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Literature review on the impact of biomedical waste management on health and the environment in healthcare facilities

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Abstract

Context: Biomedical waste management represents a major challenge for health systems, especially in developing countries where infrastructure and regulations are often inadequate. Poor management of such waste can lead to significant health and environmental risks, including the spread of infections and the pollution of soil and water. **Method:** This study aims to assess the impact of hospital waste management on health and the environment by identifying existing practices, current regulations, and their levels of enforcement.

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Results: The findings reveal several shortcomings. Although policies exist, they are not effectively implemented. Only 29% of the surveyed facilities practice waste segregation at the source, and 26% have appropriate storage areas. The majority of waste is either incinerated (68%) or buried (25%), often without proper environmental impact control. Additionally, waste management is frequently entrusted to untrained personnel, increasing the risk of nosocomial infections and pollution-related diseases. **Conclusion:** This study highlights a lack of training, funding, and suitable equipment. It is crucial to improve infrastructure, strengthen regulations, and adopt sustainable practices to reduce the health and environmental risks associated with hospital waste.

Introduction

Biomedical waste (BMW) management represents a major challenge for health systems worldwide. Healthcare facilities, as the primary producers of this type of waste, face a complex issue that involves not only the health and safety of staff and patients but also the protection of the environment. Due to their potentially infectious, toxic, or radioactive nature, BMW requires strict management in accordance with health and environmental standards to minimize its harmful effects on human health and ecosystems.

The production of BMW in healthcare facilities is steadily increasing due to population growth, expanded access to medical care, and the evolution of medical practices. According to the World Health Organization (WHO), approximately 15% of waste generated by healthcare activities is considered hazardous, as it poses a risk of chemical, biological, or radioactive contamination (WHO, 2018). Infectious, sharp, anatomical, pharmaceutical, and radioactive wastes pose a direct threat to public health when improperly managed. In the absence of appropriate management protocols, such waste can transmit infectious diseases such as hepatitis B and C, HIV, and tuberculosis, cause accidental injuries (such as needlesticks or cuts), and contaminate soil, air, and water resources (Azv Santé, 2021).

Beyond direct health risks, poor BMW management also places significant pressure on the environment. Open-air incineration or illegal dumping of medical waste releases toxic gases, including dioxins and furans, thereby contributing to air pollution (WHO, 2018). Additionally, the discharge of chemical and pharmaceutical substances into aquatic environments disrupts ecosystems and promotes the development of antibiotic resistance in aquatic wildlife (Youmatter, 2021). Soil contamination from untreated BMW leads to the degradation of agricultural land quality and jeopardizes food security (Humatem, 2006).

Given these challenges, the implementation of effective BMW management strategies in healthcare settings has become a public health and environmental protection priority. WHO and other public health organizations emphasize the need for an integrated approach, including source reduction, waste segregation, disinfection, appropriate treatment (such as autoclaving, controlled incineration, or chemical treatment), and energy recovery from waste (WHO, 2018). Effective management of BMW also relies on the continuous training of medical staff, the awareness of healthcare stakeholders, and the establishment of regulatory frameworks and strict monitoring mechanisms (ICRC, 2011).

In this context, the present literature review aims to analyze the impact of BMW management on health and the environment in healthcare facilities. The objective is to explore, through a critical review of existing literature, the current BMW management practices, the risks associated with inadequate handling, and the proposed solutions for improving waste management.

By highlighting current knowledge on this issue, this article seeks to provide a foundation for reflection and guidance for policymakers, healthcare facility managers, and health professionals in order to promote safe and sustainable BMW management.

I- Overview of Biomedical Waste

Waste is defined as any residue resulting from extraction, processing, transformation, production, consumption, use, monitoring, or filtering activities, and more generally, any object or material discarded or required to be disposed of by its holder in order to avoid harm to health, public hygiene, or the environment.

There are two main categories of waste generated by healthcare facilities:

- **Household-like waste (DAOM)**, and
- **Infectious healthcare waste (DASRI)** (WHO, 1999, cited by El Morhit, 2017).

Hospital waste also includes any waste produced by the functioning of a hospital, whether from inpatient and care services or from medical-technical, technical, administrative departments, and their dependencies (Amnrani, 2000, cited by David, 2019). Hospital waste may be solid, gaseous, or liquid in form.

Biomedical waste refers specifically to waste generated from healthcare activities, including tissues, organs, blood, and biological fluids.

I-1. Types of Biomedical Waste

Biomedical waste (BMW) encompasses a wide range of materials generated by healthcare-related activities, including hospitals, medical research centers, laboratories, and veterinary clinics. Improper management of this waste can pose significant risks to public health and the environment (WHO, 2022). Biomedical waste is generally classified into several categories:

I-1-1. Infectious Waste

Infectious waste is the most common type found in healthcare settings. It includes any material that has been in contact with blood or potentially infectious body fluids. This category includes:

- Soiled dressings
- Used syringes
- Blood bags

These wastes pose a high risk of transmitting infectious diseases such as HIV, hepatitis B, and hepatitis C (Kumar et al., 2021). Improper handling and treatment of such waste can lead to nosocomial infections and environmental contamination (Gupta et al., 2023).

I-1-2. Anatomical Waste

Anatomical waste consists of human tissues, organs, or body parts resulting from surgeries, autopsies, or medical laboratory procedures. The management of such waste requires special attention due to its sensitive nature and potential for biological contamination (Ali et al., 2022).

I-1-3. Pharmaceutical Waste

Pharmaceutical waste includes expired medications, laboratory chemicals, and unused intravenous solutions. These substances can be toxic to the environment if not properly treated. The contamination of soil and water bodies by pharmaceutical residues is an increasingly critical environmental issue (Patwary et al., 2021).

I-1-4. Chemical Waste

Chemical waste originates from laboratories and medical services that use diagnostic or therapeutic substances. It includes:

- Solvents
- Laboratory reagents
- Harsh cleaning agents

Improper disposal of these wastes can cause chemical burns, toxic reactions, and severe environmental pollution (Gupta et al., 2023).

I-1-5. Radioactive Waste

Radioactive waste is produced by nuclear medicine departments, radiotherapy units, and diagnostic imaging services (e.g., CT scans, X-rays). These wastes must be stored in specialized facilities to prevent radiological contamination of the environment (WHO, 2023).

The management of biomedical waste (BMW) has become a major concern for health systems around the world due to its significant impact on human health and the environment. This section offers a synthesis of existing work, a critical analysis of previous findings, highlights research gaps, and positions this article within the context of previous studies.

I-2. Biomedical Waste Management Approaches

Biomedical waste management refers to the set of activities that ensure the collection, segregation, storage, transport, and disposal of waste generated during healthcare activities (Ministry of Public Health, 2021).

Biomedical waste management practices vary between countries and regions:

I-2-1. Europe

In Europe, biomedical waste management is highly regulated. European Union (EU) member states have established selective collection systems, incineration treatment, and disinfection procedures for infectious waste (Liu et al., 2020). Directive 2008/98/EC on waste—also known as the "Waste Framework Directive"—sets strict requirements for the handling of all waste types, including biomedical waste. It mandates that all waste must be collected, stored, transported, and disposed of in ways that do not harm human health or the environment.

Infectious and hazardous waste must be sorted at the source, stored in designated containers, and disposed of in appropriate facilities, such as incinerators or secure landfills.

EU member states are required to implement national regulations in line with these directives. For example, the United Kingdom has adopted specific rules for healthcare facilities, such as the *Health and Safety (Sharp Instruments in Healthcare) Regulations 2013*, which imposes strict conditions for the disposal of sharps and infectious waste.

Additionally, EU regulations encourage recycling and reuse where feasible, although this is more applicable to certain waste types, such as plastics, than to infectious or chemical biomedical waste. Directive 2010/75/EU on industrial emissions provides guidance for waste incineration facilities, including those handling biomedical waste, in order to limit the environmental impact of these operations.

I-2-2. America

In the United States, the management of biomedical waste is governed by regulations established by the **Environmental Protection Agency (EPA, 2020)** and the **Occupational Safety and Health Administration**

(OSHA, 2022). The EPA enforces the *Resource Conservation and Recovery Act (RCRA)*, which regulates hazardous waste, including infectious biomedical waste. This legislative framework requires healthcare facilities to comply with strict standards for the storage, transportation, and disposal of waste to prevent environmental contamination. EPA regulations include specific requirements such as:

- The use of secure and appropriate containers;
- Treatment methods such as incineration or chemical disinfection;
- Strict waste labeling;
- and complete traceability of the disposal process.

OSHA, on the other hand, focuses on the **safety of healthcare workers** who are exposed to biological hazards. According to OSHA's *Bloodborne Pathogens Standard*, healthcare facilities must:

- provide personal protective equipment (PPE),
- train staff in safe biomedical waste handling,
- and implement safety protocols to prevent accidental exposure.

I-2-3. Africa

In Africa, biomedical waste management faces numerous structural challenges, including **lack of infrastructure, funding, and trained personnel** (Ali et al., 2022). The most commonly used treatment methods include:

- landfilling,
- open-pit incineration,
- and basic chemical disinfection.

These practices pose serious environmental risks, such as soil and groundwater contamination.

Although several African countries have adopted legal frameworks to regulate medical waste management, their **implementation remains uneven and often ineffective**.

For example:

- **In Nigeria**, national guidelines have been introduced, but implementation varies significantly between healthcare facilities (Akinmoladun & Adeola, 2021).
- **In South Africa**, despite a more structured legal framework, enforcement gaps persist, leading to public health and environmental safety concerns.

Governments in many African countries lack the resources needed to monitor waste management practices, and healthcare workers are generally not adequately trained to handle such waste properly.

I-2-4. Cameroon

In Cameroon, biomedical waste management remains **poorly organized and insufficiently regulated**. A study by Mbog Mbog et al. (2020) revealed that **70% of healthcare facilities** dispose of their waste inappropriately.

Although the country has relevant regulatory texts, such as:

- **Law No. 96/12 of August 5, 1996** on environmental management,
- **and Decree No. 2005/0575/PM of February 25, 2005** on waste management,

these texts **do not specifically or comprehensively address biomedical waste**, and their enforcement is very limited.

The major challenges include:

- **lack of awareness and continuous training** among healthcare personnel;
- **a shortage of appropriate infrastructure**, such as functional incinerators;
- **and the absence of a formal system** for sorting, collecting, and treating biomedical waste.

A 2024 WHO study reported that in most healthcare facilities in Cameroon, biomedical waste is often **disposed of in common landfills**, posing significant public health risks.

II- Methodology

II-1- Study Description

The methodology used for this study was based on a systematic and rigorous approach to collecting and analyzing data from existing research on biomedical waste management. The main objective was to synthesize available knowledge, evaluate the quality of the studies, and extract relevant information to understand the impact of this management on public health and the environment, while highlighting gaps in current research.

Data collection was carried out using a systematic literature review approach, following the standard steps of a systematic review. The search equation "(impact of waste management in healthcare) OR (impact of hospital waste management) AND (on health and environment)" was used in search engines such as PubMed, Google Scholar, Cochrane, African Journals Online (AJOL), and Online Theses and Dissertations. This search yielded approximately 5500 articles, which were then filtered based on the abstract, methodology, presence of keywords, removal of duplicates, and compliance with the objectives. After this selection process, 31 full-text articles were chosen for analysis. These articles were read in their entirety.

