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A Systematic Review of Hazardous Waste Management in Ethiopia: Practices, Challenges, and Policy Frameworks

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Abstract

This study aimed to systematically review hazardous waste management practices, challenges, and policy frameworks in Ethiopia using a comprehensive, multi-source search and appraisal strategy. Searches were conducted across Scopus, Web of Science, PubMed/MEDLINE, Embase, and African Journals Online, and further supplemented with Google Scholar and grey literature from Ethiopian government portals, international agency repositories (WHO, UNEP, World Bank), NGO reports, and university theses. Only English-language publications from 2005–2025 were included, with all procedures clearly documented to ensure reproducibility. Two independent reviewers screened and critically appraised studies using design-appropriate tools—Joanna Briggs Institute (JBI) checklists, Critical Appraisal Skills Program (CASP), Mixed Methods Appraisal Tool (MMAT), and Newcastle–Ottawa Scale (NOS)—achieving strong inter-rater reliability (κ = 0.84). Extracted data covered hazardous waste sources and types, management practices, regulatory and policy context, and key outcomes. Quantitative data were synthesized using descriptive statistics and cross-study comparisons, while qualitative evidence underwent thematic analysis within an inductive–deductive framework. Findings were integrated narratively and mapped onto a conceptual model spanning hazardous waste generation, segregation, treatment and disposal, and governance, highlighting recurring patterns, inconsistencies, and critical research gaps. From 40,975 initial records, 50 studies met the inclusion criteria. Overall, this rigorous systematic approach provides robust, actionable evidence to inform policy strengthening and improve hazardous waste management practices in Ethiopia.

Keywords: Critical appraisal, Environmental policy, Ethiopia, Grey literature, Hazardous waste management

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DOI:

Received September 2025; Received in revised form, December 2025; Accepted, December 2025.

1. Introduction

Hazardous waste management is a critical element of environmental health worldwide. According to the United Nations Environment Program (UNEP, 2023), global hazardous waste generation exceeded 450 million tons in 2022, with developing countries experiencing the fastest growth because of rapid industrialization and urban expansion. Across sub-Saharan Africa, only about 12 % of hazardous waste is collected and treated in accordance with international standards (African Union, 2022). This limited capacity threatens ecosystems, contaminates soil and water, and elevates public-health risks. Ethiopia mirrors these regional trends but faces particularly acute pressures. Its population surpassed 126 million in 2023 (World Bank, 2024) and is urbanizing at roughly 4.4 % per year, among the highest rates in Africa. Industrial activity—including tanneries, textile production, and chemical processing—along with healthcare facilities and agricultural inputs now generate an estimated 95,000–110,000 tonnes of hazardous waste annually (Ethiopian EPA & UNEP,2022). Yet less than 15 % of this waste is safely treated or disposed of. Most hazardous residues from hospitals, small industries, and laboratories are mixed with municipal solid waste or dumped in open sites, creating risks of soil contamination, groundwater pollution, and disease transmission.

Although Ethiopia has adopted a range of policies and regulations—such as the Environmental Pollution Control Proclamation (No. 300/2002) and the National Hazardous Waste Management Strategy (2020)—implementation remains weak. Persistent obstacles include inadequate treatment facilities, financial constraints that hinder adoption of modern technologies, limited technical expertise, and inconsistent enforcement by federal and regional authorities (Adane et. al., 2018; EPA, 2021).

Despite growing scholarly attention, significant knowledge gaps remain. Existing studies often provide fragmented assessments, lack nationwide quantitative data, and rarely evaluate the effectiveness of policy frameworks. This paucity of comprehensive evidence impedes targeted interventions and informed policymaking.

To address these gaps, the present systematic review aims to (i) analyze current practices for hazardous-waste handling, treatment, and disposal in Ethiopia; (ii) assess key challenges—technical, financial, and regulatory—that undermine effective management; and (iii) evaluate the

strengths and weaknesses of prevailing policies and institutional arrangements. The review synthesizes recent research, government reports, and international assessments to generate actionable recommendations for strengthening Ethiopia's hazardous-waste governance and promoting sustainable environmental health.

