

Analysis of Sustainable Solid Waste Treatment/Management Approaches for Africa: Towards Integrated Sustainable Solid Waste Management

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Abstract

Background: Sustainable solid waste management (SWM) is a pressing environmental and public health challenge across Africa, driven by rapid urbanization, population growth, and changing consumption patterns. Many systems remain inefficient, with significant implications for environmental sustainability and human well-being. **Objective:** This study provides a comprehensive analysis of sustainable solid waste treatment and management approaches across Africa, aiming to identify key trends, gaps, and opportunities while advancing an integrated framework for sustainable SWM. **Methods:** A systematic scoping review guided by the PRISMA-ScR framework was conducted. Literature published between 2010 and 2025 was retrieved from multiple academic databases and grey literature sources. From 7983 identified records, 490 studies from 46 African countries met the inclusion criteria following rigorous screening and eligibility assessment. **Results:** SWM systems across Africa are characterized by low collection coverage, ranging from below 40% in informal settlements to above 70% in formal urban areas, heavy reliance on open dumping and unengineered landfills, and limited adoption of advanced treatment technologies. Organic waste constitutes 45% - 70% of municipal solid waste, presenting significant opportunities for composting and anaerobic digestion. However, system performance is constrained by weak governance, inadequate financing, poor infrastructure, and limited technical capacity. Marked spatial disparities exist, with urban areas receiving greater research and implementation attention than rural and peri-urban settings. **Conclusion:** The study highlights critical gaps across the waste management value chain while identifying opportunities for improvement through policy reform, sustainable financing, tech-

nological innovation, and stakeholder integration. It proposes an integrated SWM framework emphasizing enabling environments, value chain efficiency, and inclusive governance to support Africa's transition toward circular and sustainable waste management systems.

Keywords

Solid Waste Management, Africa, Scoping Review, ISWM, Waste-to-Energy, Informal Sector, Circular Economy

1. Introduction

The rapid pace of urbanization, population growth, and industrial expansion across Africa has intensified the challenges of solid waste generation and management (Godfrey et al., 2020). The continent generates an estimated 180 million tonnes of municipal solid waste (MSW) annually, with projections suggesting an increase to 250 million tonnes by 2030 if current trends persist (Awino & Apitz, 2024). However, less than 10% of wastes generated are adequately treated or recycled, while the remainder is openly dumped or burned (Vetterlein & Schmidtke, 2024). These practices not only degrade the environment but also pose severe public health risks and contribute significantly to greenhouse gas emissions. Solid waste management, therefore, represents one of the most pressing environmental sustainability challenges facing African countries in the twenty-first century (Peters, 2025; Sengupta & Agrahari, 2017).

Sustainable solid waste management (SSWM) refers to the systematic and integrated handling of waste materials in a manner that minimizes environmental and health impacts while maximizing resource recovery and economic value (Banerji et al., 2026). It involves environmentally sound practices across the entire waste management chain, including generation, collection, storage, transportation, treatment, and final disposal (Soni et al., 2023). Integrated Solid Waste Management (ISWM) is a widely adopted framework that emphasizes the coordinated use of multiple waste management options and prioritizes waste prevention, reuse, recycling, and recovery before final disposal (Gahana Gopal et al., 2018).

Yet, most African cities rely heavily on unsanitary landfills, open dumping, and informal waste picking systems, with minimal adoption of advanced treatment options such as anaerobic digestion, composting, incineration with energy recovery, or material recovery facilities (Niyobuhungiro & Schenck, 2022). Inadequate infrastructure, limited technical capacity, and weak policy enforcement exacerbate inefficiencies across the entire waste management value chain, from waste generation to disposal (David et al., 2020). The informal sector remains the backbone of recycling in most urban centers, contributing to resource recovery but operating without formal recognition and safety regulations (Snehalatha et al., 2025).

The technological gap in Africa's waste management systems is further widened by financial constraints and lack of integrated planning (Debrah et al., 2022). Many municipalities depend on donor-funded and pilot-scale projects that rarely achieve scalability and long-term sustainability (Hassan, 2025). Moreover, existing waste-to-energy (WtE) and composting plants often fail due to inadequate segregation at source, poor feedstock quality, and the high cost of maintenance and imported machinery (Beyene et al., 2018). For example, despite the establishment of the Reppie Waste-to-Energy plant in Addis Ababa, Ethiopia, operational interruptions and limited technical expertise have impeded its consistent performance (Tiruye et al., 2021). Similar trends are observed in Lagos, Nairobi, and Accra, where waste accumulation outpaces management capacity, resulting in environmental degradation and disease proliferation (Agboola et al., 2025).

The urgency for sustainable solid waste management technologies in Africa is also driven by climate change mitigation commitments under the African Union's Agenda 2063 and the Sustainable Development Goals (SDGs), particularly Goals 11, 12, and 13 (Froehlich et al., 2021). Emerging technologies such as decentralized composting, anaerobic co-digestion, pyrolysis and AI-assisted waste sorting systems are increasingly being explored for African contexts (Kumar et al., 2025). However, their integration into local systems requires enabling regulatory frameworks, financing mechanisms, and community participation to ensure both environmental and economic sustainability.

This study provides an analytical overview of sustainable solid waste treatment and management technologies across Africa, assessing their applicability, efficiency, and constraints within the continent's socio-economic and institutional settings. It explores the entire waste management value chain including collection, storage, transportation, treatment, and final disposal and identifies gaps in governance, technology and financing. Furthermore, it proposes a sustainable framework that aligns with integrated solid waste management (ISWM) principles, aiming to enhance environmental health, energy recovery and circular economy outcomes.

2. Materials and Methodology

2.1. Research Design

This study employed a systematic scoping review methodology to critically analyze and synthesize the current state of sustainable solid waste treatment and management technologies across Africa. The review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) protocol (O'Dea et al., 2021), which provides a structured and transparent framework for reviewing broad, complex, and interdisciplinary topics.

The rationale for selecting a scoping review approach lies in the multidisciplinary nature of solid waste management, which encompasses environmental science, engineering, governance, and socio-economic dimensions. The study aimed

to identify, classify, and evaluate sustainable waste management technologies that are either implemented and piloted within African countries, with a particular focus on context-specific innovations, successes, and gaps. The methodological framework facilitated comprehensive coverage of all African sub-regions: North, West, East, Central and Southern Africa, ensuring balanced continental representation and enabling comparative regional analyses.