Selection criteria for the articles included studies published in English or French, research papers, government reports, and surveys conducted on biomedical waste management in various geographical contexts (Europe, America, Africa, and Cameroon). Articles were selected based on their relevance to the topic, methodological rigor, and impact on biomedical waste management.

Data collection also involved reviewing reports from international agencies, such as the World Health Organization (WHO), the Environmental Protection Agency (EPA), as well as government documents regarding the regulation of biomedical waste management in the countries studied.

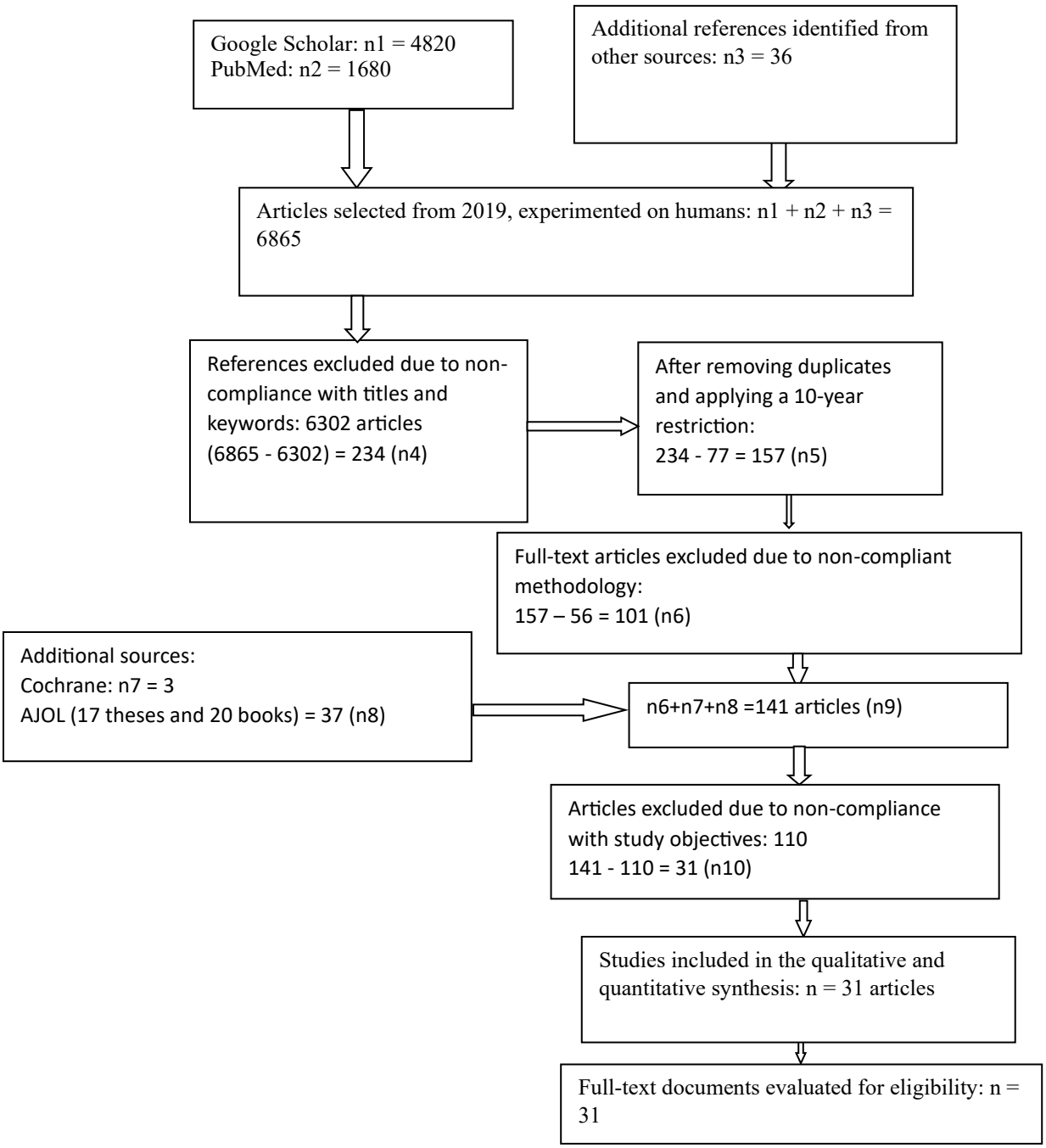

Figure 1: Diagram of the Document Processing Workflow

II-2. Data Sources

The main data sources used in this study include:

• **Scientific articles**: Peer-reviewed publications on biomedical waste management, regulations, and their impact on health and the environment.

• **Reports from international agencies**: Reports from WHO, EPA, the World Bank, and other international organizations on best practices in biomedical waste management.

• **Surveys and field studies**: Some empirical studies based on surveys conducted in healthcare facilities in developing countries, such as Cameroon, to understand local practices in biomedical waste management.

• **Government documents**: Legislative and regulatory texts related to biomedical waste management in different countries, including laws, decrees, and local standards.

II-3. Selection Criteria for Studies Included in the Review

The studies included in this review were selected based on several criteria:

• **Relevance**: Studies must specifically address biomedical waste management and its impact on health and the environment.

• **Publication period**: Preference was given to studies published within the last ten years (2010–2019) to ensure the inclusion of the most recent data and analyses.

• **Rigorous methodology**: Selected studies must use rigorous scientific methodologies, whether qualitative, quantitative, or mixed-method research.

• **Geographic diversity**: The selection included studies from various geographic regions (Asia, Africa, and Cameroon) to ensure a global representation of the topic.

• **Quality of publication**: Studies must be published in high-quality, peer-reviewed scientific journals or in reports from recognized public health agencies.

Table 1: Classification of Articles by Year of Publication, Country, Study Type, and Number of Articles

Year of Publication	**Number of Articles and Theses**	**Study Type**	**Country/Countries**
2010	01	Mixed	India
2013	04	Quantitative	Ethiopia, Cameroon
2014	02	Quantitative	India, Morocco
2015	01	Quantitative	Benin
2016	04	Quantitative, Mixed	DRC Kinshasa, Morocco, Cameroon, Chad
2017	07	Quantitative, Mixed	Mediterranean, Algeria, Morocco, Senegal, Cameroon
2018	03	Quantitative, Mixed	Pakistan, Algeria, DRC Brazzaville
2019	09	Quantitative, Mixed	Morocco, Myanmar, Morocco, Morocco, Cameroon
Total	**31**	/	/

II-4. Analytical Tools

Several tools were used to analyze the studies, including:

- **Comparative analysis**: This method allowed for the comparison of different biomedical waste management systems in the countries studied by examining regulations, local practices, and the effectiveness of strategies implemented to minimize environmental and health impacts.

- **Thematic analysis**: A thematic analysis was conducted to identify recurring themes across the studies, such as challenges related to staff training, awareness of health risks, and gaps in law enforcement. This method made it possible to group the studies by common themes and synthesize the findings according to different axes of analysis.
- **Coding method**: Coding was used to extract relevant information from each study and organize it into specific categories (e.g., type of waste, health impact, environmental impact, legislative framework, etc.). Each study was coded based on its main findings, thereby facilitating comparison and synthesis of the data.
- **Study quality assessment**: The studies were assessed based on methodological rigor, sample size, and the quality of collected data. This quality assessment made it possible to determine the reliability and validity of the results presented in each study.

The analysis of collected data was conducted using a questionnaire designed for this purpose. The software **KOBO COLLECT** was used to generate graphs and charts corresponding to the various objectives of this literature review.

III. Results and Discussion

III-1. Existence or Absence of Laws Supporting Hospital Waste Management

The analysis of scientific literature on biomedical waste management reveals significant heterogeneity regarding the existence and application of regulatory frameworks worldwide. Among all the reviewed articles, **46%** mention the existence of specific local or international laws governing this management, suggesting a normative recognition of the issue. However, **19%** of publications report the absence of regulation, while **35%** remain silent on the matter, reflecting a lack of clarity or interest from certain countries on this issue.

These findings are consistent with observations by the **World Health Organization (WHO, 2017)**, which points out that in many countries—especially low- and middle-income ones—biomedical waste legislation is either non-existent, incomplete, or poorly enforced. Thus, the mere presence of a legal framework does not guarantee its effective implementation. In this regard, studies by **Zeeshan et al. (2018)** and **Mukhaiber (2017)** reveal similar dysfunctions, even in contexts where theoretically robust laws are in place.

An intercontinental comparison helps to illustrate this disparity. In Europe, mechanisms such as **Directive 2008/98/EC** on hazardous waste provide a binding legal foundation. However, implementation remains uneven, particularly in Eastern European or recently industrialized countries, where logistical capacities and human resources are limited. Conversely, in several African and Latin American countries, laws do exist but are only partially operational. Funding shortages, lack of control mechanisms, and inadequate training are key factors limiting the effectiveness of existing systems (Mukhaiber, 2017).

Critical data analysis highlights two trends: on one hand, a growing formalization of hospital waste-related issues, expressed through the adoption of laws; on the other, a concerning gap between the regulatory framework and operational reality. Indeed, although nearly half of the studies report the existence of laws, few focus on their effectiveness or practical applicability, thus exposing a disconnect between political intent and everyday practices.

The **19%** of articles indicating the absence of regulation reflect a clear disregard for health and environmental concerns. This legal vacuum is especially alarming given that mismanaged biomedical waste is a major source of risks: nosocomial infections, accidental exposure to blood, environmental pollution, and the spread of multidrug-

resistant bacteria (Zeeshan et al., 2018). Therefore, the absence of legislation equates to a failure to recognize a major public health issue.

Furthermore, the lack of explicit data in **35%** of the articles indicates a lack of transparency or an absence of evaluation of public policies on the matter. It also underscores the need for more rigorous methodological approaches in documenting and assessing legislative frameworks at both national and regional levels.

This review reveals that the quality of hospital waste management is closely tied to the existence of clear legal standards—most importantly, to their effective application, supported by coherent and sustainable policies. Continuous training of healthcare personnel, investment in appropriate infrastructure, community awareness, and institutional strengthening emerge as essential pillars of a successful policy. The absence of supervision, control, and stakeholder involvement represents a major obstacle, exacerbated by a lack of coordination between healthcare institutions and regulatory authorities.

Finally, the consequences of these failures are not merely institutional—they directly affect human health and the environment. The risks involved, whether biological, chemical, or environmental, are heightened by persistent legal and operational shortcomings. As highlighted by the **WHO (2017)**, poor medical waste management contributes to the spread of pathogens, endangers healthcare workers, and permanently harms ecosystems.