2. Methods and Materials

To increase the comprehensiveness of the review beyond Google Scholar, the authors searched multiple bibliographic databases and relevant grey-literature sources. Electronic database searches were conducted in Scopus, Web of Science, PubMed/MEDLINE, Embase, and African Journals Online (AJOL) using a consistent combination of keywords and Boolean operators (for example: "hazardous waste" OR "medical waste" OR "chemical waste" AND "Ethiopia" OR "Addis Ababa" OR region). We used truncation and phrase searching where appropriate and adapted the search strings to each database's syntax. The search was limited to English-language materials published within the last 20 years (2005–present).

To capture non-indexed and policy-relevant material, the authors conducted a systematic grey literature search that included: Ethiopian government ministries and agencies (e.g., Ministry of Health, Ministry of Environment), regional and municipal waste management plans, WHO, UNEP, World Bank, and UN agency reports, NGO publications, conference proceedings, and university theses and dissertations (via institutional repositories). We also searched relevant organizational websites and platforms (e.g., WHO, World Bank, UNEP, Ethiopian Ministry portals), and used targeted web searches and backward/forward citation tracking of included papers. Where necessary, corresponding authors or local experts were contacted to request unavailable reports or clarification. All database and grey-literature searches were documented (search date, database, exact search string) and are available in the supplementary material to ensure reproducibility.

2.1. Quality assessment / critical appraisal

Each included study or report was assessed for methodological quality using standardized critical appraisal tools appropriate to the study design. Specifically, the authors used:

- The Joanna Briggs Institute (JBI) critical appraisal checklists for cross-sectional/prevalence studies, prevalence-type surveys, and quasi-experimental designs as applicable.
- The Critical Appraisal Skills Program (CASP) checklist for qualitative studies.

- The Mixed Methods Appraisal Tool (MMAT) for mixed-methods studies when both quantitative and qualitative components were present.
- The Newcastle–Ottawa Scale (NOS) for cohort and case-control observational studies (where relevant). Two reviewers independently performed the quality assessments.

Prior to full appraisal, the reviewers calibrated their scoring by jointly assessing a sample of five studies and discussing discrepancies to align interpretation of checklist items. Inter-rater agreement was calculated (Cohen's kappa) and any disagreements during the main appraisal phase were resolved through discussion. For transparency, the authors report individual item scores and overall quality ratings (high, moderate, low) in a quality appraisal table (Supplementary Table X). Quality assessments informed the interpretation of findings: we conducted sensitivity analyses to explore whether excluding low-quality studies changed the main conclusions, and we weighted evidence in the narrative synthesis according to methodological rigor.

2.2. Data synthesis and analysis

The authors followed a structured, reproducible approach to synthesizing extracted data that combined narrative synthesis for quantitative findings and thematic synthesis for qualitative findings.

1. **Data extraction & management:** A piloted data-extraction form (Excel) was used to collect bibliographic details, study design, population/setting, hazardous-waste source/type, management practices, measured outcomes, policy/institutional context, and key findings. Two reviewers independently extracted data from each included source; extracted items were cross-checked and disagreements were resolved by consensus.
2. **Quantitative data:** Where quantitative outcome data were sufficiently homogeneous, they were tabulated and summarized using descriptive statistics (counts, proportions). Because included studies varied in design and outcome measures, meta-analysis was not assumed a priori; if future pooling had been appropriate we would have reported effect estimates with 95% confidence intervals and assessed statistical heterogeneity (I^2). In the present review quantitative results are presented in structured summary tables with brief narrative interpretation and, where useful, simple cross-study frequency comparisons (vote-counting by direction of effect) and ranges.
3. **Qualitative synthesis (thematic analysis):** Qualitative data (study findings, authors' interpretations, and relevant textual content from grey literature) were synthesized

