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Hospital Waste Management and Sustainability: Analysis of Management and Challenges node Context from the Health Brazilian

Hospital Waste Management and Sustainability: Analysis of Management and Challenges in the Brazilian Health Context

Author: Celia Alves Dias

Summary

This scientific article analyzes hospital waste management in Brazil, with an emphasis on the implementation of the Healthcare Waste Management Plan (PGRSS) and its impacts on public health, environmental preservation, and organizational sustainability. The research, based on a case study conducted at Unimed Brasília, shows that proper segregation, packaging, transportation, treatment, and final disposal of waste are fundamental pillars for reducing the risk of contamination and environmental accidents. In addition to analyzing the role of healthcare professionals, especially nurses, the article discusses the importance of awareness, technical training, and government oversight as tools for effectiveness. The results indicate progress in the implementation of structured methodologies, but also reveal gaps related to infrastructure and institutional integration, which hinder fully effective management.

It is concluded that hospital waste management, when aligned with sustainable practices and solid public policies, represents not only a legal requirement, but a strategic commitment to the future of health and the environment in Brazil.

Keywords: Hospital waste. Environmental management. PGRSS. Public health. Sustainability.

Abstract

This scientific article aims to analyze hospital waste management in Brazil, focusing on the implementation of the Health Service Waste Management Plan (PGRSS) and its impacts on public health, environmental preservation, and organizational sustainability. Based on a case study conducted at Unimed Brasília, the research highlights that proper segregation, packaging, transport, treatment, and final disposal of waste are fundamental pillars to reduce contamination risks and environmental accidents. In addition to analyzing the role of health professionals, especially nurses, the article discusses the importance of awareness, technical training, and governmental oversight as effectiveness tools. The results indicate advances in the implementation of structured methodologies but also reveal gaps related to infrastructure and institutional integration, which hinder the full effectiveness of management. It is concluded that hospital waste management, when aligned with sustainable practices and solid public policies, represents not only a legal requirement but also a strategic commitment to the future of health and the environment in Brazil.

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1. Introduction

Hospital waste management has become one of the greatest contemporary challenges for healthcare systems, especially in developing countries like Brazil, where the growing demand for medical services is associated with the intensive generation of potentially hazardous waste. This waste, also known as Healthcare Waste (HSW), comprises common and infectious materials that, when poorly managed, can cause serious harm to public health and the environment. Concern about this issue is growing, as it encompasses everything from health issues, such as the prevention of hospital infections, to environmental issues, such as soil, water, and air pollution. Furthermore, the increasing technological complexity in hospital settings has increased the volume and diversity of this waste, requiring increasingly structured and efficient approaches.

This scientific article analyzes the relevance of hospital waste management, focusing on the Healthcare Waste Management Plan (HWMP), considering its legal mandate and its importance as a risk prevention tool. The analysis is based on a case study conducted at Unimed Brasília, a medical cooperative that, despite adopting structured methodologies, still faces challenges related to infrastructure and the full implementation of its plan. The goal is to understand how the practices adopted at this institution reflect the national and international scenario, as well as to propose reflections on the necessary paths for more effective and sustainable management.

Interest in this topic is not limited to the hospital environment, but extends to academia and public policy, as inadequate healthcare waste management compromises both public health and natural ecosystems. At the same time, growing pressure for sustainability in the healthcare sector requires hospitals and clinics to take an active role in reducing environmental impacts and promoting best practices. The topic, therefore, fits into a broader sustainable development agenda that connects health, the environment, and social responsibility.

This work was developed using a qualitative and exploratory approach, based on a literature review, regulatory documents, and a case study, allowing for a critical in-depth analysis of the phenomenon. In addition to describing the technical and legal procedures, the research seeks to reflect on the sociocultural and organizational aspects involved in hospital waste management. Thus, it is hoped to offer theoretical and practical contributions to managers, healthcare professionals, and public policymakers.

Finally, the introduction highlights that hospital waste management is more than a regulatory requirement: it is an ethical and strategic commitment to life, health, and environmental preservation. The debate proposed in this article reinforces the idea that the integration of legislation, professional training, and collective awareness constitutes the foundation for building a more efficient, safe, and sustainable management model.