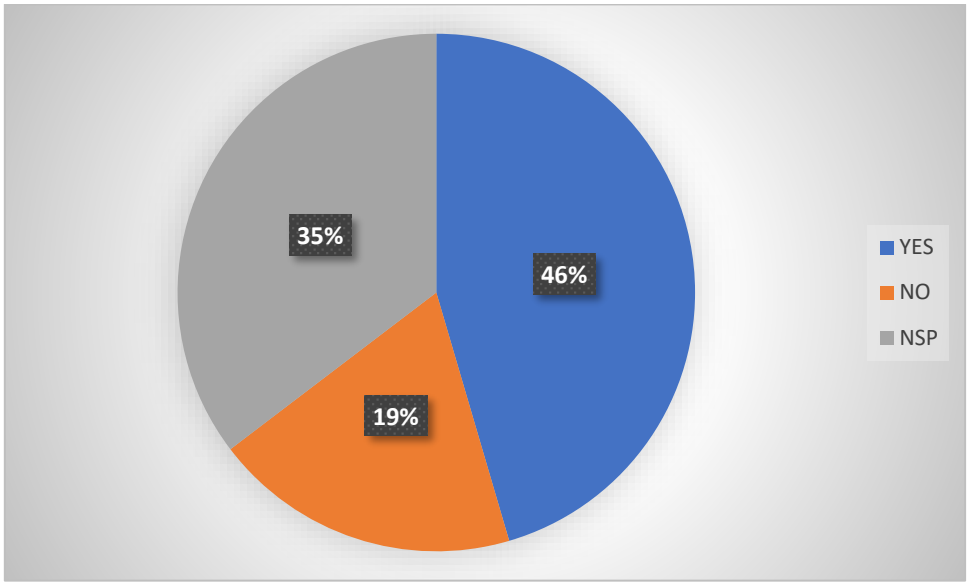

Figure 1: Existence or Non-existence of Legislation

III-2. Existence or Non-existence of a Biomedical Waste Management Unit within Health Facilities in the Literature

The presence of a dedicated structure for biomedical waste management (BMWM) within health facilities is a key indicator of institutional commitment to preventing health and environmental risks. However, data analysis from the literature reveals a concerning finding: many health facilities, particularly in resource-limited countries, lack a unit specifically responsible for this essential function.

This structural deficit reflects a lack of prioritization of biomedical waste management within the internal policies of health facilities. Although several legislative texts—especially national decrees on hospital hygiene—mandate

the establishment of hygiene and sanitation services, their implementation remains inconsistent in practice. This gap between regulatory obligations and on-the-ground realities raises concerns about the effectiveness of public environmental health policies.

Studies by Bonkoungou (2017) and El Morhit (2017) converge in emphasizing that the absence of formal BMWM structures significantly increases the risks of contamination, pathogen spread, and environmental pollution. They also highlight a frequently overlooked issue: how users perceive hygiene affects their likelihood of using health facilities. A dirty or poorly maintained environment, coupled with poor waste management, not only undermines care quality but also erodes public trust in the health system.

Mbog's (2018) research reveals that even when BMWM falls under the hygiene and safety service, this service is often nonexistent or under-resourced in many health structures. The problem is not just the absence of a formal administrative entity, but also the lack of qualified human resources, as noted by Mwisa et al. (2018). This double shortfall—quantitative and qualitative—greatly limits the ability of facilities to manage biomedical waste effectively, exposing patients, caregivers, and communities to avoidable risks.

An international comparative analysis shows that in well-structured health systems (such as in some European or East Asian countries), biomedical waste management is handled by dedicated functional units with trained personnel and strict protocols. In contrast, in several Sub-Saharan African and South Asian countries, BMWM structures are often non-existent or barely functional due to lack of resources and political will.

Even more alarmingly, in the few facilities where such services do exist, their role remains marginalized. Research by Bidias (2016) and Yaya (2011) shows that recommendations from hygiene services are rarely taken into account by hospital management. This lack of intersectoral collaboration illustrates a disconnect between technical management requirements and the managerial logic of institutions.

Thus, mere existence is not enough to ensure a hygiene service's effectiveness. It must also be granted decision-making power, sufficient resources, and institutional recognition. Without these conditions, existing structures remain formalities with no real impact on practices.

Ultimately, literature analysis demonstrates that having a hygiene service dedicated to BMWM is not only desirable but essential. This service must be integrated into each health facility's functional organizational chart, with clear roles, dedicated resources, and ongoing staff training. Its implementation cannot be separated from decision-makers' commitment to ensuring safe and sustainable biomedical waste management.

III-3 Existence or Absence of a Hospital Waste Management Policy

The establishment of a hospital waste management policy is a fundamental pillar for ensuring care safety, protecting public health, and preserving the environment. However, the analysis of the 17 scientific articles reviewed in this study reveals a significant paradox: although the existence of waste management policies is frequently reported, their actual implementation remains largely deficient with 45.1% not apply.

Indeed, 14 out of the 17 studies mention the formal existence of a waste management policy within healthcare facilities, but also highlight its ineffectiveness in practice. This observation reinforces an idea already well supported in the literature (WHO, 2017; Zeeshan et al., 2018), namely that the existence of a regulatory framework

by itself does not guarantee the effective implementation of safe and sustainable practices. This represents a gap between policy and practice, a phenomenon widely observed in low- and middle-income countries.

Several factors explain this implementation gap: lack of staff training, weak financing, misalignment of regulations with local contexts, and limited political will. As emphasized in the study by Zeeshan et al. (2018), a policy, no matter how well designed, remains ineffective if it is not supported by resources, skills, and strong institutional commitment. The absence of monitoring and accountability mechanisms further exacerbates this inefficiency, as healthcare facilities are not held responsible for their inaction.

This situation is further complicated by a structural issue: excessive policy standardization. National policies are often too general and fail to consider the logistical, geographical, and human specificities of individual healthcare facilities. This lack of local adaptation is a major obstacle to operationalization. A comparative study conducted in India and Nepal illustrates this point well: policies there are not only compliant with national standards but are also tailored to the realities of tertiary hospitals. These facilities have successfully integrated sustainable practices such as waste sorting, recycling, and source reduction, demonstrating that the effectiveness of a policy also depends on its contextual grounding.

In contrast, in most African countries, hospital waste management suffers from a severe lack of rigor in policy enforcement. This shortcoming, noted by many authors (Bidias, 2016; Mbog, 2018), stems from a shortage of qualified personnel, the absence of suitable infrastructure, and chronic underfunding. As a result, healthcare facilities paradoxically become sources of pollution and health risks, undermining the safety of patients, healthcare workers, and surrounding communities.

The intercontinental comparison also highlights the importance of a participatory approach in the development and implementation of policies. In some Asian countries, waste management policies are the result of collaboration between health authorities, hospital administrators, and civil society organizations, which enhances their acceptability and applicability. Conversely, in Africa, policies are often imposed in a top-down manner, without consultation, which limits their ownership by local stakeholders.

It follows that the mere existence of a policy is not enough: it must also be adapted, funded, known, and enforced. An effective policy relies on four interdependent levers: a clear regulatory framework, trained personnel, adequate material resources, and active local governance. The absence or weakness of any one of these components compromises the entire system.

In conclusion, the critical analysis of available literature reveals that hospital waste management remains largely theoretical in many regions of the world, particularly in sub-Saharan Africa. To reverse this trend, it is essential not only to strengthen legal texts, but also to operationalize them through contextualized policies, continuous training strategies, and sustained institutional commitment.

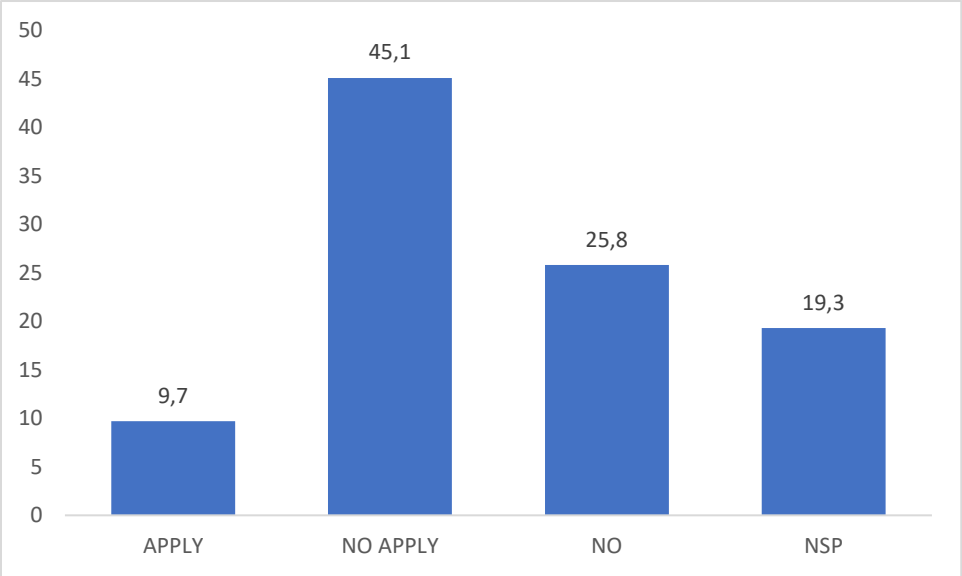

Figure 2: Existence or lack of a waste management policy and Its application

III-4- Existence of a Budget for Biomedical Waste Management

The analysis of scientific literature reveals a structural deficiency in the budgeting of activities related to biomedical waste management in healthcare facilities. This weakness, observed in the majority of the articles reviewed, constitutes a major barrier to the implementation of safe, sustainable, and effective practices. The handling of this issue remains largely peripheral in the funding policies of healthcare systems. The results show that only 3% of the studies explicitly mention the existence of a budget dedicated to biomedical waste management, while 23% state the total absence of a specific budget line. The remaining publications do not provide clear data on the topic, illustrating a concerning opacity or disinterest in this crucial aspect of hospital management. This budgetary silence can be interpreted as a symptom of the invisibility of biomedical waste issues in institutional priorities. In comparison, countries where waste management is integrated into national health policies show significantly better performance. In India, for example, biomedical waste management is financed through dedicated hospital budgets, often supported by public-private partnerships. Incentive mechanisms have also been put in place to encourage facilities to invest in modern treatment infrastructures (autoclaves, high-performance incinerators, sorting units). Similarly, some regions in the Maghreb, such as Morocco, have begun to integrate specific budget lines into their regional health development plans. In contrast, in most sub-Saharan African countries, as highlighted by Mbog (2017) and Kasuku et al. (2016), biomedical waste management remains marginalized in budget plans. The lack of funding not only prevents the acquisition of appropriate equipment but also hinders staff training, the implementation of standardized procedures, and the creation of monitoring and evaluation structures. This situation leads to a chronic dependence on external funding, notably from NGOs or international donors such as the Global Fund or GAVI. However, these funding sources, often limited in time, do not guarantee either sustainability or the autonomy of management systems. This financial precariousness has direct and serious consequences:

• Inadequate infrastructures: lack of sorting areas, defective or nonexistent incinerators, and irregular collection.

• Insufficient training: healthcare personnel do not receive continuous training on secure waste handling procedures.

• Risky practices: accumulation of waste in the open, open-air burning, and abandonment of syringes or contaminated materials in community dumpsites.

• Increased exposure to infections: medical staff, patients, and surrounding populations are exposed to pathogens, accidental pricks, and toxic waste discharges.