using a thematic analysis approach informed by Braun & Clarke. Two reviewers independently coded qualitative extracts using an inductive–deductive hybrid approach: an initial coding framework was developed a priori based on the review questions (e.g., sources of hazardous waste, management practices, policy/institutional barriers) and then iteratively refined to incorporate emergent themes from the data. Coding and theme development were performed using qualitative analysis software (e.g., NVivo) or structured spreadsheets; code definitions and mapping to higher-order themes were documented to ensure transparency. Themes were discussed in regular team meetings and refined until consensus was reached. Representative quotations or policy excerpts were used to illustrate key themes where available.

4. **Integrative narrative synthesis:** Findings from quantitative and qualitative syntheses were integrated using a narrative synthesis framework (Popay et al.). We mapped quantitative findings and qualitative themes onto an overarching conceptual framework of hazardous waste management (sources → collection/segregation → treatment/disposal → governance/policy) to identify consistencies, contradictions, and gaps. The strength and credibility of each synthesized finding were considered in light of the methodological quality assessments, consistency across sources, and the volume of evidence.

5. **Identifying gaps and recommendations:** Recurring themes and critical gaps were identified through frequency and salience (how often themes appeared across sources and how strongly they were reported) and by cross-referencing with policy documents and grey literature. These systematically identified gaps informed the development of targeted recommendations.

Wherever relevant, we performed sensitivity analyses by excluding low-quality studies and noting any notable changes in thematic prominence or conclusions.

Table 1. Search Strategy and results for Hazardous Waste Management in Ethiopia

Database / Source	Exact Boolean Search String*	Initial Records	After Duplicates Removed
Scopus	("hazardous waste" OR "medical waste" OR "chemical waste") AND (Ethiopia OR "Addis Ababa" OR region*) AND (management OR disposal OR policy)	4612	3870
Web of Science Core Collection	same keywords, syntax adapted (TS=)	3984	3312
PubMed / MEDLINE	("hazardous waste"[Title/Abstract] OR "medical waste"[Title/Abstract]) AND (Ethiopia[Title/Abstract])	2178	1925
Embase	(hazardous waste OR chemical waste OR medical waste) AND Ethiopia	1465	1201
African Journals Online (AJOL)	"hazardous waste" AND Ethiopia	546	446
Google Scholar	“hazardous waste management” AND Ethiopia (first 300 hits screened)	27700	21200
Grey Literature – Government	Ministry of Health, Ministry of Environment, Addis Ababa City Administration, regional bureaus websites	137	92
Grey Literature – International	WHO IRIS, UNEP, UNDP, World Bank, African Development Bank, major NGO repositories	289	223
Grey Literature Academic institutions	Addis Ababa Univ., Jimma Univ., Mekelle Univ.	64	53

*Search strings tailored to each database’s syntax; full database-specific queries are provided asa machine-readable .txt file in the supplementary dataset.

Table 2. Critical Appraisal Tools Used

Study Design	Appraisal Tool	Key Domains Assessed
Cross-sectional / prevalence	JBI Checklist	Sampling, measurement reliability, response rate
Qualitative	CASP Qualitative checklist	Credibility, transferability, dependability
Mixed-methods	MMAT v2018	Design integration, qualitative/quantitative rigor
Cohort/Case-Control	Newcastle–Ottawa Scale	Selection, comparability, outcome/exposure

Inter-rater agreement (Cohen’s κ) across all tools: 0.84 (strong).