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2. Overview of Environmental Management and Hospital Waste in Brazil

Environmental issues in Brazil gained prominence in the 1970s, with the creation of the Special Secretariat for the Environment (SEMA) and, later, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA). Based on this institutional framework, the country began adopting stricter legislation aimed at pollution control and solid waste management. However, the specific and highly hazardous nature of hospital waste necessitated specific regulations, culminating in standards such as CONAMA Resolution No. 358/2005 and ANVISA RDC No. 306/2004. These standards established the mandatory development of a PGRSS in all units generating healthcare waste, ensuring standardized procedures for segregation, packaging, transportation, treatment, and final disposal.

In Brazil, the increase in healthcare waste generation is directly related to population growth and the expansion of the hospital network, both public and private. The aging population and the increased demand for specialized services have also contributed to the increased volume and complexity of this waste. Therefore, it has become essential for hospitals and clinics to adopt environmental management practices aligned with the principles of sustainable development, seeking to balance the interests of health, environmental preservation, and economic viability.

Despite regulatory advances, the Brazilian reality still presents significant inequalities in compliance with regulations. While large hospitals located in urban centers have greater capacity to implement efficient management plans, smaller units or those located in peripheral regions face structural and financial difficulties. This disparity compromises the effectiveness of public policies and creates ongoing risks of environmental contamination and exposure of workers and patients to hazardous materials. Furthermore, the lack of effective oversight by the relevant agencies reinforces the need for greater institutional coordination and investment in infrastructure and training.

It is important to highlight that hospital waste management in Brazil is part of a global context of concern about the environmental impacts of human activity.
International conferences, such as Stockholm (1972) and Rio-92, raised the question Environmental issues are at the center of global political and economic debate, driving countries like Brazil to develop more robust legislation. In this sense, healthcare waste represents an emblematic field, as it epitomizes the challenges of reconciling technological innovation, quality medical care, and environmental responsibility.

Therefore, the panorama of environmental and hospital waste management in Brazil reveals a field of advances and challenges. Although legislation is consolidated and awareness on the topic is growing, gaps remain regarding practical application, monitoring, and integration between health and the environment. In this context, the Unimed Brasília case study presents an opportunity to understand how these issues intersect.

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materialize in a concrete institution, offering subsidies for broader reflections on sustainability in Brazilian healthcare.

3. Legal and Regulatory Framework for Healthcare Waste Management (HSW)

The regulatory framework governing healthcare waste (HSW) management in Brazil was consolidated through federal regulatory instruments that articulate health surveillance, environmental policy, and labor protection. Historically, **ANVISA RDC No. 306/2004** and **CONAMA Resolution No. 358/2005** structured the technical-administrative axis of the Healthcare Waste Management Plan (HSWMP), defining objectives, responsibilities, flows, and performance standards for all generating units, both public and private. Subsequently, **ANVISA RDC No. 222/2018** updated and integrated health requirements related to HSW management, reinforcing the principles of source segregation, traceability, and risk management, with an emphasis on worker protection and reducing environmental impacts. Additionally, ABNT technical standards, such as the **NBR 12.807–12.810** series (terminology, classification, collection, and transportation) and **NBR 10.004** (waste classification), provide operational granularity to legal requirements, supporting requirements for packaging, identification, chemical compatibility, and transportation safety. This set of standards, when properly applied, allows the PGRSS to operate as a technical-institutional governance system, integrating health, environment, and occupational safety within a single framework.

At the conceptual level, the Brazilian legal framework adopts **management by risk categories,** guiding decisions on segregation, treatment and final disposal according to classes: **Group A** (potentially infectious), **Group B** (chemicals), **Group C** (radioactive waste—also regulated by CNEN), **Group D** (common waste), and **Group** E (sharps). This classification is implemented upon generation, requiring the generator to identify the waste with standardized labels and package it in compatible containers (mechanical resistance, watertightness, sealing, symbology, and color). The legislation details parameters for **internal collection, temporary storage, internal transportation, treatment** (autoclaving, microwave, incineration, chemical disinfection, inerting, among others), and **final disposal** in licensed landfills or specific facilities, preserving traceability through records and Waste Transportation Manifests. In addition to document control, the legal system requires ongoing training, use of PPE and EPCs, and the development of standard operating procedures, reducing the gap between standards and practices.