Beyond these observations, it appears urgent to reconsider biomedical waste management from the perspective of strategic investment. A sustainable approach necessarily involves a clear inclusion of biomedical waste management in public health budgets, accompanied by transparency mechanisms and expenditure evaluations. It is essential to view waste management not as a secondary item but as a lever for improving care quality, preventing infections, and protecting the environment.

Finally, interregional comparison offers a major lesson: countries that succeed in stabilizing their biomedical waste management systems are those that have chosen anticipatory, structured, and autonomous funding. In Africa, as elsewhere, further efforts are needed to evolve budgetary governance and integrate waste management as an essential public health priority.

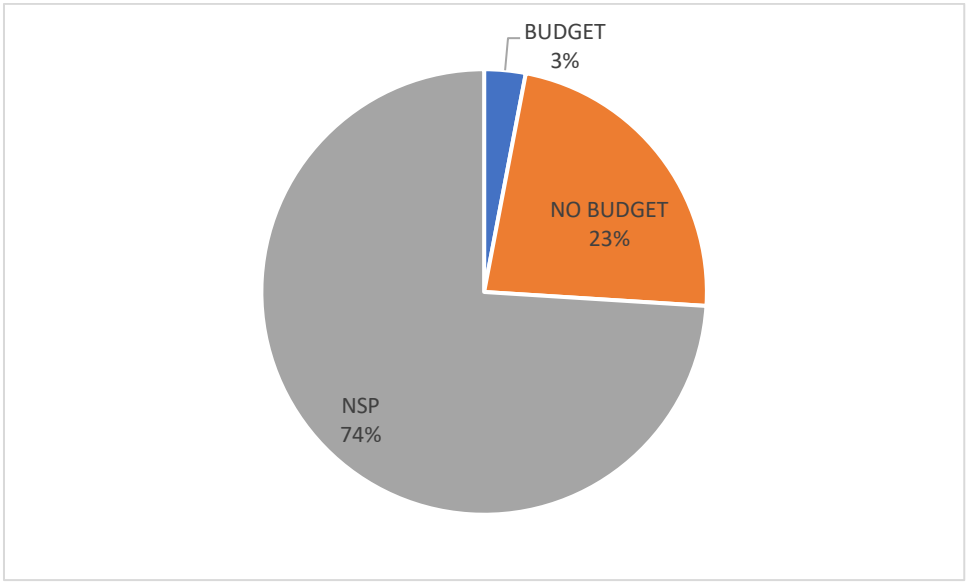

Figure 3: Existence or absence of a budget allocated to waste management

III-5 - Personnel Responsible for Waste Management in Healthcare Facilities

Biomedical waste management in healthcare facilities is, in most cases, handled by personnel who are either poorly qualified or not qualified at all for this specific task. The analysis of reviewed articles highlights a concerning reality: in 32% of the studies, waste management is carried out by maintenance staff who lack proven technical skills in hospital hygiene. Furthermore, 22% of those involved come from the traditional medical workforce (doctors and nurses), taking on these responsibilities as a secondary duty, often without adequate training.

This situation reveals a stark lack of specialization and institutional recognition of waste management as a technical field in its own right. Yet, as emphasized by the WHO (2018), preventing infectious and environmental risks associated with hospital waste requires specific expertise, incorporating strict protocols and mastery of management tools.

Unlike basic collection or sorting, biomedical waste management involves a complex chain of responsibilities—from packaging to disposal, including storage, transportation, disinfection, and monitoring. Ideally, this chain should be overseen by a public health engineer or a technician specialized in hospital hygiene, working in close collaboration with healthcare teams. However, the studies analyzed show that such profiles are rarely present in healthcare facilities, especially in sub-Saharan Africa.

The work of Bop et al. (2017) and Ahlam (2016) reminds us that medical staff, patients, visitors, and surrounding communities are not always aware of the risks associated with poor waste management. This lack of awareness represents a major weakness in the overall prevention system, making the population vulnerable to nosocomial infections and environmental contamination.

Moreover, Ndiaye et al. (2012) stress the need for advanced technical skills to ensure the safe disposal of hazardous waste, particularly those classified as highly infectious. However, the chronic undertraining of responsible staff, often coupled with the underrepresentation of hygiene professionals, exacerbates the system's failures. This is even more alarming given that private facilities, although subject to the same legislation, also struggle to recruit and retain qualified personnel, as noted by Yaya (2011).

Internationally, some initiatives can serve as models. For example, in Rwanda, a continuing education program on biomedical waste management was established in district hospitals, in partnership with NGOs and public health institutions. This approach, combining practical training, continuous evaluation, and capacity building, has led to significant improvements in sorting and disposal practices.

In contrast, in many French-speaking African countries, the risks related to biomedical waste continue to be downplayed, reflecting a low prioritization of the issue in health policies. This situation is fueled by the lack of involvement of hospital administrators, who are often unaware of the consequences of poor waste management on the facility's image, staff health, and the surrounding environment.

Thus, structural reform is essential, built around three priority areas:

1. Professionalization of the sector, with the creation of degree programs in hospital waste management;
2. Capacity building of existing staff, through continuing education and modules integrated into paramedical curricula;
3. Awareness-raising among administrators and decision-makers, to fully integrate this function into hospital development plans.

As emphasized by Daoudi (2008) and Bidias (2016), only a collective awareness—at the institutional, local, and community levels—will transform waste management into a lever for quality and safe care.

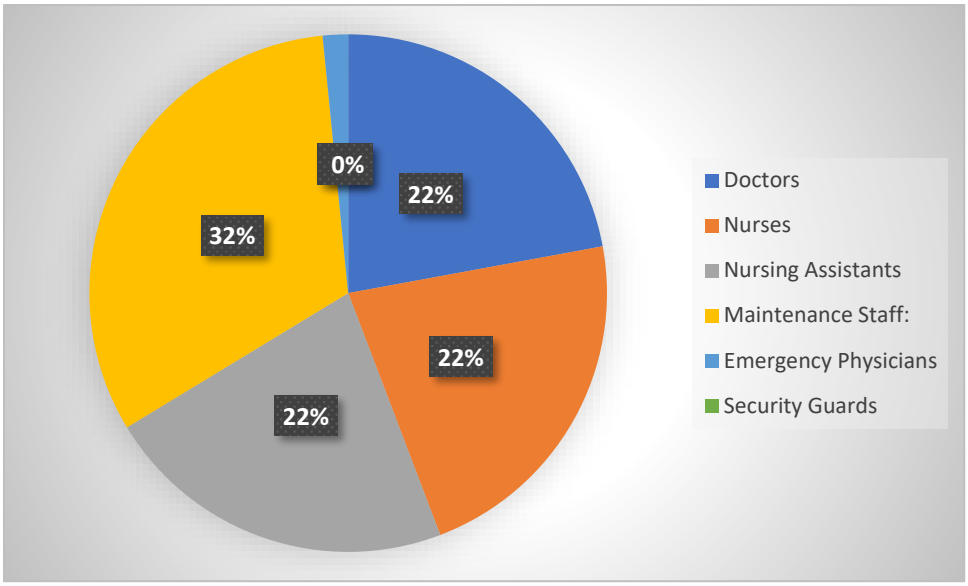

Figure 4: Existence of Personnel in Charge of Waste Management Mentioned in the Documentation

III-6. Waste Management Systems in the Literature Reviewed within Healthcare Facilities

III-6-1. External Waste Collection Systems

The effectiveness of a hospital waste management system largely depends on the quality of the collection mechanisms established within healthcare facilities. The analysis of the reviewed articles reveals a high degree of variability in the methods used for external biomedical waste collection, reflecting disparities in resources, institutional choices, and contextual constraints specific to each facility.

Plastic bags appear to be the most commonly used collection method, accounting for 42% of the practices reported. This choice is explained by their low cost and ease of use. However, their use raises significant safety concerns: in the absence of strict handling and disposal procedures, these bags can become sources of cross-contamination and accidental injuries, especially when they contain sharp objects or infectious fluids.

Evacuation bins, used in 35% of cases, offer a safer alternative, particularly for solid waste containment. When these bins are airtight, color-coded, and used according to standardized protocols, they enable better traceability and reduce the risk of leaks or staff exposure.

Regarding liquid waste management, 23% of facilities use pits—a solution often chosen by default due to the lack of adequate sanitation infrastructure. Although pits may offer temporary containment, poor maintenance or inadequate design (lack of lining, proximity to groundwater) raises serious environmental concerns, particularly soil and water pollution.

Additionally, 10% of healthcare facilities have collection bins located at the level of services or buildings, allowing for more decentralized management and placement closer to the points of waste generation. This system facilitates initial sorting at the source, a necessary condition for any differentiated treatment strategy (incineration, autoclaving, secure burial). However, its effectiveness largely depends on staff training and the presence of clear protocols.

A study by Kamelan (2017) in Côte d'Ivoire illustrates the major challenges associated with liquid waste management: several healthcare facilities lacked any specific system due to the absence of appropriate

infrastructure. The use of autonomous sanitation systems (rudimentary pits, improvised drainage) often occurs without secure protocols, exposing workers, users, and the environment to increased biological and chemical risks. The situation observed in many African countries contrasts with that of certain Asian or European nations, where centralized vacuum collection systems, single-use containers, or secured carts for intra-hospital transport are routinely employed in compliance with WHO standards. These practices reflect an institutional will to consider waste management not as a marginal task, but as a strategic lever for health and environmental prevention.

In summary, the absence or inadequacy of standardized waste collection systems, particularly for liquid waste, highlights a structural gap in the implementation of biomedical waste management policies. This observation underscores the urgent need to:

- Strengthen the technical and material capacities of healthcare facilities;
- Implement operational protocols tailored to local resources;
- Ensure regulatory monitoring to guarantee compliance with international standards for hospital waste collection and treatment.

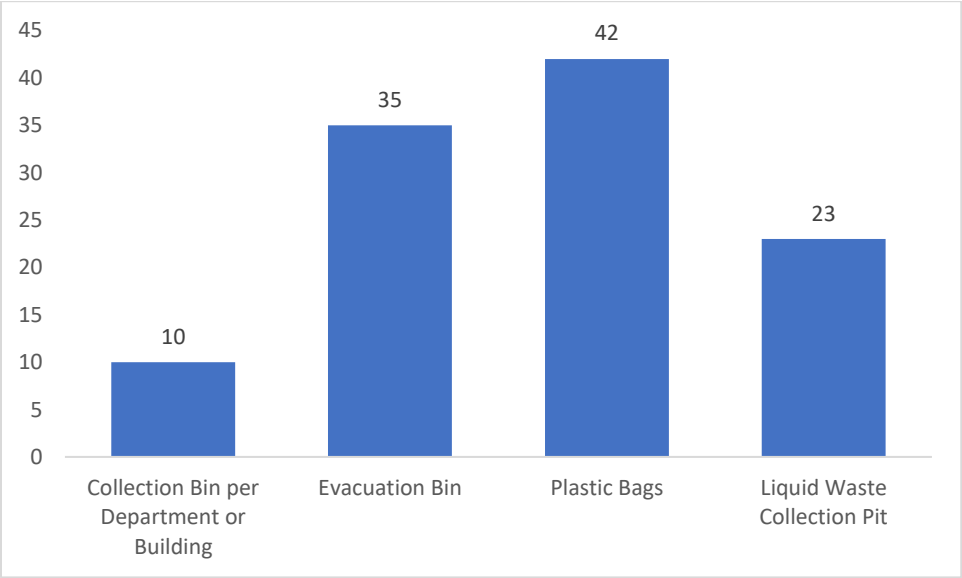

Figure 5: External Waste Collection Equipment

III-6-2. Existence of a Source-Sorting System

Source sorting is a crucial step in the hospital waste management chain. It not only ensures the safety of subsequent steps (storage, treatment, disposal), but also helps reduce the volume of hazardous waste, optimize treatment costs, and prevent health and environmental risks. However, the analysis of the reviewed scientific articles reveals that only 39% mention the existence of a source-sorting or pre-collection system in the healthcare facilities studied.