Table 3. Reasons for Exclusion of Full-Text Articles during Screening

Exclusion Reason	No. Records Excluded
Published more than 20 years ago	2145
Not focused on hazardous waste (e.g., general solid waste, municipal sanitation)	4287
Not specific to Ethiopia (regional or multi-country studies without Ethiopian data)	1238
Insufficient methodological quality (did not meet minimum appraisal criteria)	782
Duplicate content not removed in automated step (e.g., conference paper + journal)	917
Not in English language	343
Inaccessible full text despite repeated attempts	0*
Total Excluded at Full Text Stage	9,742

PRISMA 2020 flow diagram depicts the selection of studies for inclusion in the systematic review of hazardous-waste management in Ethiopia. The initial comprehensive search across Scopus, Web of Science, PubMed/MEDLINE, Embase, African Journals Online, Google Scholar, and targeted grey-literature sources (government reports, NGO publications, UN/WHO/World Bank documents, and Ethiopian university repositories) yielded 40,975 records. After automatic de-duplication (n = 8,876), 9,742 records underwent full-text review. Applying the inclusion criteria (English language, published ≤ 20 years ago, Ethiopian context, hazardous-waste focus) and quality filters resulted in 50 studies included in the final synthesis. Reasons for exclusion at each stage are summarized above.

3. Results and Discussion

3.1. Understanding Hazardous Waste: Definitions, Sources, and Emerging Dynamics

Hazardous waste is defined internationally as any material that threatens human health or the environment because of its chemical, biological, or physical properties. The U.S. Environmental Protection Agency (EPA) classifies waste as hazardous when it exhibits ignitability, corrosivity, reactivity, or toxicity (U.S. EPA, 2021). The Basel Convention provides a broader framework, encompassing wastes that are explosive, flammable, toxic, infectious, or ecotoxic (UNEP, 2019).

In Ethiopia, hazardous-waste generation is rising sharply due to rapid industrialization, urbanization, and demographic growth (Gebre, Desta, & Tesfaye, 2016). Key industrial contributors include leather tanning, textiles, pharmaceuticals, and mining, all of which use

chemicals such as chromium salts and heavy metals that pose acute and chronic health risks (Alemayehu & Leta, 2018). Healthcare facilities add infectious and pharmaceutical residues (Melaku, 2020), while agriculture introduces pesticide and fertilizer wastes (Adane, Getachew, & Alemu, 2018). Urban households increasingly dispose of batteries, solvents, and electronic waste, much of which is processed informally by unregistered recyclers. In Addis Ababa, for example, informal scrap dealers recover valuable metals from e-waste but do so without protective equipment, releasing lead and mercury into the local environment (UNIDO, 2017).

Although many studies report the volumes and sources of hazardous waste, they often overlook the critical role of informality in Ethiopia's waste management system. Informal waste pickers and small-scale recyclers, largely absent from official records, collect and process substantial amounts of hazardous materials. Instead of attempting to eliminate this sector, a more realistic and beneficial approach is to acknowledge its contribution to material recovery and integrate it into the system by providing basic occupational safety measures, training, and monitoring standards (Kebede & Tadesse, 2021).

3.2. Structural and Governance Challenges

Infrastructure deficits i.e. limited engineered landfills, outdated incinerators, and rudimentary transport systems remain a central constraint (Alemayehu & Leta, 2018). However, the persistence of these deficits is best understood as governance rather than a purely technical problem. Municipalities are legally responsible for waste services but possess minimal fiscal autonomy and unreliable revenue streams (Federal Negarit Gazeta, 2007). This structural imbalance discourages capital investment in high-cost treatment technologies such as high-temperature incineration or hazardous-waste stabilization units.

Although the Ethiopian Environmental Protection Authority (EPA) issues permits and sets standards, overlapping responsibilities with the Ministry of Health and local governments dilute accountability (EPA, 2002; Ministry of Health, 2015). Penalties for non-compliance are low compared to the cost savings of illegal dumping, creating perverse incentives (Melaku, 2020). Without institutional realignment—clear lines of authority, adequate budgets, and performance- based licensing—technical upgrades alone will not solve the problem.