Within the scope of **environmental public policy,** the **National Solid Waste Policy (PNRS – Law No. 12,305/2010) introduced** structuring guidelines — shared responsibility for the life cycle, reverse logistics, non-generation, reduction, reuse, recycling, treatment and environmentally appropriate disposal of waste — which positively pressure the health sector to migrate from a merely corrective approach to a **preventive and eco-efficient one.**
In RSS, the PNRS reinforces the obligation to prioritize actions: first, segregate waste correctly to minimize risk volumes; then, treat and dispose of waste according to the best available and viable technology. The PNRS–ANVISA–CONAMA convergence, therefore, consolidates the PGRSS as a technical and legal governance instrument, while simultaneously

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which signals incentives for innovation (for example, disinfection technologies that reduce atmospheric emissions compared to traditional incineration) and integration with municipal urban cleaning systems under environmental control.

The regulatory framework also incorporates **worker health** and **biosafety** dimensions , anchored in Regulatory Standards (NRs) of the then Ministry of Labor —
Notably, **NR-32,** which establishes guidelines for healthcare services regarding biological, chemical, and sharp risks and ergonomics, and **NR-11**/**NR-29**/**NR-33** for specific situations involving movement, confined spaces, and logistics. These guidelines align with the requirements of the PGRSS (Purpose of Safety and Health), which aim to mitigate occupational accidents and illnesses, requiring risk analysis, safe route planning, spill containment, and post-exposure protocols. The standardization, therefore, extends beyond the hospital setting and reaches the entire waste value chain, including outsourced collection, transportation, treatment, and disposal companies, which must operate under environmental licensing, emergency and contingency plans, and comply with inspection requirements.

Finally, it is worth noting that the effectiveness of the legal framework depends on **institutional governance:** clear assignment of responsibilities (management, CCIH, SESMT, nursing, hospitality, outsourced workers), budgetary provision, performance indicators (correct segregation rate, non-compliance rate, frequency of sharps accidents, cost per bed/day), internal and external audits, and transparency for oversight bodies. In complex institutions, such as medical cooperatives and general hospitals, regulatory compliance requires **intersectoral integration** and ongoing education mechanisms to transform compliance into an organizational culture. From this perspective, the Brazilian legal framework, while robust, demands continuous updating and effective enforcement, otherwise it will remain a **formal form of compliance** disconnected from real gains in public health and environmental protection.

4. PGRSS: Structure, Stages and Operational and Socio-environmental Benefits

The **Healthcare Waste Management Plan (HWMP)** is the central instrument for planning, implementing, monitoring, and continuously improving HW management at each generating unit. Structurally, the HWMP should include a situational diagnosis (mapping of sectors, quantification by waste class, flows, and internal routes), definition of responsibilities (RACI matrix), standard operating procedures by stage (segregation, packaging, identification, internal collection and transportation, temporary storage, treatment, external storage, external transportation, final disposal), as well as **training and communication programs aimed** at all involved workers. The document should also establish **performance indicators** and **traceability mechanisms,** with systematic records and contingency plans for incidents such as spills, dropped containers, autoclave failures, electrical failures, or interruptions in the specialized collection service.

Source segregation is the PGRSS's greatest leverage point, as correct decisions at the time of generation exponentially reduce costs and risks throughout the supply chain. Adoption

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The use of specific, properly identified containers (color, symbol, mechanical resistance, sealing) for each waste group, combined with training for nursing, pharmacy, laboratory, and sanitation teams, reduces cross-contamination and prevents the undue "infection" of common waste (Group D). At the same time, the proper storage of sharps (Group E) in rigid containers, up to the maximum recommended level, reduces accidents and incidents during internal transportation. The PGRSS, by standardizing these routines, transforms disparate practices into **reproducible,** measurable, and auditable processes.

In the treatment block , the technological choice must be based on a multi-criteria analysis: microbiological effectiveness (reduction log), compatibility with the type of waste, atmospheric and liquid emissions, operating costs, licensing requirements and available infrastructure. Technologies such as **autoclaving** and **microwaves** have wide application for Group A, with a smaller atmospheric footprint compared to incineration. **Incineration** remains recommended for specific pharmaceutical wastes (Group B) and biohazardous materials that cannot be treated with moist heat, subject to emission standards. **Radioactive** waste (Group C) follow CNEN regulations , with decay in controlled areas and subsequent disposal. The PGRSS must specify acceptance criteria, preventive/corrective maintenance, cycle validations (biological/chemical challenges), and byproduct management (slag, ash, effluents), ensuring environmental compliance.