This low rate of adherence to primary sorting can be explained by several interrelated factors:

1. **Lack of awareness about the impact of source sorting**

A significant proportion of hospital staff are unaware of the risks associated with improper segregation of biomedical waste. Due to a lack of training and awareness, personnel often view sorting as an additional burden

rather than a collective safety requirement. This gap was highlighted by Bop et al. (2017), who reported an almost universal absence of training programs focused on best practices in waste management.

2. **Insufficient technical and logistical resources**

The absence of specific equipment (color-coded containers, labels, sorting zones), combined with inadequate or non-existent signage, hinders the practical implementation of effective sorting. In many facilities, infectious, chemical, anatomical, and household wastes are mixed together, compromising any effort at differentiated treatment and increasing the risk of cross-contamination (WHO, 2018).

3. **Structural financial constraints**

Implementing a rigorous sorting system requires significant investment, both in infrastructure and in the continuous training of staff. However, in many regions of Africa and Latin America, budgets allocated to hospital waste management are minimal or non-existent. Mukhaiber (2017) emphasizes that this financial fragility severely limits the capacity of facilities to establish sustainable procedures that comply with international standards.

Chardon (2018) proposed a structured five-step model for hospital waste management:

- Pre-collection and source sorting
- Conditioning and collection
- Storage and transport
- Treatment and disposal
- Evaluation and monitoring

However, the literature analysis shows that no study has reported this model as fully functional in a real-world setting, which reflects a significant gap between theoretical recommendations and field realities—even in countries with well-established regulatory frameworks.

The lack of source sorting is therefore one of the major weak links in the hospital waste management system. It reflects a lack of systematic approaches adopted by healthcare facilities and an absence of institutional ownership of this issue. This calls for a revision of national strategies, focusing on:

- Mandatory training of personnel at all levels;
- Development of sorting protocols adapted to local contexts;
- Integration of source sorting into health audits and facility management plans.

In short, the widespread adoption of source sorting should be considered a top priority for effective, safe, and sustainable biomedical waste management. Its implementation should not be viewed as a cost, but as a strategic investment in public health and environmental protection.

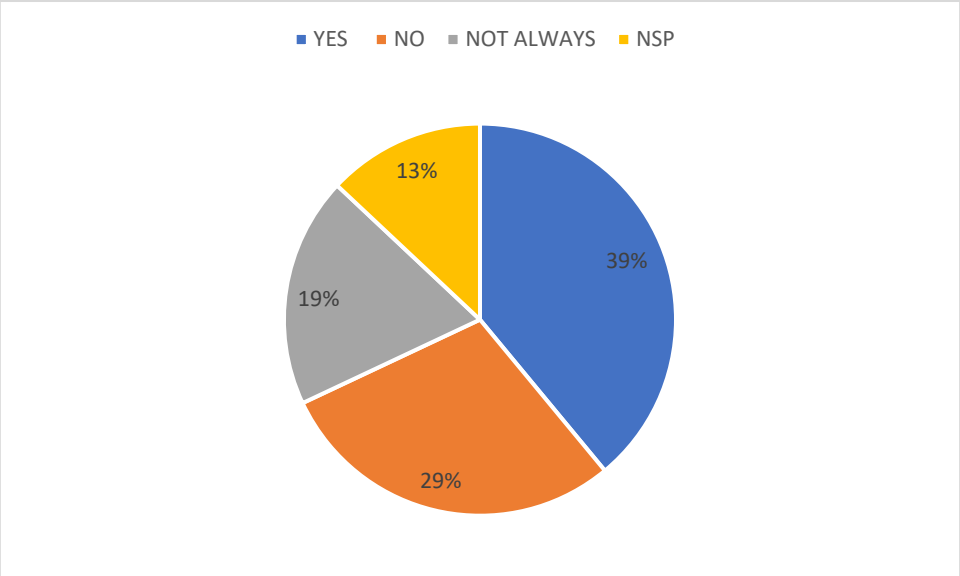

Figure 6: Effectiveness of Sorting Based on the Documentation

III-7. Existence of a Comprehensive Hospital Waste Management System

The analysis of the scientific literature reveals a unanimous observation: none of the reviewed documents report the existence of a complete and integrated hospital waste management system that includes all the fundamental steps such as pre-collection, sorting, conditioning, transport, disposal, treatment, and differentiated recovery of waste according to its nature. This gap highlights a clear absence of systemic organization in management practices, reflecting an institutionalized neglect of a crucial issue for the functioning and safety of healthcare facilities.

In most cases, healthcare institutions exhibit a fragmented approach to waste management. Each step is addressed in isolation, often empirically and without overall coherence. The lack of strict regulation, insufficient training, and absence of a clear strategic framework prevent the establishment of a secure and closed-loop biomedical waste treatment process. Management is often entrusted to untrained maintenance staff with no specific expertise, which exposes patients, healthcare workers, nearby populations, and the environment to significant risks of contamination and infection (Mbog Mbog, 2017).

Moreover, although some private companies are involved in the collection and treatment of waste, their scope of action remains very limited when it comes to biomedical waste. Companies such as HYSACAM, BOCOM, or BOCAM, as well as certain community-based organizations, are primarily engaged in the management of household solid waste. Yet, biomedical waste requires specific collection, treatment, and disposal procedures, which are often outside their operational mandate. This mismatch reveals a confusion of roles and a lack of coordination among the various stakeholders involved in local waste management.

Even when health or environmental development plans are drafted, hospital waste management is rarely addressed, or only mentioned peripherally and in a non-operational manner. As a result, the treatment of biomedical waste is relegated to a secondary level, dependent on the goodwill of hospital administrations or on sporadic initiatives funded by international donors (Kamelan, 2017; Djocgoue, 2016).

The structural financing of hospital waste management relies mainly on:

- The Public Treasury, whose allocations are often insufficient or poorly targeted;

- Technical and Financial Partners (TFPs), who support pilot projects that are rarely sustainable;
- Almost non-existent local mobilization, especially in rural and peripheral areas.

The absence of an integrated, regulated, and funded system thus prevents the implementation of sustainable and efficient hospital waste management. This situation calls for a profound restructuring through:

- The establishment of standardized national protocols;
- The clear definition of responsibilities among public and private actors;
- The creation of a sustainable and autonomous financing mechanism;
- The recovery of waste (recycling, controlled incineration, etc.) for a more circular and ecological management approach.

Therefore, beyond simply acknowledging dysfunctions, it is necessary to initiate a structural reform that considers hospital waste management as a key pillar of public health and environmental policies.

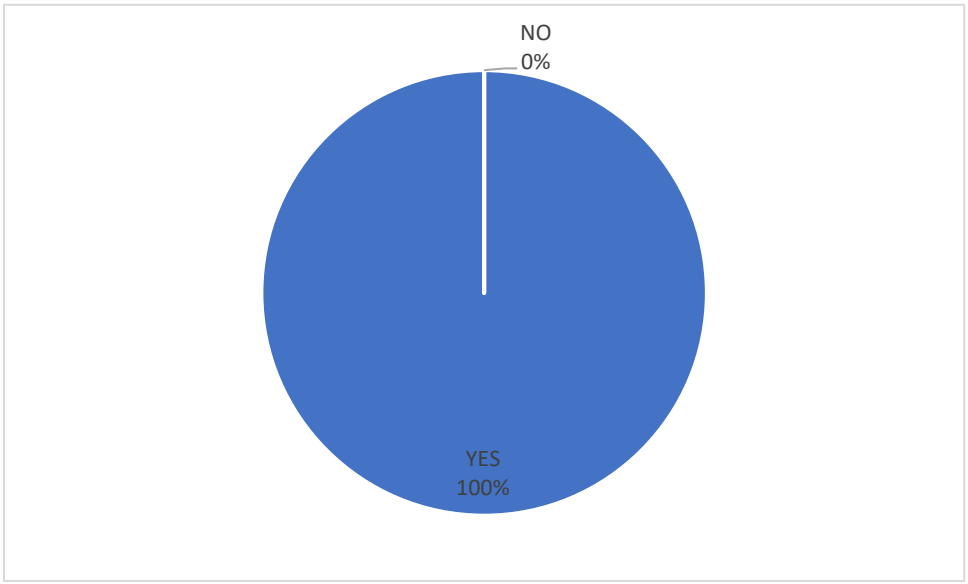

Figure 7: Existence of a Comprehensive Waste Management System

III-8. Equipment Used for Waste Sorting and Pre-Collection

The analysis of scientific articles reveals a concerning observation: only 29% of healthcare facilities practice any form of pre-collection and sorting of hospital waste, and among these, only 31% are equipped with appropriate materials. This low rate of adequate equipment reflects a major gap in the implementation of internationally recommended standards, particularly those set by the World Health Organization (WHO).

International Standards and Recommendations

According to international guidelines, an effective hospital waste management system relies on the implementation of different types of containers to allow for source separation:

- A black bin with a black bag for household and similar waste,
- A yellow bin with a yellow bag for infectious waste,
- Another yellow bin (or a specific container) for pharmaceutical and chemical waste,
- A yellow safety box for sharp, cutting, and piercing objects (sharps) (Kamelan, 2017).

These tools not only facilitate sorting but also reduce cross-contamination and ensure differentiated waste flow management. However, this fundamental system is often only partially applied, particularly in settings where financial and material resources are limited.

Context and Empirical Findings

Studies conducted in healthcare facilities, especially in many African countries, show limited compliance with these standards. Several key issues emerge from the analysis:

- **Lack of adequate equipment**: In most facilities, specific containers are either missing or do not follow the recommended color codes, making sorting ineffective and prone to handling errors.
- **Poor staff awareness**: The absence of regular training on the importance of sorting, combined with a lack of appropriate tools, results in healthcare personnel—often untrained in managing diversified waste streams—not being able to apply the correct procedures.
- **North-South comparison**: Some high-income countries with better infrastructure and resources show partial compliance with standards, highlighting the significant gap between developed and developing regions. In many African contexts, the lack of adequate technical means significantly increases the risk of contamination and exposure to hazardous substances.