2.2. Data Sources and Search Strategy

A comprehensive literature search was conducted to capture the most relevant and recent evidence on sustainable solid waste management technologies in Africa. The search covered the period from January 2010 to February 2025 and encompassed multiple academic and institutional databases, including Scopus, Web of Science, ScienceDirect, SpringerLink, PubMed, Taylor and Francis Online, JSTOR, and Google Scholar. To complement the peer-reviewed literature, grey literature sources from reputable organizations, such as UNEP, the African Union Commission, the World Bank, the African Development Bank (AfDB), and national environmental agencies, were also consulted. These additional sources were included to capture policy frameworks, implementation reports, and technical documents often absent in peer-reviewed publications.

The search strategy employed Boolean operators to combine key concepts related to solid waste management, treatment technologies, sustainability, and geographic scope. Keywords and their synonyms were grouped and combined using “OR”, while major concepts were linked using “AND”. A typical search string was structured as follows:

(“solid waste management” OR “municipal solid waste” OR “MSW”)
AND (“treatment” OR “waste treatment” OR “waste-to-energy” OR composting
OR recycling OR “anaerobic digestion”) AND (sustainability OR “sustainable de-
velopment” OR “integrated waste management”) AND (Africa OR “Sub-Saharan
Africa” OR “SSA”)

This comprehensive search strategy initially identified a total of 7983 records, which were subsequently subjected to rigorous screening and selection processes.

2.3. Inclusion and Exclusion Criteria

To ensure relevance and focus, inclusion criteria were established prior to screening. Only peer-reviewed journal articles, conference papers, and institutional reports published between 2010 and 2025 were considered. Eligible studies specifically addressed solid waste management or treatment technologies within African countries and covered aspects of environmental, economic, social, and technological sustainability. Publications in English or French were included, with French articles translated into English where necessary.

Exclusion criteria were equally stringent to maintain the quality and relevance of the review. Studies focusing solely on hazardous, radioactive, or electronic waste were excluded, as were research outputs conducted outside Africa. Dupli-

cate records, articles lacking full-text availability, and non-scientific literature, such as opinion pieces, news items, or blogs, were also excluded. This approach ensured that only robust, relevant, and empirically grounded evidence was synthesized.

2.4. Screening and Selection Process

Following the removal of duplicate records, 6521 studies proceeded to the initial title and abstract screening phase. Screening and study selection were conducted by the author (KSB) at both title/abstract and full-text stages. To enhance consistency, a research assistant (GD, University of Skills Training and Entrepreneurial Development) independently assisted with screening of records at both stages. Disagreements between the author and the research assistant were resolved through discussion, and where consensus could not be reached, eligibility was re-checked against the predefined inclusion criteria to ensure consistency.

During this phase, 5084 articles were excluded for irrelevance to the study objectives, leaving 1437 articles for full-text assessment. Full-text review identified 947 studies that did not meet methodological standards, lacked sufficient data, or focused narrowly on single-city waste characterization without addressing treatment technologies.

Of the 947 excluded full-text articles, 612 were single-city case studies without system-level analysis, 187 lacked sufficient methodological detail and did not report treatment or management outcomes, 98 focused exclusively on waste characterization without treatment components, and 50 were excluded due to non-peer-reviewed status and insufficient scientific rigor.

Single-city studies were excluded to ensure a continent-wide analytical perspective and to avoid overrepresentation of localized findings that may not reflect national/regional waste management systems. This approach was necessary to maintain comparability across countries and strengthen the synthesis of integrated solid waste management practices at the African scale.

Consequently, 490 studies were included in the final synthesis. These studies collectively represent 46 African countries, providing comprehensive continental coverage. The sub-regional distribution of included studies was as follows: West Africa contributed 33% of studies (Nigeria, Ghana, Côte d'Ivoire, Senegal, Liberia); East Africa contributed 27% (Kenya, Tanzania, Ethiopia, Uganda); Southern Africa represented 21% (South Africa, Botswana, Zambia, Zimbabwe); North Africa contributed 12% (Egypt, Morocco, Tunisia); and Central Africa accounted for 7% (Cameroon, Democratic Republic of Congo, Rwanda). This distribution ensured balanced representation, enabling robust regional comparisons of sustainable waste management and treatment practices.

2.5. Data Extraction and Analysis

Data extraction was performed using a structured template capturing multiple variables relevant to the study objectives. Extracted data included country or re-

gion, type and quantity of waste generated (kg/person/day or tonnes/year), technologies applied (composting, anaerobic digestion, pyrolysis, gasification, WtE), key outcomes (energy recovery, recycling efficiency, cost reduction), environmental and socio-economic impacts, and implementation barriers or enabling policy frameworks.

The extracted data were analyzed using thematic content analysis to identify patterns, trends, and innovations across countries. Quantitative information on waste generation, energy recovery, and recycling rates was summarized using descriptive statistics for comparative analysis. Studies were grouped into five thematic clusters: treatment technologies and innovations, policy and governance mechanisms, informal sector integration, environmental and public health impacts, and challenges and opportunities in technology adoption and financing. This categorization facilitated in-depth understanding of operational, technological, and policy dimensions of sustainable MSW management in Africa.

Reported quantitative values, including waste generation rates, composition percentages, collection coverage, and treatment performance indicators, were derived as descriptive ranges representing the minimum and maximum values reported across included studies. No statistical pooling or meta-analysis was conducted due to heterogeneity in study design, measurement approaches, and reporting formats. Where multiple studies reported similar indicators, descriptive aggregation was used to summarize trends rather than generate weighted continental estimates. Accordingly, all reported ranges reflect observed variation across the literature rather than author-calculated statistical summaries.

2.6. Quality Appraisal

All included studies were assessed using the Critical Appraisal Skills Programme (CASP) checklists appropriate to study design. Most included studies were cross-sectional in design, with a smaller proportion of qualitative case studies and a limited number of cohort-based studies. Accordingly, the CASP Qualitative Studies Checklist was applied to qualitative studies, the CASP Cohort Studies Checklist to cohort studies, and the CASP Analytical Cross-Sectional Studies Checklist (adapted) to cross-sectional studies.

Each study was appraised for methodological clarity, appropriateness of study design, data reliability, analytical rigor, and transparency of reporting. The appraisal was undertaken to assess the quality and reliability of the evidence rather than to exclude studies at the outset. However, studies were excluded at the synthesis stage where they lacked sufficient methodological description, did not report clear data collection or analytical procedures, or provided evidence that could not be adequately appraised using the CASP criteria.