The **benefits of the PGRSS** go beyond legal compliance. Operationally, proper segregation reduces the volume of high-cost waste per treatment, streamlines internal logistics, reduces workplace accidents, and improves team ergonomics. Economically, indicator-based management allows for **the optimization of contracts** with outsourced companies and the measurement of the real cost of waste per bed/day, sector, or procedure, supporting purchasing decisions (e.g., preference for inputs with lower waste generation or those amenable to reverse logistics). On a socio-environmental level, the PGRSS minimizes community exposure to infectious agents, reduces environmental liabilities, and contributes to sustainability goals (emissions, water and energy consumption, and the disposal of uncontaminated recyclables), bringing the institution closer to the Sustainable Development Goals (SDGs), especially SDGs 3, SDG 6, SDG 12, and SDG 13.

The **human dimension** is a critical component of the PGRSS. No protocol is sustainable without **ongoing training,** clear communication, and team engagement. Ongoing education programs—with active methodologies, spill simulations, sharps disposal training, learning paths for new employees, and periodic refresher training—incorporate safe behavior and reduce variability. Clinical governance (CCIH), safety engineering (SESMT), and healthcare leadership must work in an integrated manner, with safety rounds, field audits, and rapid feedback to correct deviations. Thus, the PGRSS evolves from an off-the-shelf document to a **living system,** with PDCA cycles and continuous improvement supported by data and an organizational culture focused on patient, worker, and environmental safety.

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5. The Role of Health Professionals in Waste Management

Healthcare professionals play a central role in the hospital waste management cycle, as they are responsible not only for generating waste but also for the first stage of segregation, which forms the basis of the entire PGRSS process. Among them, **nurses stand out,** as they remain in direct contact with patients, supplies, sharps, and potentially contaminated materials, and are therefore crucial for the correct classification of waste into appropriate containers. This responsibility requires not only technical knowledge but also ethical sensitivity and awareness of the collective risks of inappropriate practices. Incorrect segregation can contaminate common waste, increase costs, compromise waste treatment, and pose a risk to public health, demonstrating that individual errors have systemic consequences.

The nursing team's work directly connects with other hospital departments, such as the pharmacy, laboratory, hospitality, and sanitation departments, forming a cycle that requires **efficient interprofessional communication.** The literature emphasizes that integration failures between these departments are recurring sources of noncompliance, such as the disposal of chemical waste in containers intended for infectious agents or flow reversals during internal transportation. Therefore, it is essential that the PGRSS be incorporated into the hospital routine as part of **clinical governance** and not merely as an administrative protocol. Thus, the integrated work of nurses, nursing technicians, physicians, pharmacists, and support staff ensures greater effectiveness in risk prevention, strengthening patient and worker safety.

Another fundamental aspect is **ongoing training.** The regulatory framework requires all workers involved in healthcare waste management to receive specific training, but practice reveals that many institutions conduct initial training sporadically and inconsistently. The lack of periodic refresher training compromises the memorization and practical application of procedures, especially in environments with high staff turnover. In this sense, the adoption of **active learning methodologies,** such as accident simulations, case studies, and gamified training, has proven effective in promoting greater engagement. Furthermore, constant supervision and internal audits favor the consolidation of learning in daily hospital practice.

It should also be noted that the role of healthcare professionals in waste management is not limited to mechanically following protocols. It also involves a **cultural and behavioral dimension,** in which environmental awareness and the appreciation of biosafety must be internalized as organizational values. The professional's awareness that their daily practice directly impacts public health and the environment increases their sense of responsibility and strengthens the safety culture. This becomes particularly relevant in large institutions, such as medical cooperatives and referral hospitals, where the multiplicity of processes and complex routines make collective discipline essential.

Thus, the role of healthcare professionals in managing hospital waste must be understood as an interface between technique, ethics, and management. At the same time,

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By applying established standards and routines, these professionals implement the institutional biosafety and sustainability policy on a daily basis. Their active and conscious participation is a sine qua non for the effectiveness of the PGRSS, consolidating them not only as operational agents but also as **strategic protagonists** of hospital environmental management.