Implications and Recommendations

The lack of proper equipment for sorting and pre-collection has multiple consequences:

- **Increased health and environmental risks**: Without rigorous waste separation, the risk of cross-contamination increases, directly affecting the health of medical staff, patients, and surrounding communities.
- **Difficulty integrating into a comprehensive system**: The absence of specific equipment undermines the overall effectiveness of the waste management chain—from collection to treatment and disposal.
- **Insufficient investment and planning**: The lack of adequate equipment points to issues of underfunding and low prioritization in health policy planning. To reverse this trend, it is essential to incorporate specific budget lines in hospital financing for the purchase and regular maintenance of sorting equipment.

In light of these findings, it is crucial to develop local and national strategies aimed at:

- Strengthening training and awareness for healthcare workers on the importance of source sorting,
- Allocating dedicated budget resources for the acquisition and regular updating of sorting equipment,
- Harmonizing sorting practices with international recommendations to ensure coherence and efficiency at the facility level.

The lack of proper equipment for hospital waste sorting and pre-collection remains a weak link in the overall waste management system. Transitioning from an empirical to a standardized and norm-compliant approach is essential to reducing health and environmental risks, positioning source sorting as a strategic investment in public health.

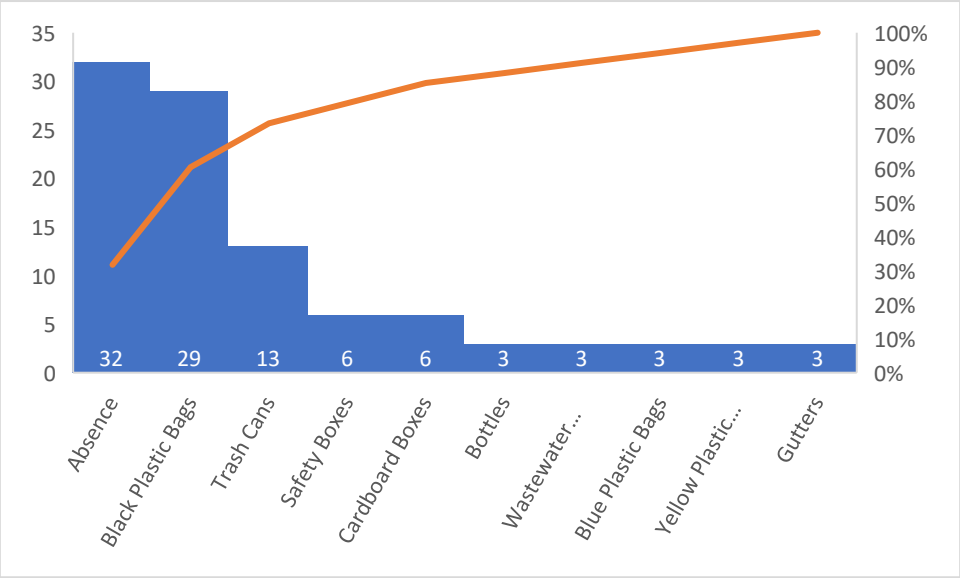

Figure 8: Equipment Used for Waste Sorting and Pre-Collection

III-9. Existence of a Waste Storage Area within Healthcare Facilities

The analysis of scientific literature reveals a concerning observation: only 25% of the studies reviewed mention the existence of a designated storage area for hospital waste within healthcare facilities. This statistic highlights a structural and organizational failure in the management of biomedical waste in many health institutions, especially in resource-limited settings.

Factors Contributing to the Lack of Adequate Storage Areas

The absence or inefficiency of hospital waste storage structures can be attributed to several interconnected factors:

1. **Lack of awareness and training**: Hospital personnel responsible for waste management, particularly in developing countries, are often insufficiently trained in the requirements for the safe storage of biomedical waste. This lack of training leads to poor management of storage spaces.
2. **Insufficient funding**: Setting up suitable storage rooms requires investment in specific infrastructure, which is often considered secondary compared to other healthcare funding priorities, particularly in countries with constrained budgets.
3. **Failure to enforce existing regulations**: Although international standards for biomedical waste management exist (including those from the WHO), their application often remains deficient. Regulations are either ignored or poorly implemented due to a lack of monitoring and resources.
4. **Poor planning of hospital infrastructure**: In many cases, waste storage areas are not included in the initial design of healthcare facilities, making their later installation difficult. This lack of planning reflects a failure to consider the health risks associated with waste management.

Compliance with International Standards

Among the facilities that do have a storage area, 44% do not comply with international quality and safety standards. According to the World Health Organization (WHO, 2018), a compliant storage area should:

- **Be located away from care areas**: This helps limit the risk of cross-contamination, especially for patients and healthcare workers.

- **Have proper ventilation and restricted access**: These features reduce the risk of exposure to pathogens contained in the waste.
- **Be equipped with impermeable and washable surfaces**: This ensures cleanliness and prevents soil pollution.
- **Include a system for separating waste by category**: Rigorous sorting of waste must be conducted to ensure safe storage before disposal or treatment, respecting the various stages of the waste management cycle—from sorting to elimination.

Consequences of Inadequate Waste Storage Management

The health and environmental risks associated with the absence of an appropriate storage room are considerable:

- **Cross-contamination**: Without proper separation, infectious and non-infectious waste can mix, increasing the risk of nosocomial infections and environmental contamination.
- **Exposure of staff and patients**: An unsecured storage area exposes healthcare staff, patients, and even visitors to direct contact with hazardous waste, especially sharps.
- **Environmental pollution**: Non-sealed storage can lead to leakage of toxic or biological substances into the environment, heightening the risk of soil and groundwater pollution.

Improvement Perspectives

It is crucial to strengthen the following measures to improve hospital waste management:

1. **Enhance awareness and training** of healthcare personnel on best practices for biomedical waste storage.
2. **Increase funding** for the development of suitable infrastructure, especially in public health institutions and in developing countries.
3. **Strengthen the enforcement of existing regulations**, through regular inspections and training for waste management personnel.
4. **Reform hospital planning** to integrate secure biomedical waste storage areas from the design phase of healthcare facilities.

Although having a storage area is a fundamental component of hospital waste management, much remains to be done to ensure that these facilities meet international standards. Improving hospital waste management requires a combination of appropriate infrastructure, targeted funding, and continuous training of healthcare personnel.

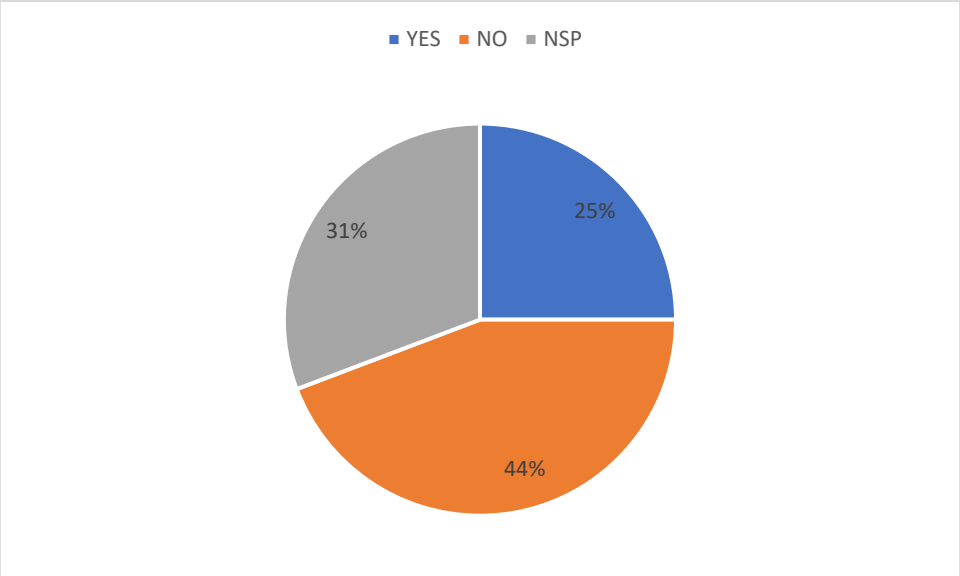

Figure 9: Existence of a Waste Storage Area and Responsible Party for Waste Transport to Disposal Sites

III-10. Responsible Parties for the Transport of Waste to the Disposal Site

An analysis of available data reveals that multiple units are involved in the evacuation of biomedical waste within healthcare facilities. However, this responsibility is fragmented and lacks coordination, which negatively affects the overall management of hospital waste.

The main actors in charge of transporting waste to disposal sites are distributed as follows:

- **29%** of facilities rely on specialized companies for the collection and disposal of biomedical waste. These companies generally possess the necessary equipment and expertise to ensure safe transport.
- **19%** of facilities manage the transportation of waste to disposal sites internally, which can lead to non-compliance with health and environmental standards.
- **3%** of facilities delegate this task to cleaning staff—a practice that is inappropriate and risky, as these workers often lack the required training to handle potentially hazardous waste.
- **3%** of communal services take on waste evacuation duties, even though this is not their primary responsibility.

The study also reveals that healthcare facility managers and municipal authorities participate only marginally in hospital waste management:

- Only **28.8%** of health facilities have a specific budget allocation for the management of biomedical waste.
- Health districts and hospitals lack structured waste management plans and do not have clear internal procedures for waste disposal.

A particularly concerning observation is that **the management of liquid waste resulting from healthcare activities is completely neglected**. No significant initiatives are observed from:

- Central and local health authorities,
- Healthcare facility managers,
- Healthcare personnel.

This situation severely exposes populations, hospital workers, and the environment to risks of contamination and pollution.

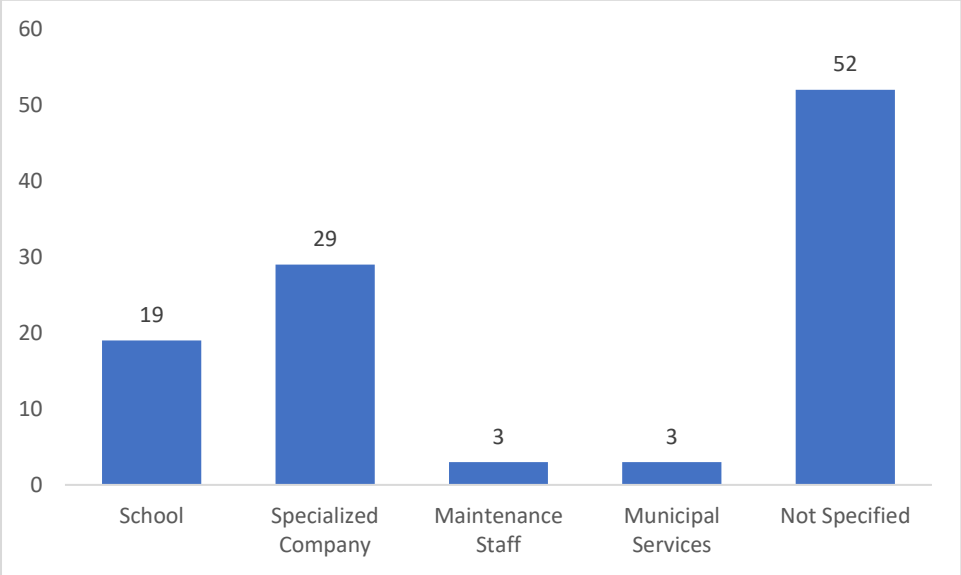

Figure 10: Parties Responsible for Transporting Waste to Disposal Sites

III-11. On-Site Methods for the Treatment of Biomedical Waste

The on-site treatment methods for hospital waste vary depending on available resources, applicable regulations, and the technical capabilities of healthcare facilities. Data analysis shows that the main methods used are incineration, burial, and neutralization.