Findings from the appraisal informed the synthesis by assigning greater interpretive weight to methodologically robust studies, particularly in cases where evidence across studies was inconsistent or context-dependent. Policy and institutional reports were cross-checked against multiple sources to ensure consistency

and credibility.

3. Results

3.1. PRISMA Flow Diagram

The PRISMA flow diagram (**Figure 1**) illustrates the process of screening and selection for this review. Initially, 7983 records were identified through database and grey literature searches. After removing duplicates, 6521 records remained for title and abstract screening, resulting in the exclusion of 5084 irrelevant studies. Full-text review of 1437 articles led to the exclusion of 947 studies that did not meet eligibility criteria. Ultimately, 490 studies from 46 countries were included in the final synthesis, providing comprehensive coverage of MSW treatment and management technologies across Africa.

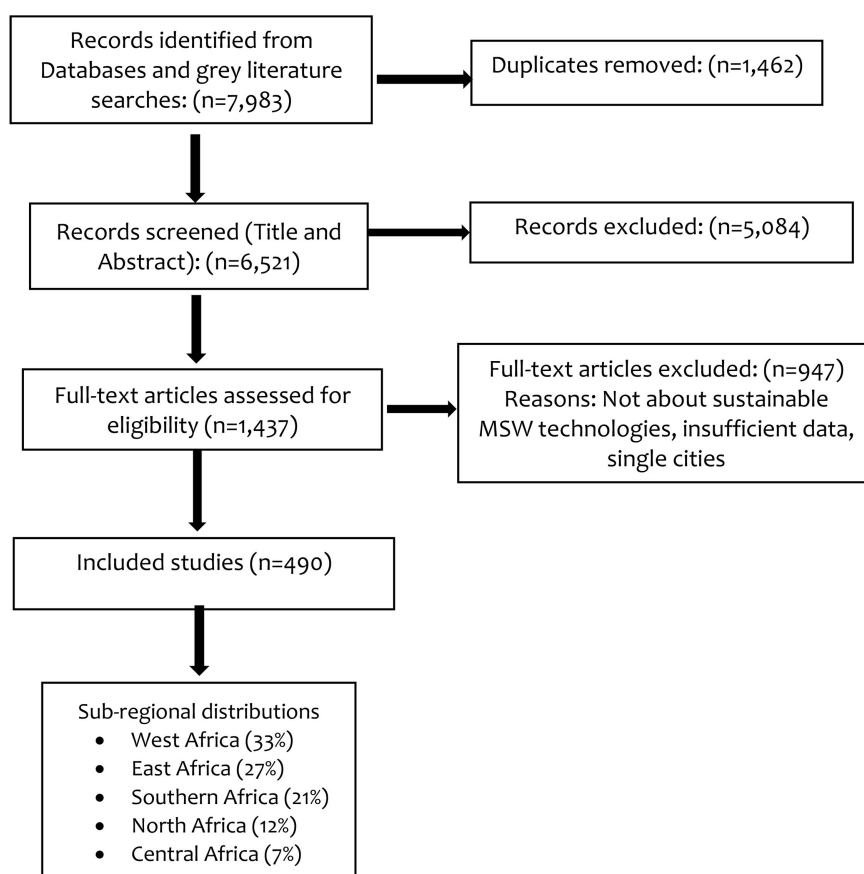


Figure 1. PRISMA flow diagram for “Analysis of Sustainable Solid Waste Treatment/Management Technologies in Africa”.

3.2. Characteristics of Evidence Sources

The review included 490 studies from 46 African countries, covering all five sub-regions. Most studies originated from highly urbanized countries, particularly Nigeria, South Africa, Egypt, Kenya, and Ghana. Evidence sources were dominated by peer-reviewed journal articles, policy reports, and institutional publications.

West Africa contributed the highest proportion of studies (33%), followed by East Africa (27%), Southern Africa (21%), North Africa (12%), and Central Africa (7%) (**Table 1**). Urban areas were disproportionately represented, while rural and peri-urban regions received limited research attention. Common patterns across studies included low collection coverage, dependence on open dumping and unlined landfills, weak recycling systems, fragmented governance structures, and limited adoption of advanced treatment technologies. The informal sector appeared consistently across regions as a major contributor to recycling and material recovery.

Table 1. Regional distribution of studies in Africa.

Sub-Region	% of Studies	Key Characteristics
West Africa	33%	High urban focus, dominant informal sector
East Africa	27%	High organic waste dominance
Southern Africa	21%	Better infrastructure in selected cities
North Africa	12%	Higher industrial/commercial waste
Central Africa	7%	Limited research coverage

3.3. Solid Waste Generation and Composition

Organic waste formed the largest fraction of municipal solid waste, ranging from 45% to 70%. Plastics, paper, metals, and glass constituted the remaining fractions. East African cities showed high organic waste dominance, while North African cities recorded higher shares of commercial and industrial waste. Informal settlements showed high concentrations of plastic waste and unmanaged refuse. Waste composition varied significantly across regions, cities, and income groups (**Table 2**).

Table 2. Urban centers generated between 0.5 and 1.2 kg of waste per person per day.

Indicator	Range/Pattern
Waste generation rate	0.5 - 1.2 kg/person/day
Organic waste fraction	45% - 70%
Plastic, paper, metal, glass	Remaining fractions
East Africa	High organic dominance
North Africa	Higher commercial/industrial waste
Informal settlements	High plastic and unmanaged waste

3.4. Collection, Storage, and Transportation

From **Table 3**, collection coverage ranged from below 40% in informal settlements to over 70% in formal urban areas. Many cities experienced limited vehicle fleets, poor routing systems, and weak infrastructure. Storage systems were largely informal, including open containers, roadside dumping, and uncovered pits. De-

layed collection and poor storage led to waste accumulation, odour generation, vector breeding, and surface water contamination. Pilot interventions using community-based collection, digital tracking tools, and public-private partnerships showed improved efficiency in selected cities.

Table 3. Collection, storage, and transport systems.

Component	Observed Pattern
Collection coverage	<40% (informal areas), >70% (formal areas)
Storage systems	Open containers, roadside dumping, pits
Transport	Limited fleets, poor routing
Environmental effects	Odour, vectors, water contamination
Innovations	PPPs, digital tracking, community-based systems

3.5. Treatment and Disposal Practices

Most sites lacked leachate control, gas capture systems, and environmental monitoring. Advanced treatment technologies were present in limited form. These included composting, anaerobic digestion, waste-to-energy plants, pyrolysis, and controlled incineration (**Table 4**). Adoption levels remained low due to high costs, weak technical capacity, poor segregation at source, and policy gaps.