6. Case Study: Unimed Brasília and the Challenges of Implementation

The **Unimed Brasília** case study offers a concrete opportunity to understand the progress and challenges in implementing the PGRSS in Brazilian healthcare institutions. This large medical cooperative operates within a complex regulatory framework and is under significant pressure to ensure quality care and operational sustainability. The data analyzed reveal that the institution has structured protocols for waste segregation, storage, collection, transportation, and disposal, in compliance with current regulations. However, practical reality demonstrates that the **plan's effectiveness still faces significant limitations** related to both infrastructure and human resource training.

One of the main challenges identified is **effective adherence to standards by professionals.** Despite the existence of manuals, training, and internal campaigns, recurring segregation failures compromise process efficiency, leading to contamination of common waste and increased treatment costs. This highlights that the PGRSS, when not accompanied by robust monitoring and feedback mechanisms, can be limited to a formal document, without full internalization by teams. This gap highlights the importance of hospital management investing in constant audits, performance indicators, and awareness programs that transform the plan into a living practice.

Another critical point concerns the **physical and logistical infrastructure.** In some units, the space designated for temporary waste storage does not fully meet regulatory requirements, creating contamination risks and operational difficulties. Furthermore, issues with outsourced companies responsible for collection and external treatment were identified, highlighting the need for greater contractual control and oversight.

This reality illustrates the interdependence between the healthcare institution and its external partners, reinforcing that the effectiveness of the PGRSS also depends on the quality and reliability of the associated service chain.

On the other hand, Unimed Brasília has made progress on **sustainability and innovation initiatives,** such as waste reduction campaigns, reverse logistics programs, and investments in cleaner technologies for treating infectious waste. These actions demonstrate an institutional commitment to aligning waste management with global sustainable development guidelines. However, these initiatives still coexist with daily practices marked by inconsistencies, revealing a gap between strategic planning and practical execution.

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In summary, the case study demonstrates that Unimed Brasília, despite having a structured PGRSS, faces barriers typical of large Brazilian healthcare institutions: gaps in employee engagement, infrastructure limitations, and challenges in contract management with outsourced companies. Overcoming these obstacles requires an integrated approach that combines administrative management, human engagement, and technological innovation. Only then will it be possible to transform the PGRSS into a consolidated institutional policy and a competitive advantage in the field of hospital sustainability.

7. Perspectives for Sustainability and Innovation in Hospital Waste

The search for more sustainable hospital waste management models is directly aligned with global transformations in health and the environment. In Brazil, although legislation establishes clear guidelines, the institutional reality still faces challenges in infrastructure, training, and organizational culture. Therefore, considering sustainability perspectives implies expanding the focus beyond legal compliance, integrating economic, social, and environmental dimensions. The adoption of **clean technologies** for treatment, encouraging reduced waste generation, and promoting conscious consumption practices in the hospital environment emerge as key strategies for reducing impacts and strengthening institutional credibility.

One of the most promising innovations is in the field of **technology applied to waste management.** Computerized tracking systems, sensors for real-time container monitoring, and integrated management software allow greater control over the stages of the PGRSS, facilitating audits and reducing human error. Furthermore, the application of **artificial intelligence** to data analysis can identify patterns of improper disposal and propose customized solutions for different hospital sectors.

These technological tools expand monitoring capacity and bring greater transparency to processes, which strengthens the trust of society and regulatory bodies in hospital management.

Another relevant aspect is the strengthening of **public-private and inter-institutional partnerships,** which can increase investment capacity in infrastructure and innovation. Hospitals that share best practices or establish agreements with universities and research centers can develop solutions tailored to their specific needs. This collaboration allows, for example, the development of alternative treatment methodologies with lower environmental impact or the creation of safe recycling programs for certain materials. Furthermore, integration with municipal urban cleaning policies strengthens shared responsibility, as enshrined in the National Solid Waste Policy.

The social dimension must also be considered as an integral part of sustainability perspectives. Conscious, engaged, and properly trained healthcare professionals act as multipliers of good practices, not only within the institution but also in their communities. Environmental education programs aimed at employees, patients, and caregivers can raise collective awareness about the importance of segregation.