1. **Incineration: The Dominant Method**

Incineration is practiced by **68%** of healthcare centers. This method involves burning biomedical waste at high temperatures in incinerators, thereby reducing its volume and hazardousness.

- This technique is considered effective for destroying pathogens and reducing the risk of contamination.
- However, it raises major environmental concerns, particularly due to emissions of dioxins and furans, which are toxic pollutants (Ahlam, 2016).
- Moreover, many hospital incinerators do not meet environmental standards and are often poorly maintained, resulting in incomplete combustion of waste.

2. **Burial: A Still-Widespread Practice**

Burial is used by **25%** of facilities as a method of biomedical waste treatment. This technique involves burying waste in specially designed pits within hospital premises.

- Burial is often practiced in the absence of suitable waste treatment infrastructure.
- This method carries high risks of soil and groundwater contamination due to the decomposition of infectious and toxic waste without prior treatment.
- In some settings, burial is seen as a cost-effective alternative, but it is far from being a sustainable solution for biomedical waste management.

3. **Neutralization: An Underused Method**

Only **7%** of hospitals use neutralization, a technique that involves disinfecting waste to render it harmless before disposal.

- Neutralization typically relies on chemical or thermal treatments to neutralize pathogens.
- This method is more environmentally sustainable than incineration or burial, as it reduces pollutant emissions and lowers the risk of contamination.
- However, it remains underutilized due to the high cost of equipment and the lack of training among healthcare personnel regarding these procedures.

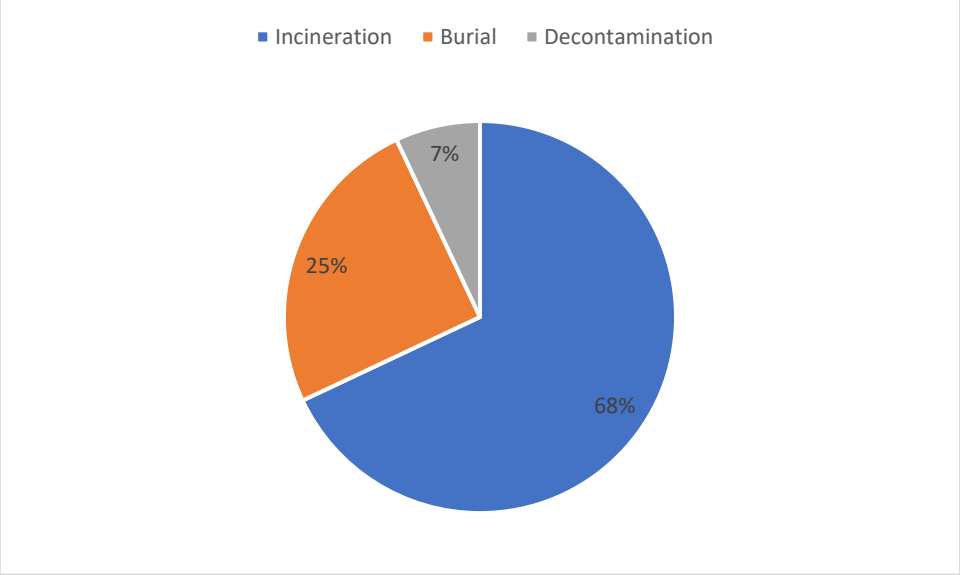

Figure 11: On-Site Methods for Waste Treatment

III-12. Impact of Waste Management on Health and the Environment

Inadequate management of hospital waste poses significant risks to both human health and the environment. Such waste contains pathogens, toxic substances, and pollutants that can affect human health and disrupt ecosystems. Hospital effluents analyzed in various studies contain a wide range of pollutants capable of degrading soil and water quality. These include:

- **Physicochemical pollutants**: heavy metals, chemical solvents, pharmaceutical residues, and radiological contrast agents (Kedonkouo, 2018; Zang et al., 2019).
- **Pathogenic biological agents**: bacteria, viruses, and fungi that can cause nosocomial infections (Ameziane & Benaabidate, 2014).
- **Pharmaceutical compounds**: antibiotics, anti-inflammatory drugs, anesthetics, and other medications discharged without proper treatment (Kasuku et al., 2016).

These substances are present in hospital effluents across all studied countries, with varying levels depending on the stringency of regulations and the waste treatment methods implemented (El Morhit, 2017).

Exposure to improperly managed medical waste increases the risk of infectious diseases and other health complications. Several epidemiological studies have highlighted:

- An increase in nosocomial infections due to the spread of antibiotic-resistant bacteria (Kasuku et al., 2016).
- Chemical intoxication among healthcare workers and nearby populations exposed to untreated toxic substances.
- A heightened risk of accidents for hospital staff and waste collectors, particularly due to mishandling of sharp and cutting objects.

Neglect in biomedical waste management is thus a major public health concern, demanding urgent corrective action.

Untreated hospital waste contaminates natural resources and contributes to several ecological problems:

- **Water pollution**: Pharmaceutical substances and pathogens seep into groundwater and rivers, threatening aquatic biodiversity (Ameziane & Benaabidate, 2014).
- **Soil degradation**: Improper burial of waste leads to the accumulation of persistent pollutants in agricultural soils (Zang et al., 2019).
- **Toxic emissions**: Uncontrolled incineration of medical waste releases dioxins and furans—carcinogenic substances hazardous to both environmental and human health (El Morhit, 2017).

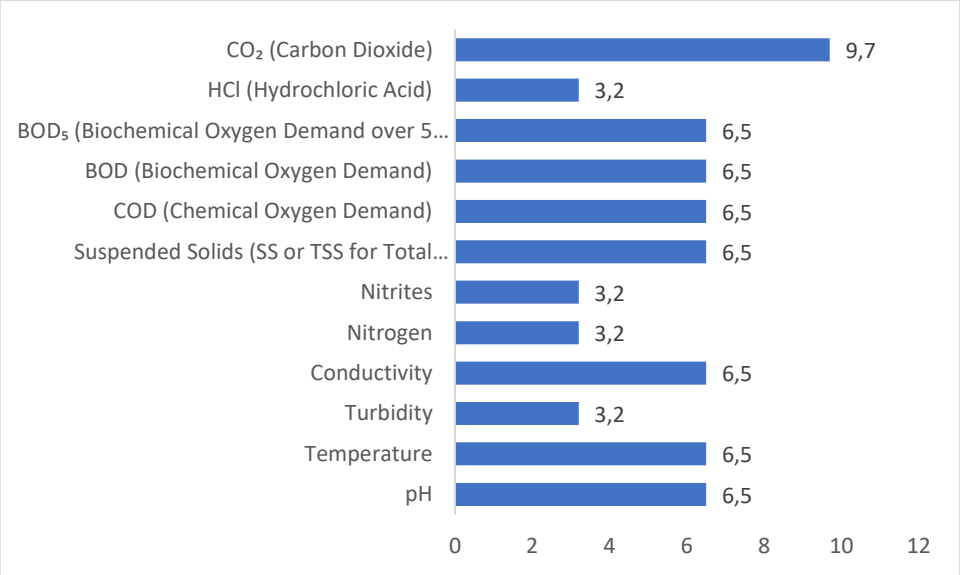

Figure 12: Biochemical Parameters Mentioned

III-13. Environmental Impacts Identified in the Exploited Articles

The analysis of the scientific articles highlights a series of serious environmental impacts associated with the poor management of hospital waste. These impacts affect various aspects of the living environment and ecosystem, with direct and indirect repercussions on public health and biodiversity. Among the main negative effects identified, impacts on air quality, water resources, soil, and the quality of life of nearby populations are noted.

III-13-1. Air Pollution (71%)

Air pollution is one of the most frequently reported environmental impacts in the studies analyzed. It primarily results from:

- **Uncontrolled incineration of medical waste**: This process releases dioxins, furans, and heavy metals, which are highly toxic pollutants harmful to both the environment and human health. These substances are particularly dangerous because they can bioaccumulate, leading to severe long-term health issues.
- **Decomposition of organic waste under anaerobic conditions**: This phenomenon generates methane (CH_4), a potent greenhouse gas, contributing to global warming.

These phenomena directly affect the air quality around healthcare facilities, exposing local populations to increased risks of respiratory and cardiovascular diseases (Mbog Mbog, 2017).

III-13-2. Odor Pollution (55%)

The unpleasant odors associated with the accumulation and decomposition of biomedical waste represent a major source of nuisance for patients, healthcare staff, and nearby residents. These odors primarily result from:

- **Fermentation of organic waste under inadequate storage conditions**, releasing volatile compounds with strong odors such as ammonia, hydrogen sulfide, and mercaptans.

Symptoms associated with these nuisances include headaches, nausea, and respiratory irritation, severely affecting the quality of life of those exposed, which negatively impacts the well-being of healthcare workers and nearby residents.

III-13-3. Visual Nuisances (52%) and Aesthetic Issues (39%)

Inefficient hospital waste management also leads to visual nuisances and aesthetic problems in and around healthcare facilities:

- Accumulation of waste around healthcare establishments, contributing to an unsanitary environment.
- Illegal waste dumping in public spaces, severely damaging the image and reputation of hospitals.

These visual nuisances discourage patients from visiting healthcare facilities and also affect the morale of staff and visitors, thus diminishing the overall quality of the hospital environment (Bidias, 2016).

III-13-4. Water and Groundwater Pollution (48%)

Ineffective disposal of hospital waste has dramatic consequences for water resources:

- Chemical and pharmaceutical substances contained in liquid and solid waste end up in rivers and groundwater.
- The absence of proper treatment of hospital wastewater leads to the contamination of drinking water sources with pharmaceutical residues, antibiotic-resistant bacteria, and viruses.

This exposes nearby communities to a high risk of gastrointestinal infections, dermatological diseases, and endocrine disruptions, with long-term effects on public health (Mbog Mbog, 2017).

III-13-5. Soil Pollution (48%)

Improper burial of medical waste results in the accumulation of toxic substances in the soil:

- Heavy metals from medical equipment contaminate agricultural land, affecting crop quality and soil health.
- Pathogens from infectious waste can survive in the soil, promoting the spread of infectious diseases among humans and animals.

This degradation of soil quality threatens local biodiversity and compromises the fertility of agricultural lands, thereby reducing the ability of rural communities to produce healthy and sustainable crops (Bidias, 2016).