Table 4. Open dumping and unengineered landfills remained the dominant disposal methods.

Method	Status
Open dumping	Dominant
Unengineered landfills	Dominant
Composting	Limited
Anaerobic digestion	Limited
Waste-to-energy	Very limited
Pyrolysis	Rare
Controlled incineration	Rare

3.6. Governance, Financing, and Stakeholder Systems

Governance systems varied across countries as shown in **Table 5**. Some states had structured policies and regulatory systems, while others showed fragmented institutional responsibilities and weak enforcement. Financing was mainly dependent on municipal budgets and donor funding. Market-based mechanisms such as extended producer responsibility, green bonds, pay-as-you-throw systems, waste taxes, and sanitation levies were limited in application. The informal sector played a consistent role in recycling and recovery but operated largely outside formal regulatory systems. Community participation varied widely across regions.

Table 5. Governance and financing systems.

Domain	Pattern
Governance	Fragmented/uneven
Enforcement	Weak
Financing	Municipal budgets and donors
Market mechanisms	Limited
Informal sector	Central role in recycling
Community participation	Highly variable

4. Discussion

4.1. Characteristics of Evidence Sources across Africa

The scoping review synthesizes a heterogeneous body of evidence from 490 studies spanning 46 African countries and all five sub-regions, with peer-reviewed journal articles, policy reports, and institutional publications predominating. West Africa leads with 33% of studies (**Table 1**), driven by acute urbanization pressures in Nigeria and Ghana, followed by East Africa (27%), Southern Africa (21%), North Africa (12%), and Central Africa (7%). This urban bias, evident in disproportionate coverage of cities like Lagos, Johannesburg, Cairo, Nairobi, and Accra mirrors global patterns in waste management research, where high-density areas attract 70% - 80% of studies due to visible crises (**Danso & He, 2025**). Rural and peri-urban gaps persist, akin to underrepresentation in sub-Saharan reviews, underscoring the need for expanded longitudinal data to capture informal systems.

Common patterns align with continental trends: collection coverage below 44% - 67% overall, heavy reliance on open dumping/unlined landfills, nascent recycling (often informal), governance fragmentation, and minimal advanced technology uptake (**Badejo, 2020**). North Africa's formalized systems (e.g., WtE in Egypt) contrast Central/West Africa's informality, paralleling **Michel Devadoss et al. (2021)** who note sub-regional disparities in ISWM maturity. The informal sector's pivotal recycling role (e.g., plastics/metals recovery) echoes (**Okot-Okumu & Nyenje, 2011**), yet hazardous conditions highlight integration failures seen in 80% of sub-Saharan cases.

4.2. Waste Generation and Organic Waste Dominance

Urbanization, population growth (projected 60% urban by 2050), and consumption shifts propel MSW generation to 0.5 - 1.2 kg/person/day, with organics dominating at 45% - 70% (**Table 2**) higher than Asia's 50% - 60% but comparable to Latin America's organic-heavy profiles (**Voukkali et al., 2023**). East African organic dominance (Nairobi/Kigali food waste) versus North Africa's industrial skew (Cairo/Casablanca) reflects dietary/economic variances, consistent with **Awuor et al. (2023)**. Informal settlements' plastic surges exacerbate risks like flooding/vector diseases, amplifying single-use packaging trends noted by **Hossain &**

Haque (2026).

These patterns inform technology prioritization: organics favor composting/anaerobic digestion, non-biodegradables suit WtE/recycling, echoing ISWM hierarchies (Miezah et al., 2015). Compared to Europe's <30% organics (Laureti et al., 2024), Africa's composition demands circular, context-specific models to curb 250 Mt annual projections by 2030 (Sharma et al., 2024).

Indicator	Africa Range	Global Comparison
Generation (kg/p/d)	0.5 - 1.2	Asia: 0.4 - 1.0; Europe: 1.5
Organics (%)	45 - 70	Latin America: 50 - 65
Plastics (%)	10 - 25	Asia: 15 - 20

4.3. Collection, Storage, and Transportation Systems

Collection disparities (<40% informal, >70% formal urban; **Table 3**) bottleneck the value chain, fueled by fleet shortages, poor routing, and informal storage (open pits/dumping), yielding odors, vectors, and contamination (Shabani et al., 2024). This mirrors 55% continent-wide coverage (Thabit et al., 2022), worse than Asia's 70% urban rates, with leachate/methane amplifying GHG emissions (Zheng et al., 2025).

Innovations shine: PPPs in eThekweni/Casablanca boosted efficiency 20% - 30%; informal picker integration in Kenya/Ghana/Nigeria cut hazards while lifting recovery (Akyen et al., 2025). Digital/GIS pilots parallel global successes (e.g., Singapore's routing AI), yet scale lags due to infrastructure gaps underscoring needs for inter-modal transfers versus Europe's near-100% collection (Xue et al., 2015).

4.4. Challenges in Waste Treatment and Disposal

Open dumping/unengineered landfills prevail (>80% implied; **Table 4**), sans leachate/gas controls, driving pollution/diseases exacerbated by organics' decomposition (Issa et al., 2022). Limited advanced tech (composting/WtE/pyrolysis rare) lags Asia's 20% thermal adoption, hindered by costs, skills gaps, and segregation failures (Osoro et al., 2024).

Pilots succeed regionally: Reppie WtE (Ethiopia), composting (sub-Saharan), biogas (Morocco/South Africa) yield energy/soil benefits, yet scalability falters like India's early WtE stalls. ISWM integration per Asefi et al. (2020), optimizes via local composition/capacity, promoting circularity versus landfilling's 90% African reliance (Sithole, 2025).

Method	Africa Status	Adoption Comparison
Open Dumping/Landfills	Dominant	Asia: Declining (50%)
Composting/Digestion	Limited	Europe: 30% - 40% organics
WtE/Pyrolysis	Very Limited	Asia: 15% - 20%

4.5. Governance, Financing, and Stakeholder Structures

In **Table 5**, fragmented governance/weak enforcement relies on municipal/donor funds, sidelining EPR/green bonds/pay-as-you-throw, unlike Europe's tariff-driven models (Chioatto & Sospiro, 2023). Informal sector centrality (recycling backbone) under unsafe conditions echoes Latin America's 2% GDP contribution, with variable community buy-in.

