severely limited, particularly in developing regions where the wastewater nexus poses the greatest challenges. Most existing monitoring programmes operate within sectoral silos, measuring wastewater quality parameters independently of upstream waste disposal activities. This fragmented approach fails to capture the dynamic interactions between waste sources and receiving water bodies. There is an urgent need for synchronised monitoring networks that track pollutant flows from generation through transport to final deposition in aquatic ecosystems.

8.1.2 Quantification of Cumulative Pollutant Loads

Few studies have attempted to quantify cumulative pollutant loads across multiple pathways—from landfill leachate, direct runoff, wastewater discharge, and groundwater seepage—to determine their relative contributions to surface water contamination. Mass balance studies that account for all input sources are essential for prioritising intervention strategies. Furthermore, the fate and transport of emerging contaminants (pharmaceuticals, microplastics, per- and polyfluoroalkyl substances) through these interconnected pathways remain poorly understood and require dedicated investigation.

8.1.3 Climate Change Interactions

Limited research exists on modelling wastewater interactions under extreme rainfall scenarios and projected climate change conditions. As monsoon patterns shift and extreme precipitation events become more frequent, the dynamics of leachate generation, runoff intensity, and pollutant mobilisation will change substantially. Predictive models that integrate climate projections with hydrological and waste management parameters are critically needed to inform climate-resilient infrastructure planning. This is particularly relevant for hill towns and mountainous regions, such as those in the Himalayan belt, where steep topography accelerates pollutant transport.

8.1.4 Socio-Economic Dimensions

The socio-economic dimensions of wastewater pollution linkages require greater attention. Communities living near dumpsites, along polluted drains, or downstream of waste facilities often bear disproportionate health and environmental burdens. Environmental justice frameworks should be integrated into research designs to understand differential vulnerability and inform equitable policy responses. Additionally, the economic costs of inaction—including healthcare expenditures, loss of ecosystem services, and reduced property values—need systematic quantification to build the case for integrated management investments.

8.1.5 Technology and Treatment Gaps

Research on cost-effective treatment technologies suitable for combined waste–leachate–stormwater streams in resource-constrained settings is lacking. While advanced treatment methods exist for separate waste streams, integrated solutions that can handle the variable composition and shock loads characteristic of monsoon-driven pollution events remain underdeveloped. Nature-based solutions, including constructed wetlands and bioretention systems, show promise but require further validation across diverse climatic and socio-economic contexts.

8.2 Policy Implications

From a policy perspective, the findings of this review highlight the urgent need to move beyond fragmented regulations toward integrated urban environmental governance. Several key implications emerge:

8.2.1 Regulatory Integration

Solid waste policies should explicitly address downstream water quality impacts through mandatory environmental impact assessments that trace pollution pathways to receiving water bodies. Conversely, water quality regulations should formally recognise solid waste as a significant diffuse pollution source, establishing discharge standards that account for waste-derived contaminant loads. The development of unified environmental quality standards that span waste, wastewater, and surface water domains would provide a coherent regulatory foundation for integrated management.

8.2.2 Institutional Coordination

Breaking down institutional silos between municipal corporations (responsible for waste), public health engineering departments (responsible for water supply and sewerage), and pollution control boards (responsible for environmental monitoring) is essential. Inter-departmental coordination mechanisms, such as joint planning committees or unified urban environment authorities, should be established at municipal and state levels. Clear protocols for information sharing, joint inspections, and coordinated enforcement would enhance regulatory effectiveness.

8.2.3 Infrastructure Investment Priorities

Investment in infrastructure should prioritise projects that deliver co-benefits across waste and water sectors. Engineered landfills with robust leachate collection and treatment systems, separated stormwater and sewage networks, and decentralised wastewater treatment facilities near waste hotspots represent high-impact interventions. Urban planning frameworks should mandate buffer zones between waste facilities and water bodies, with vegetated filter strips or constructed wetlands to intercept polluted runoff.

8.2.4 Data Integration and Decision Support

Investment in data infrastructure and capacity building is essential for evidence-based decision-making. Geographic information systems (GIS) that overlay waste facility locations, drainage networks, wastewater infrastructure, and water quality monitoring stations can identify pollution hotspots and prioritise interventions. Real-time monitoring systems linked to early warning mechanisms would enable rapid response to pollution events, particularly during monsoon seasons when contamination risks peak.

8.2.5 Community Engagement and Behavioural Change

Policies should emphasise source-level interventions through community engagement and behavioural change programmes. Effective waste segregation at the household level reduces the toxicity of leachate generated at disposal sites. Public awareness campaigns linking individual waste disposal practices to downstream water quality impacts can build support for improved waste management. Economic instruments, such as user fees linked to waste generation and subsidies for composting, can incentivise waste minimisation and diversion from landfills.

9. FUTURE PERSPECTIVES

Moving forward, research should prioritise the development of integrated assessment frameworks that capture the full spectrum of waste–water interactions. Longitudinal studies tracking pollutant dynamics across seasons and years are needed to understand temporal variability. Comparative studies across cities with different waste management practices, drainage configurations, and climatic conditions would help identify context-specific solutions and transferable lessons. Ultimately, bridging the science-policy gap requires closer collaboration between researchers, practitioners, and policymakers to ensure that emerging evidence translates into effective action on the ground.

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