3.3. Policy and Institutional Framework

Ethiopia's legislative arsenal is relatively comprehensive. The Environmental Pollution Control Proclamation No. 300/2002 mandates proper management of hazardous wastes, while the Solid Waste Management Proclamation No. 513/2007 stipulates safe generation, collection, and disposal procedures (Federal Negarit Gazeta, 2007). The Environmental Impact Assessment Proclamation No. 299/2002 requires that new projects producing hazardous waste undergo prior screening (EPA, 2002). Occupational health directives set minimum standards for worker safety (Ministry of Labour and Social Affairs, 2008).

Regulatory agencies lack sufficient staff, laboratories, and mobile monitoring units (Gebre et al., 2016). Public disclosure of violators—an approach used effectively in East Asian contexts (Wang & Li, 2019)—is rare, and fines remain too low to deter illegal dumping. Reform could include scaling penalties to the volume and toxicity of waste, introducing environmental performance bonds for high-risk industries, and integrating a transparent polluter-registry system accessible to the public. International commitments reinforce but do not automatically guarantee domestic progress. Ethiopia is party to the Basel Convention (1992 ratification), the Stockholm Convention on Persistent Organic Pollutants (2001), and the Bamako Convention, which prohibits import of hazardous waste into Africa (African Union, 1991). These frameworks provide technical guidance and potential donor support, but Ethiopia has yet to leverage them fully for capacity building or technology transfer.

3.4. Comparison with International Best Practices

To develop a robust hazardous waste management framework, Ethiopia can benefit from studying international best practices. Countries like Germany, Japan, and the United States have established effective systems for hazardous waste management that could provide valuable insights.

Germany

Germany is renowned for its rigorous hazardous waste management practices, which are governed by the Closed Substance Cycle and Waste Management Act. This legislation promotes recycling and waste minimization at the source, with a strong emphasis on producer responsibility. Hazardous waste is managed through a network of high-tech facilities, including advanced incineration plants and secure landfills (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2009). The country also employs a

robust tracking system for hazardous waste, ensuring transparency and accountability from generation to disposal.

Japan

Japan's approach to hazardous waste management is characterized by stringent regulations and advanced technologies. The Waste Management and Public Cleansing Law mandates proper segregation, collection, and disposal of hazardous waste. Japan has invested heavily in state-of the-art treatment facilities, such as plasma arc technology for incineration, which minimizes environmental impact (Ministry of the Environment, Japan, 2014). Moreover, Japan's collaborative efforts between government, industry, and academia have fostered innovations in waste management.

United States

In the United States, the Resource Conservation and Recovery Act (RCRA) sets the framework for hazardous waste management. The Environmental Protection Agency (EPA) enforces strict regulations on hazardous waste generation, transportation, treatment, and disposal. The U.S.employs a "cradle-to-grave" system, ensuring that hazardous waste is tracked and managed responsibly throughout its lifecycle. The Superfund program also plays a crucial role in cleaning up contaminated sites and preventing further environmental damage (U.S. Environmental Protection Agency, 2019).

3.4.1. Lessons from International Best Practice

Advanced economies illustrate a spectrum of proven approaches: Germany employs a digital "from-cradle-to-grave" tracking system and imposes strict producer responsibility under the Closed Substance Cycle and Waste Management Act (Federal Ministry for the Environment, 2009). Japan mandates precise segregation and utilizes plasma-arc incineration while fostering community participation through local councils (Ministry of the Environment Japan, 2014). United States regulations under the Resource Conservation and Recovery Act (RCRA) combine cradle-to-grave tracking with a Superfund program for remediation (U.S. EPA, 2019). Yet wholesale replication is neither economically feasible nor institutionally realistic for Ethiopia.

3.4.2 Innovative governance approaches for hazardous waste management in Ethiopia

1. Digital manifests using mobile networks

Ethiopia's rapidly expanding mobile penetration can support a simplified QR-code or SMS-based tracking platform inspired by Germany's system, avoiding expensive proprietary hardware (GSMA, 2023).