PPPs/training formalize informals, boosting equity/efficiency (e.g., South Africa cooperatives), aligning Agenda 2063/SDGs 11 - 13 (Razzaq et al., 2025). Gaps demand multi-stakeholder ISWM: policy reforms, blended finance, capacity-building transcending pilots for resilient systems. This synthesis reveals Africa's MSW as solvable via integrated, context-tailored advances, bridging evidence gaps for policy impact.

4.6. Gaps, Opportunities, and Value Chain Considerations

Significant gaps persist across the solid waste (SW) value chain in Africa, limiting the effectiveness and sustainability of waste management systems. Inefficient and ineffective collection remains a major challenge, particularly in informal settlements and peri-urban areas, where coverage can fall below 40% (Baye, 2025). Inadequate storage infrastructure, such as the widespread use of open containers and roadside dumping, further exacerbates environmental contamination, vector proliferation, and public health risks (Basavaraju et al., 2025). Transportation inefficiencies, including limited vehicle fleets, poor routing strategies, and substandard road networks hamper timely waste removal. This often results in accumulations that deteriorate urban living conditions and increase greenhouse gas emissions (Sulemana et al., 2018). In parallel, adoption of advanced treatment technologies, such as composting, anaerobic digestion, pyrolysis, and waste-to-energy (WtE) plants, remains limited due to high capital costs, lack of technical expertise, and insufficient feedstock segregation.

Governance and policy frameworks in many African countries are fragmented and inconsistently enforced. While nations such as South Africa, Morocco, and Egypt have implemented relatively advanced strategies, including enforceable landfill standards and integration of WtE technologies, many West and Central African countries suffer from weak regulatory oversight, limited institutional coordination, and lack of enforcement mechanisms (Hemidat et al., 2022). Financing mechanisms are similarly constrained, with municipal budgets and donor-funded projects dominating, often failing to achieve long-term sustainability (Ezeudu & Ugochukwu, 2024). Market-based approaches, such as pay-as-you-throw schemes, extended producer responsibility (EPR), and green bonds, are underutilized, limiting incentives for technology adoption and private sector investment. These governance and financial gaps reduce operational efficiency, hinder technological uptake, and compromise public accountability.

Africa presents multiple opportunities for sustainable MSW management despite these challenges. Context-specific deployment of appropriate technologies

such as decentralized composting for organic-rich waste, modular WtE plants, and material recovery facilities can enhance resource recovery and energy generation. Integration of the informal sector, which already diverts significant waste from landfills, offers potential for increased recycling efficiency, economic empowerment, and social inclusion when combined with legal recognition, capacity-building, and safety interventions. Circular economy frameworks provide additional opportunities, linking waste reduction, material reuse, and renewable energy generation, while reducing reliance on landfills and mitigating environmental pollution.

Regional lessons demonstrate the value of coordinated policy, technological investment, and participatory approaches. In Morocco, for instance, a combination of PPP-driven recycling initiatives, modern landfill standards, and composting facilities has resulted in higher waste diversion rates and improved environmental outcomes (Alhowaish, 2025). South Africa's formalization of waste cooperatives and integration of informal actors into municipal contracts has enhanced recycling efficiency and worker safety (Samson et al., 2022), while Egypt's pilot WtE plants illustrate both the potential and challenges of technology adoption in high-density urban settings (Allam, 2022).

To fully leverage these opportunities, the development of a comprehensive, continent-wide sustainable MSW management framework is critical. Such a framework should encompass the entire value chain: collection, storage, transportation, treatment, disposal, regulatory oversight, financing, and stakeholder engagement. Emphasis on multi-level coordination spanning municipal authorities, national agencies, informal sector actors, communities, and private stakeholders can enhance operational efficiency, protect public health, and generate economic and environmental benefits. Additionally, embedding monitoring, evaluation, and data-driven decision-making into this framework enables continuous improvement, transparency, and accountability. Aligning interventions with global sustainability agendas, such as the SDGs and the African Union's Agenda 2063, ensures that initiatives contribute not only to local environmental and public health outcomes but also to broader climate and socio-economic objectives.

Finally, research and knowledge gaps remain a critical consideration for publication. Empirical studies assessing the performance, cost-effectiveness, and social impacts of integrated MSW management systems are limited, particularly in low-resource urban settings. There is a need for longitudinal and comparative research on the effectiveness of informal sector integration, circular economy implementation, and decentralized technological solutions. Such studies will provide evidence-based guidance for policymakers, practitioners, and investors seeking to scale sustainable waste management solutions across the continent. African cities can move towards resilient, environmentally sound, and socially inclusive MSW management systems by addressing these gaps. This will ensue both short-term operational efficiency and long-term sustainability.