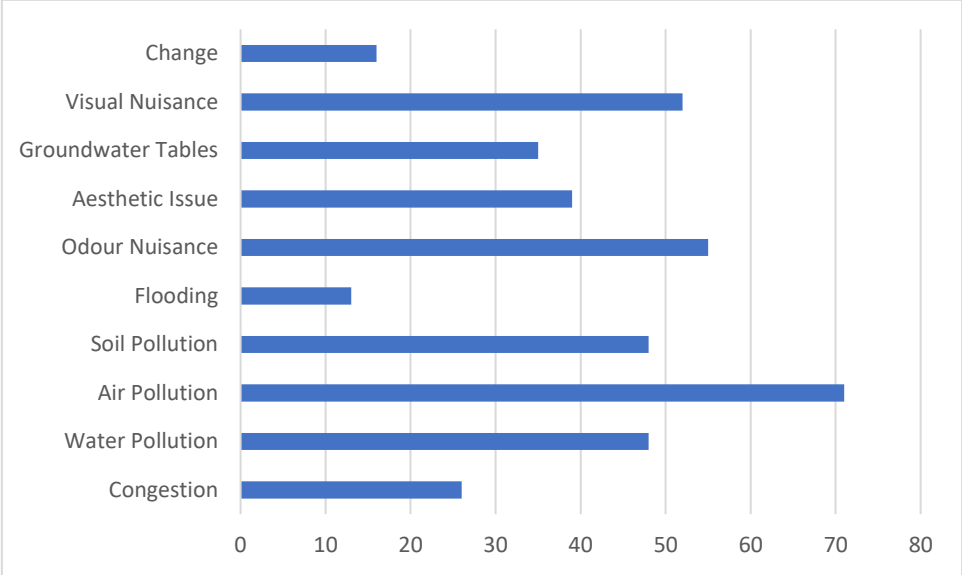

Figure 13: Environmental Impacts Identified

III-14. Health Impacts Related to Hospital Waste Management

The exploitation of scientific articles has identified a series of diseases affecting both hospital users and healthcare staff due to exposure to poorly managed biomedical waste. These diseases are often the result of direct or indirect contamination by infectious, chemical, or toxic agents present in hospital waste. The main conditions identified are as follows:

III-14-1. Respiratory Disorders (55%)

Respiratory infections are the most common diseases among hospital staff and patients exposed to poor hospital waste management. These conditions are caused by:

- **Inhalation of toxic fumes released during the uncontrolled incineration of biomedical waste.**
- **Exposure to airborne bacteria and viruses present in infectious waste.**
- **Ambient air pollution caused by fine particles from decomposing organic waste.**

Clinical manifestations include bronchitis, pneumonia, asthma attacks, and chronic respiratory infections, which can have severe health consequences (Regazzetti, 2016).

III-14-2. Gastrointestinal Disorders (45%)

Gastrointestinal diseases are common in hospital settings, particularly due to:

- **Contamination of healthcare workers' hands when handling hospital waste without adequate protection.**
- **Consumption of water contaminated by improperly disposed of liquid waste.**
- **Presence of pathogenic bacteria such as E. coli, Salmonella, Shigella, and Vibrio cholerae, which are often found in the hospital environment.**

Symptoms include severe diarrhea, vomiting, abdominal pain, and serious intestinal infections that can lead to complications (Arbi, 2018).

III-14-3. Hepatitis B and C (45%)

Viral hepatitis B and C pose a major risk in healthcare settings, particularly due to:

- **Improper handling of sharp, cutting, and piercing objects (SCPO), such as contaminated needles and scalpels.**
- **Failure to follow safety protocols when disposing of infectious waste.**

The risk of infection is high among healthcare staff, especially when they do not use proper personal protective equipment. These forms of hepatitis can lead to serious chronic health issues (Oroei et al., 2014).

III-14-4. Chest Tightness (42%)

Chest tightness symptoms are commonly observed in hospital staff and patients exposed to:

- **Toxic emissions from incinerators.**
- **Irritant gases from waste decomposition, such as ammonia, sulfur dioxide, and volatile organic compounds.**
- **Lung infections caused by bacteria and viruses in ambient air.**

These conditions can progress into chronic respiratory disorders and serious cardiovascular issues (Retour, 2015).

III-14-5. Blood Exposure Accidents (BEA) – 36%

Blood exposure accidents (BEA) are a major risk for hospital staff handling biomedical waste. These accidents can occur due to:

- **Accidental needle sticks from contaminated needles.**
- **Cuts from contaminated sharp objects.**
- **Blood or biological fluid splashes to mucous membranes (eyes, mouth, open wounds).**

BEA exposes healthcare workers directly to severe infections such as HIV/AIDS, hepatitis B and C, and other bloodborne diseases (Arbi, 2018).

III-14-6. Malaria (23%)

Although malaria is a parasitic disease, it is exacerbated by poor hospital waste management. The accumulation of medical waste promotes mosquito breeding, primarily due to:

- **Improper disposal of liquid waste.**
- **Inadequate storage of waste in open containers, creating breeding sites for Anopheles mosquitoes.**

This issue is particularly concerning in regions of Africa and South Asia, where malaria remains a leading cause of morbidity and mortality (Regazzetti, 2016).

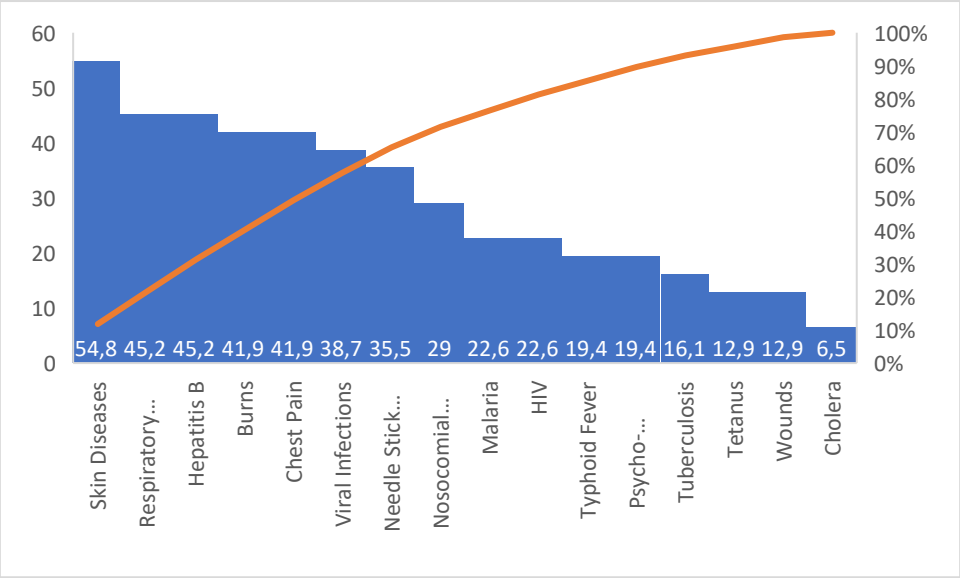

Figure 14: Diseases Observed in Users and Healthcare Personnel

III-15. Influence of Socio-Cultural Factors on Hospital Waste Management

Cultural practices play a significant role in the management of hospital waste, especially regarding anatomical waste. This includes: placentas, umbilical cords, fetuses, and stillbirths.

- According to several studies, these wastes are often retrieved by the patient's attendants for cultural and traditional reasons. Bob et al. (2017), Mwisa et al. (2018), Zeeshan et al. (2018), and Mbog (2019) show that, in some communities, it is common for the families of patients to request the retrieval of these wastes for:
    - **Traditional and funeral rites**, such as burying placentas according to local beliefs.
    - **Spiritual protection practices** aimed at preserving the health of the newborn and the mother.
    - **Mystical beliefs**, where these wastes are considered to have particular significance and must be handled by family members.

III-15-1. Ethical Issues and Associated Risks

- The retrieval of anatomical waste raises several ethical and health concerns:
    - **Risk of environmental contamination**: If these wastes are not disposed of properly, they can pollute the environment and attract animals.
    - **Handling by untrained individuals**: Improper handling can lead to infections, the spread of diseases, and accidental contamination.
    - **Lack of clear regulatory framework**: In some countries, there are no strict guidelines on managing anatomical waste, making it difficult for healthcare structures to handle them appropriately.

III-15-2. Need for Awareness and Supervision

In light of these practices, it is imperative to implement appropriate measures that take into account socio-cultural realities while ensuring health safety.

Improvement Proposals:

- **Develop protocols that respect cultural beliefs** while ensuring the safe disposal of anatomical waste.

- **Involve community and religious leaders** in raising awareness about the risks associated with these practices.
- **Train healthcare staff** on the ethical and safe management of anatomical waste.
- **Establish dedicated spaces for the disposal or transfer of waste** according to supervised protocols.

Conclusion

The management of biomedical waste is a major challenge for public health and environmental preservation. This review of existing work highlights the numerous gaps and deficiencies in waste management across Europe, America, Africa, and Cameroon. Despite the existence of regulatory frameworks, their implementation remains uneven and often ineffective, particularly in developing countries where financial and technical resources are limited.

The analysis of the consulted articles reveals the frequent absence of an effective waste management policy, lack of training for involved staff, insufficient infrastructure, and the absence of dedicated funding. Moreover, waste treatment methods remain rudimentary, dominated by incineration and burial, with concerning environmental and health impacts. Air, soil, and water pollution, as well as nosocomial infections and infectious diseases, affect both healthcare professionals and patients, as well as the surrounding population.

In light of these findings, it is essential to strengthen the enforcement of existing regulations, integrate specific biomedical waste management training into health curricula, and ensure rigorous monitoring of best practices. A more integrated approach, combining awareness, technological innovation, and political commitment, is necessary to reduce health and environmental risks. Further research is also required to propose strategies tailored to local realities and to improve the sustainable management of these wastes.

Recommendations

Strengthening the Regulatory Framework and its Enforcement:

- Establish mechanisms for monitoring and evaluation to ensure the effective application of existing laws regarding biomedical waste management.
- Integrate sanctions for non-compliance with hospital waste management regulations.
- Harmonize national policies with international standards for healthcare waste management.

Improvement of Training and Awareness:

- Introduce specific modules on hospital waste management into the curricula of health training schools.
- Organize continuous training for hospital staff, particularly housekeeping agents, on best practices for sorting, collecting, and disposing of waste.
- Raise awareness among patients and the general public about the risks of improper biomedical waste management.

Optimization of Infrastructure and Equipment:

- Equip each healthcare facility with a complete waste management system, including sorting, collection, storage, transport, and secure treatment.
- Provide healthcare facilities with sorting equipment that meets standards (color-coded bins, safety boxes for sharp objects, etc.).
- Build storage areas that meet sanitary and environmental requirements.

Allocation of Dedicated Financial Resources:

- Allocate a specific budget for biomedical waste management within hospital funding.
- Encourage public-private partnerships to implement innovative and sustainable solutions.
- Mobilize funding from donors and international institutions to support projects focused on ecological hospital waste management.

Improvement of Waste Treatment Methods:

- Promote more environmentally-friendly waste treatment methods (recycling, sterilization, energy recovery) as replacements for systematic incineration.
- Set up modern treatment units within hospitals or in partnership with specialized companies.

Strengthening Monitoring and Research:

- Develop comprehensive studies on the health and environmental impacts of hospital waste to improve decision-making.
- Establish national and regional observatories responsible for monitoring and evaluating hospital waste management practices.

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