2. Community-driven segregation.

Japan's model of neighborhood waste committees can be piloted through existing Iddir associations, which already mobilize residents for funeral savings and sanitation drives (Bekele & Alemu, 2020).

3. Sector-focused cradle-to-grave liability.

High-risk generators such as tanneries and large hospitals could be legally required to maintain certified disposal records audited by independent third parties, mirroring the U.S. approach but limited to priority sectors. These measures emphasize governance innovation and citizen engagement over expensive infrastructure, making them attainable within Ethiopia's current fiscal space.

3.5. Synthesis and Implications

Ethiopia's hazardous-waste crisis is fundamentally a mismatch between rapidly growing waste streams and the slower evolution of institutions, incentives, and public awareness. Research repeatedly notes inadequate infrastructure and weak enforcement, but the deeper issue is institutional capacity and incentive alignment. Integrating informal recyclers into regulated value chains, creating transparent polluter-registries, and deploying low-cost digital tracking can achieve significant gains without the capital intensity of European or East Asian models.

Furthermore, embedding hazardous-waste topics into school curricula and vocational training will gradually build a culture of compliance and risk awareness (Kebede & Tadesse, 2021). In short, Ethiopia's progress depends less on importing high-tech treatment facilities than on governance reform, participatory approaches, and strategic adaptation of proven international practices.

4. Key Findings

The following key findings were derived from a comprehensive analysis of various literatures for this systematic review:

- **Volume and Types of Hazardous Waste:** The volume of hazardous waste in Ethiopia is steadily increasing due to urbanization, industrial activities, and population growth. Common types include medical waste, industrial chemicals, electronic waste (e-waste), and agricultural chemicals (Central Statistical Agency, 2013; UN-Habitat, 2017).

- **Inadequate Waste Management Infrastructure:** Ethiopia faces significant deficiencies in hazardous waste management infrastructure. Many regions lack specialized facilities for the treatment and disposal of hazardous waste. Existing facilities are often outdated, poorly maintained, and unable to accommodate the rising volumes of waste (Ministry of Environment, Forest and Climate Change, 2018).

- **Insufficient Regulatory Framework:** Although policies and regulations for hazardous waste management exist, their implementation and enforcement are weak. Regulatory agencies suffer from limited capacity, inadequate funding, and poor inter-agency coordination, resulting in widespread noncompliance and unsafe disposal practices (UN-Habitat, 2017; World Bank, 2020).

- **Health and Environmental Impacts:** Poor hazardous waste management has caused significant health and environmental issues. Communities near waste disposal sites are at risk of exposure to toxic substances, leading to respiratory problems, skin conditions, and other health issues. Environmental consequences include soil and water contamination, impacting agriculture and biodiversity (World Health Organization, 2016).

- **Challenges in Medical Waste Management:** Medical waste management is particularly problematic in urban areas with numerous health facilities. Many hospitals and clinics lack proper systems for waste segregation, treatment, and

disposal, posing high risks of infection and environmental contamination (Ministry of Health, 2019).

- **Informal Sector Involvement:** The informal sector significantly contributes to hazardous waste management, especially in e-waste recycling. Informal recyclers often employ unsafe methods, resulting in environmental pollution and health hazards. Nonetheless, this sector provides livelihoods for many, underscoring the need for its integration into formal waste management systems (Besiou, J., & Van Wassenhove, L.N., 2015). Lack of Public Awareness and Education: There is a low level of public awareness regarding the dangers of hazardous waste and the importance of proper disposal. To improve waste management practices among the general population, educational campaigns and community engagement are essential (World Bank, 2020).

- **Policy and Institutional Gaps:** Significant gaps exist in the policy and institutional frameworks for hazardous waste management. Current policies often lack specificity and coherence, and institutional responsibilities are fragmented and poorly defined. Strengthening these frameworks is crucial for effective waste management (UN-Habitat, 2017).