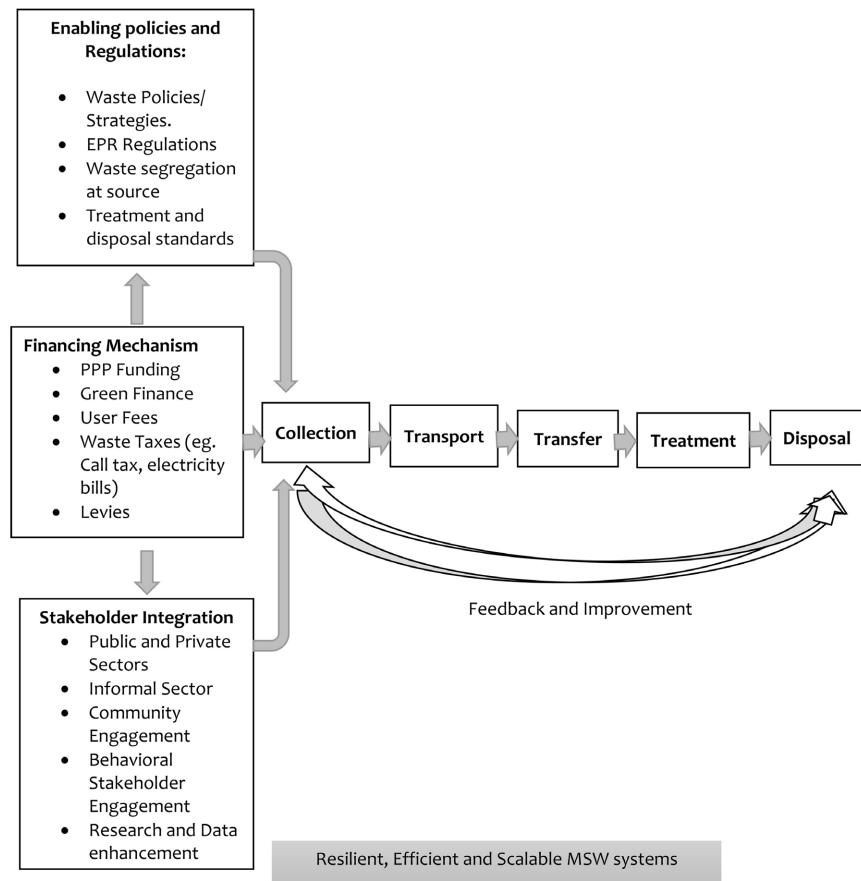


Figure 2. Proposed value chain for integrated sustainable MSW management in Africa.

5. Frameworks for Effective Implementation

The proposed value chain for Integrated Sustainable Municipal Solid Waste (MSW) Management in Africa was developed based on the synthesis of the key themes identified in this review. The framework integrates the Enabling Environment Framework, which provides the policy, financial, institutional, and technical foundations necessary for effective implementation. It further incorporates the Stakeholder Integration and Accountability Framework to ensure collaboration among governments, private sector actors, communities, and informal waste workers. The framework also recognizes the importance of Behavioral and Social Dimensions in influencing waste generation, segregation, and participation in waste management initiatives. As illustrated in **Figure 2**, these themes collectively support the Value-Chain Effective Framework which creates a comprehensive and sustainable approach to MSW management across Africa.

5.1. Enabling Environment Framework for Effective Implementation

The effectiveness of sustainable solid waste management (SWM) technologies in African contexts is strongly shaped by the broader enabling environment within which these systems operate (Awino & Apitz, 2024). An enabling environment

refers to the combination of policy, institutional, financial, and technical conditions that determine whether waste management technologies can be successfully adopted, operated, and sustained over time (Gupta et al., 2023). In the absence of coherent policies and regulatory enforcement, even technically sound waste treatment solutions often fail to progress beyond pilot stages (Hammoud et al., 2025). Clear legal frameworks such as national waste management strategies, landfill standards, and extended producer responsibility (EPR) regulations, provide the necessary foundation for compliance, private sector participation, and accountability across the waste sector.

Beyond policy, institutional capacity plays a decisive role in implementation effectiveness. Clearly defined mandates, coordination among government agencies, and decentralized governance structures enable efficient planning, monitoring, and enforcement of waste management activities. Financing mechanisms further determine system viability, as chronic underfunding remains a major constraint in many African municipalities (Dorasamy & Kapesa, 2024). Innovative financing approaches, including public-private partnerships, user-based tariffs, and climate or green financing instruments, help bridge funding gaps and support long-term operations. Complementing these elements, sustained investment in technical and human capacity ensures appropriate technology selection, skilled operation, and routine maintenance. Collectively, these interacting components create the conditions necessary for scaling up sustainable SWM technologies and embedding them within resilient urban service systems.

5.2. Value-Chain Effective Framework

The Value-Chain Effective Framework conceptualizes sustainable municipal solid waste (MSW) management as a fully integrated continuum, where the performance of each stage from waste generation to final disposal directly affects overall system efficiency, environmental outcomes, and public health (Awino & Apitz, 2024). Successful implementation requires a structured approach that clearly identifies actions and responsibilities along each stage of the value chain, while simultaneously aligning with enabling policies, financing mechanisms, and stakeholder participation. Inefficiencies at upstream stages, such as poor source segregation and unreliable collection can significantly compromise the performance of downstream treatment and disposal technologies (Grote et al., 2012). This ultimately reduces material recovery, energy generation, and overall system sustainability.

At the collection stage, the framework emphasizes the importance of community engagement, source separation of organic and inorganic fractions, and integration of informal waste actors through training, protective equipment, and contractual arrangements. Efficient transportation relies on optimized routing, sufficient vehicle fleets, and the strategic use of transfer stations to ensure uninterrupted flow of materials while minimizing spillage, secondary pollution, and operational costs. The transfer stage focuses on temporary storage, material quality

control, and preparation for treatment facilities, ensuring that feedstock meets the technical requirements of composting, anaerobic digestion and waste-to-energy (WtE) systems. Treatment involves selecting appropriate technologies based on waste composition, operational capacity, and local energy or material recovery needs, while maintaining rigorous monitoring and maintenance standards. Finally, disposal is managed through engineered landfills, with proper leachate collection, gas capture, and environmental monitoring to mitigate residual impacts.

A core principle of this framework is a continuous feedback loop. The performance data from treatment and disposal stages inform improvements in collection, transport, and transfer operations, enabling adaptive management and progressive optimization. When linked to the Enabling Environment Framework and the Stakeholder Integration Framework, this approach ensures that technological solutions are supported by policy, financing, and social structures, resulting in resilient, cost-effective, and scalable MSW systems.

5.3. Stakeholder Integration and Accountability Framework

Effective implementation of sustainable solid waste management systems depends on the coordinated involvement of multiple stakeholders operating at different levels of governance. The Stakeholder Integration and Accountability Framework emphasizes that no single actor can deliver effective SWM in isolation. Municipal authorities typically serve as the central coordinating bodies, responsible for planning, regulation, contracting, and performance monitoring, while ensuring alignment with national environmental and development priorities (Issa et al., 2022). However, limited technical and financial capacity at the municipal level often necessitates collaboration with private sector operators, who contribute investment, operational efficiency, and technological expertise.

In parallel, the informal waste sector remains a critical yet frequently overlooked component of waste management systems across Africa, particularly in recycling and material recovery activities (Aparcana, 2017). Formal recognition and structured integration of informal actors through licensing, cooperative models, training, and occupational health protections can significantly improve system efficiency while advancing social inclusion and livelihoods. Community participation further strengthens implementation outcomes by encouraging waste reduction, source segregation, and compliance through sustained education and behavior-change initiatives. At higher governance levels, national and regional institutions provide policy direction, financing frameworks, and alignment with global commitments such as the Sustainable Development Goals. Clearly defined accountability mechanisms and transparent information flows across stakeholders are essential for adaptive management, trust, and long-term sustainability.