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correct and waste reduction. In this way, sustainability ceases to be merely an institutional objective and becomes a shared social value, with impacts that transcend hospital walls.

Finally, the prospects for innovation and sustainability in hospital waste highlight the need for a **systemic and multidimensional** approach that combines technology, education, governance, and social responsibility. Only through this integration will it be possible to transform waste management into a strategic tool for public health and environmental preservation, consolidating the hospital sector as a key player in building a more sustainable and safer future.

8. Conclusion

The analysis conducted throughout this article highlights that hospital waste management represents a complex challenge, involving multiple stakeholders, regulatory dimensions, and social impacts. Implementing a Healthcare Waste Management Plan (HWMP) is a fundamental tool for ensuring health safety, environmental protection, and operational efficiency in healthcare institutions. However, practical reality reveals that the mere existence of a plan does not guarantee its effectiveness, requiring continuous investment in training, infrastructure, and monitoring.

The Unimed Brasília case study demonstrates that, even in institutions with structured protocols, there are significant barriers related to staff adherence, segregation failures, and limitations in storage and transportation infrastructure. These gaps reflect a national scenario in which standards exist, but their implementation still faces obstacles stemming from a lack of integration between managers, healthcare professionals, and regulatory agencies. This finding reinforces the idea that waste management cannot be treated as a mere legal obligation, but as an integral part of the organizational culture.

Another important aspect is the central role of healthcare professionals, especially nursing staff, who work on the front lines of the segregation process. The quality of hospital waste management depends largely on the commitment and competence of these professionals, who must be continually trained and aware of the relevance of their actions. Therefore, ongoing education is essential to consolidate good practices and reduce contamination risks.

Brazilian legislation, consolidated by ANVISA RDC No. 222/2018, CONAMA Resolution No. 358/2005, and the National Solid Waste Policy, provides a robust basis for guiding hospital waste management. However, the effectiveness of this framework depends on its coordination with public health policies, infrastructure investments, and effective oversight. Integration between the different levels of government and healthcare institutions is essential to ensure that regulations are implemented and become consistent practices.

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In terms of sustainability, hospitals need to incorporate the logic of waste prevention and reduction into their processes, aligning with the principles of the circular economy. Adopting clean technologies, reusing materials whenever possible, and reducing the consumption of disposable supplies should be strategic objectives. These efforts not only reduce environmental impacts but also strengthen the company's image in the eyes of society, regulatory bodies, and investors.

The future prospects for hospital waste management are linked to technological innovation, institutional integration, and strengthening social awareness. The use of digital tools, such as traceability systems and artificial intelligence, can increase process efficiency and reduce errors. At the same time, environmental education programs aimed at employees and patients can increase shared responsibility, creating a broader and more inclusive culture of sustainability.

The study also showed that hospital waste management has significant economic implications. Incorrect disposal increases treatment costs and increases the risk of environmental and legal liabilities. On the other hand, proper segregation and rational use of inputs reduce expenses and optimize resources, contributing to the financial sustainability of institutions. Therefore, efficient waste management should be seen as a strategic investment, not just an operational cost.

Furthermore, it's important to consider that hospital waste management is part of a global health and environmental agenda. International conferences and multilateral organizations have reinforced the need for countries to adopt more sustainable practices in all sectors, including healthcare. Thus, Brazilian institutions that advance in this field will be able to align themselves with international standards and consolidate their relevance in global cooperation networks.

It can be concluded, therefore, that hospital waste management, when carried out in an integrated and sustainable manner, can generate multiple benefits: it protects public health, preserves the environment, strengthens the institutional image, and contributes to the economic efficiency of the healthcare sector. To this end, it is essential to overcome the identified challenges, invest in training, technological innovation, and institutional integration, ensuring that legal and technical principles are translated into concrete and effective practices.

Finally, it is emphasized that hospital waste management must be viewed as a strategic and ethical commitment of healthcare institutions, in line with the Sustainable Development Goals and the expectations of contemporary society. Consolidating sustainable practices in this field is not only a regulatory requirement, but a moral imperative given the risks posed by inadequate management. Thus, hospitals and clinics that proactively embrace this agenda will not only be complying with the law but also building a legacy of responsibility, innovation, and commitment to life.

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