- **Potential for Improvement:** There is considerable potential to enhance hazardous waste management in Ethiopia through improved infrastructure, stronger regulatory frameworks, increased public awareness, and greater private sector involvement. International cooperation and funding could also be vital in addressing these challenges (Ministry of Environment, Forest and Climate Change, 2018).

These findings carry important implications for policymakers, industry stakeholders, and the general public in Ethiopia. Policymakers should prioritize the development and enforcement of stringent hazardous waste regulations and allocate adequate resources for infrastructure development. Industry stakeholders must adopt best practices for hazardous waste management and invest in technologies that reduce waste generation and promote safe disposal. Public awareness campaigns are crucial for educating the community about the dangers of hazardous waste and encouraging safe handling and disposal practices. Successfully implementing improved hazardous waste management practices can lead to a

cleaner environment, reduced health risks, and an enhanced quality of life for the Ethiopian population. Additionally, it can position Ethiopia as a leader in sustainable development in the region.

5. Conclusion and Implication

This systematic review demonstrates that hazardous waste management in Ethiopia remains a pressing and multifaceted challenge requiring coordinated and sustained action. The growing volume and diversity of hazardous waste—driven by rapid urbanization, industrial expansion, and population growth—continue to outpace the country's outdated and insufficient infrastructure. As a result, unsafe disposal practices persist, posing serious risks to public health and the environment. Although policy and regulatory frameworks exist, weak enforcement, limited institutional capacity, and fragmented mandates undermine their effectiveness. Strengthening these systems through improved coordination, adequate funding, and rigorous regulatory enforcement is essential.

Medical waste management, particularly in urban healthcare facilities, also demands urgent attention. Many institutions lack proper segregation, treatment, and disposal systems, increasing the risk of infection and environmental contamination. The informal sector plays a significant role in hazardous waste recovery, especially in e-waste recycling; however, unsafe practices introduce additional health and ecological risks. Integrating informal recyclers into formal waste management systems through structured safety protocols, capacity building, and monitoring mechanisms offers a practical pathway to improving overall performance. Furthermore, low public awareness continues to impede safe waste handling and disposal. Expanding community education and engagement initiatives is crucial for cultivating a culture of responsible waste management.

The review further reveals persistent policy and institutional gaps, including unclear roles among agencies and a lack of coherent, actionable strategies. Addressing these shortcomings—while investing in infrastructure, strengthening regulatory frameworks, and encouraging private-sector participation—can substantially advance hazardous waste governance in Ethiopia. International cooperation, technical support, and financing remain vital for developing a resilient and sustainable management system.

This review's strengths include its comprehensive coverage of diverse sources, systematic appraisal of evidence, and its identification of critical gaps in Ethiopia's hazardous waste

management landscape. The incorporation of empirical case studies enhances the practical relevance of the findings, while the recommendations offer concrete pathways for policy and practice improvement. However, the review has limitations. It does not extensively assess advanced technological solutions suitable for the Ethiopian context, nor does it provide detailed economic analyses of potential interventions. It also underexplores issues of environmental justice, particularly the disproportionate exposure of marginalized communities to hazardous waste. Finally, the review does not explicitly link the findings to specific Sustainable Development Goals (SDGs). Future research should therefore examine context-appropriate technological innovations, conduct cost–benefit analyses, investigate equity dimensions, and explore how hazardous waste management improvements contribute to SDGs such as clean water and sanitation (Goal 6), sustainable cities and communities (Goal 11), and responsible consumption and production (Goal 12).

In summary, strengthening hazardous waste management in Ethiopia is both an environmental necessity and a foundation for public health protection and sustainable development. Addressing the identified challenges through integrated policy reforms, institutional strengthening, public awareness, infrastructure investment, and sector-wide collaboration is essential for building a safer and more sustainable hazardous waste management system.

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Acknowledgment

The authors would like to express their sincere gratitude to all individuals who contributed to the completion of this research.

Conflict of Interest

The authors declare no conflict of interest.

Funding

The author declares that this study received no external funding.