5.4. Behavioral and Social Dimensions of Waste Management

The psychology of waste is central to understanding why individuals and communities generate, perceive, and interact with waste in the ways they do (Raghu &

Rodrigues, 2020). From a socio-cognitive perspective, waste behaviors are influenced by cultural norms, mental models of consumption, identity constructs, and risk perceptions. In many African counties, waste is not simply a material by-product of consumption but is tied to notions of modernity, status, and economic value, where visible consumption can signal social mobility even when disposal systems are inadequate (Bell, 2019). Psychological constructs such as cognitive dissonance and bounded rationality help explain why people may continue unsustainable disposal practices even when aware of environmental harm. Also, the immediate convenience or symbolic gain from consumption outweighs distant and abstract environmental consequences (Hasan & Ghosh, 2024). Moreover, collective efficacy and the belief that a community can enact meaningful change is often eroded by historical underinvestment in waste infrastructure. This reinforces fatalistic attitudes toward waste management and undermining participation in recycling or segregation practices (Escamilla-García, 2024).

Waste accumulation is not spatially neutral but socially and politically patterned, with certain communities, markets, transport hubs, and informal settlements disproportionately burdened as persistent waste hotspots (Millington & Lawhon, 2019). These locations often become normalized as “sacrifice spaces”, where chronic waste presence is socially accepted and politically tolerated. Leadership disengagement in such areas is frequently driven not by ignorance, but by political rationality, where resource allocation follows visibility, electoral value, and economic return rather than environmental need. Marginalized communities with limited political voice are therefore deprioritized, producing cycles of infrastructural neglect and environmental abandonment (Van Neste, 2020). This selective governance fosters what can be termed institutionalized indifference, where persistent waste conditions become administratively normalized rather than treated as crises. Over time, residents internalize this neglect, leading to adaptive behaviors that accommodate waste rather than resist it, including informal dumping, open burning, and informal disposal economies (Muheirwe et al., 2023). Consequently, leadership inaction does not merely reflect governance failure but actively reshapes community psychology, transforming waste from a solvable management challenge into a socially embedded and politically sustained condition (Esposito et al., 2021).

Sustainable solid waste treatment and management technologies in Africa must be evaluated not only in terms of technical efficiency and economic viability but also through the lens of behavioral adaptation and social acceptance (Lapiso & Roubík, 2025). Technologies such as anaerobic digesters, composting systems, and material recovery facilities promise significant environmental and economic benefits. However, their uptake is constrained by psychological barriers including distrust of new systems, perceived complexity, and lack of alignment with local practices (Chindasombatcharoen et al., 2024). For instance, households may resist source separation if they do not perceive direct personal benefits or lack confidence that separated waste will be properly processed. Similarly, informal waste

pickers, who play a crucial role in material recovery, may be marginalized by formal technologies that fail to integrate their expertise (Yu et al., 2022).

Toward integrated sustainable solid waste management (ISSWM), effective strategies must synergize technological innovation with psychologically informed policy frameworks and community engagement (Devi et al., 2024). This entails co-designing waste systems with stakeholders, leveraging social norms to foster positive behaviors, and deploying targeted communication that reframes waste as a resource rather than a nuisance. Intervention designs informed by nudge theory: for example, default options for recycling and feedback mechanisms that make waste reduction progress visible can significantly shift behavior without heavy enforcement (Barker et al., 2021). Furthermore, capacity building that enhances community self-efficacy can transform perceptions of agency, enabling citizens to advocate for service improvements and participate meaningfully in circular economy practices (Dumitru et al., 2025). In the African context, where diversity of culture, governance, and infrastructure is vast, an integrated approach must be adaptive, equitable, and rooted in psychological insights that bridge human behavior with sustainable technological pathways.

5.5. Regulatory and Policy Challenges in Solid Waste Management

Effective governance and robust regulatory oversight are essential for achieving sustainable municipal solid waste (MSW) management in Africa (Giwah et al., 2021). The continent demonstrates significant variability in policy development, institutional capacity, and enforcement mechanisms. Countries such as South Africa, Morocco, and Egypt exemplify relatively advanced governance systems, with comprehensive national strategies that incorporate enforceable landfill standards, recycling targets, and integration of waste-to-energy (WtE) technologies (Rezania et al., 2023). These regulatory frameworks facilitate higher recycling rates, increased adoption of advanced waste treatment methods, and the alignment of municipal waste management practices with environmental sustainability and climate mitigation goals.

Conversely, many nations in West and Central Africa experience fragmented policies, weak enforcement, and limited coordination among municipal, regional, and national authorities. This institutional fragmentation undermines operational efficiency, leads to inconsistent waste collection and treatment practices, and often results in widespread environmental contamination (Wong, 2025). In such contexts, the absence of clear policy mandates and accountability mechanisms restricts technological innovation and discourages private sector engagement. Moreover, overlapping responsibilities among local and national bodies frequently cause duplication of efforts and inefficiencies in waste management operations.

Public-private partnerships (PPPs) have emerged as a vital mechanism to bridge resource gaps and improve service delivery. Examples from Ghana and Kenya highlight the potential of PPPs to enhance collection coverage, operational efficiency, and community engagement. However, these partnerships often face sustainability

challenges due to inadequate regulatory oversight, inconsistent policy application, and limited monitoring frameworks, which compromise long-term outcomes. Without enforceable contracts, performance-based incentives, and regulatory compliance mechanisms, PPPs may fail to achieve scalable and sustainable impacts.

Financing for MSW management in Africa remains predominantly donor-driven or reliant on constrained municipal budgets, limiting the adoption and maintenance of advanced treatment technologies. Market-based instruments, such as extended producer responsibility (EPR), pay-as-you-throw schemes, and green bonds, remain underutilized but hold significant potential for mobilizing private investment and encouraging sustainable waste practices. Integrating such mechanisms into national and municipal strategies can create economic incentives for waste reduction, recycling, and technological innovation while fostering accountability among producers, consumers, and waste management authorities.

Fiscal instruments such as waste taxes, sanitation levies, and utility-linked charges represent underutilized but structurally powerful tools for financing sustainable MSW systems in Africa. Mechanisms such as sanitation or “call” taxes, environmental levies, and the integration of waste management fees into electricity and water bills create stable revenue streams that decouple waste financing from politically volatile municipal budgets. These embedded financing models enhance revenue predictability, improve cost recovery, and normalize waste services as essential public utilities rather than discretionary services. Moreover, earmarked levies can support infrastructure development, maintenance of treatment facilities, and the formal integration of informal sector actors into regulated waste economies. When transparently managed, such fiscal instruments also strengthen public trust and accountability, as citizens can directly associate contributions with service improvements. However, without equity safeguards, these systems risk exacerbating socio-economic inequalities; thus, progressive tariff structures and targeted subsidies are essential to protect low-income households. Properly designed, waste taxes and levies function not only as revenue mechanisms but as behavioral policy instruments, shaping consumption patterns and embedding environmental responsibility within everyday economic transactions.

To strengthen regulatory and policy frameworks, African countries must adopt integrated, multi-level governance approaches that harmonize policies across regions, clarify institutional mandates, and enforce environmental and public health standards. This includes the establishment of monitoring and evaluation systems, legal recognition of informal sector contributions, capacity building for regulatory personnel, and alignment with broader environmental and climate objectives. Such reforms are essential not only to enhance compliance and technology uptake but also to ensure that MSW management contributes to sustainable development, circular economy principles, and climate resilience across the continent.

5.6. Environmental and Public Health Implications

The environmental and health consequences of inadequate MSW management in

Africa are profound. Open dumps and uncontrolled burning release particulate matter and toxic gases, contributing to respiratory illnesses, while leachate contaminates surface and groundwater, facilitating cholera, typhoid, and diarrheal outbreaks (Siddiqua et al., 2022). Organic waste decomposition generates methane and other greenhouse gases, estimated at tens of millions of tonnes of CO₂-equivalent annually.

Mismanaged plastics and inert waste exacerbate flooding and vector-borne diseases, disproportionately affecting children and vulnerable populations. Adoption of composting, anaerobic digestion, and WtE systems mitigates these risks while promoting energy recovery and material reuse. Recognizing the nexus between environmental health and public health is vital for designing interventions that are protective, sustainable, and resilient to urban growth challenges.

5.7. Informal Sector and Community Participation

The informal waste sector constitutes a pivotal component of municipal solid waste (MSW) management across Africa. Informal actors, including waste pickers, scavengers, and small-scale recycling cooperatives significantly contribute to resource recovery, diverting between 15% and 25% of plastics, metals, and paper from landfills in cities such as Nairobi, Accra, and Lagos. Their activities not only reduce environmental burdens but also generate livelihoods for marginalized populations, which highlights the socio-economic significance of this sector. Despite these contributions, informal workers operate under hazardous conditions, lacking personal protective equipment, formal recognition, and access to health or social benefits, which exposes them to physical, chemical, and biological risks.

Integrating the informal sector into formal MSW systems presents a strategic opportunity to enhance both efficiency and equity. Legal recognition of informal waste actors, provision of capacity-building programs, contractual arrangements, and safety equipment can substantially improve operational outcomes while mitigating occupational risks. For example, formalized partnerships between municipalities and waste cooperatives in South Africa and Kenya have resulted in higher recycling rates, safer working conditions, and increased financial returns for workers. Additionally, structured inclusion facilitates data collection, monitoring, and planning, enabling municipal authorities to design more efficient collection routes, recycling initiatives, and treatment strategies.

Community participation complements the role of the informal sector by promoting source separation, waste minimization, and responsible disposal practices. Public engagement campaigns, educational initiatives, and behaviour-change programs increase household and commercial compliance, ensuring that organic, recyclable, and hazardous fractions are properly segregated. Such interventions not only support circular economy principles by recovering valuable materials and reducing landfill loads, but also strengthen environmental awareness and social accountability. Participatory approaches that combine formalization of the informal sector with active community engagement can create resilient, inclusive,

and sustainable MSW management systems that address both environmental and socio-economic objectives (Okot-Okumu & Nyenje, 2011).

6. Conclusion

Africa faces mounting challenges in solid waste management due to rapid urbanization, population growth, and changing consumption patterns. Most waste management systems rely on open dumping and unengineered landfills, causing environmental harm and public health risks, including water contamination and vector-borne diseases. While some countries, such as South Africa and Morocco, have implemented waste-to-energy plants and composting facilities, coverage is limited, and adoption is inconsistent (Mmereki et al., 2024).

This study emphasizes the need for Integrated Sustainable Waste Management (ISWM) frameworks that address reduction, reuse, recycling, and recovery in a coordinated manner. Sustainable solutions must combine context-appropriate technologies, such as source segregation, decentralized composting, material recovery facilities, and modular waste-to-energy systems with strong governance, inclusive financing, and community engagement. Integrating the informal sector, enhancing regulatory enforcement, and adapting interventions to local socio-cultural conditions are crucial to improving efficiency, environmental outcomes, and public health. Despite regional data limitations, the findings highlight opportunities for scalable, resilient, and socially inclusive waste management systems across Africa.

7. Recommendations

First, African countries should prioritize the adoption of Integrated Sustainable Waste Management (ISWM) frameworks across all levels of governance. This includes promoting source segregation, decentralized composting, material recovery facilities, and context-appropriate waste-to-energy solutions. Technology deployment should be guided by local waste composition, urban density, and socio-cultural factors. Strengthening regulatory frameworks is essential to enforce standards, ensure compliance, and provide clear mandates for municipalities, private operators, and the informal sector. Governments should also integrate the informal waste sector into formal systems through legal recognition, training, and occupational safety measures, enabling efficiency, equity, and social inclusion.

Secondly, financial sustainability and community engagement must complement technological and regulatory interventions. Diversifying funding through public-private partnerships, pay-as-you-throw schemes, extended producer responsibility programs, green financing, and fiscal instruments such as environmental levies, waste taxes, and sanitation fees can support long-term system operation and expansion. Simultaneously, behavioral interventions such as public education, awareness campaigns, and social norm-based incentives can increase household and commercial participation in waste reduction, recycling, and segregation. Ongoing monitoring, data collection, and stakeholder feedback should

guide adaptive management, ensuring that MSW systems remain responsive, resilient, and aligned with environmental, public health, and circular economy objectives across Africa.

Author Contributions

KSB: Conceptualization, methodology, investigation, data curation, validation, data analysis, writing—original draft preparation, writing—review and editing, supervision. The author has read and approved the final manuscript.

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This study is a scoping review. All data extracted and synthesized are from published articles, reports, and institutional documents, which are fully referenced in the manuscript and supplementary materials.

Permission to Publish

You have full permission to publish this manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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