

Original Research

Comparative Analysis of Healthcare Waste Legislation: Alignment and Discrepancies between Federal, State, and Municipal Regulations

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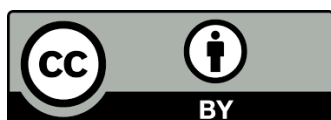
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Abstract

The management of healthcare waste (HCW) presents a significant environmental and public health challenge, aggravated by gaps in current Brazilian federal regulations. This study provides a comprehensive analysis of specific state and municipal legislation on HCW, comparing it with ANVISA Resolution No. 222/2018 and CONAMA Resolution No. 358/2005 to ascertain whether local regulations enhance management practices and can act as supplementary instruments to federal guidelines. The methodology was structured into three distinct phases: (I) a systematic survey of state and state capital regulations concerning HCW; (II) the development of a qualitative and quantitative analysis matrix to compare the identified local legislation with the federal reference frameworks; and (III) a complementary term-frequency analysis. A total of 33 legislative documents were identified, of which only six exhibited no significant divergences from the federal regulations. It is noteworthy that legal provisions establishing more stringent compliance deadlines,



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dedicated supervisory bodies, transparent decision-making processes, and a differentiated approach for small versus large generators can significantly contribute to an integrated, sustainable, and efficient HCW management system. Furthermore, initiatives related to the reverse logistics of pharmaceuticals and the regulation of household healthcare waste, areas not yet addressed at the federal level, represent notable advancements in promoting a circular economy. The findings of this study demonstrate that well-formulated local legislation strengthens the HCW management system by adapting it to regional specificities, thereby extending the reach of public policies and fostering circular economic models. The implementation of HCW generation indicators, effective oversight mechanisms, simplified criteria for small generators, the promotion of less-polluting treatment technologies, and robust environmental education programs are critical to developing a more integrated, sustainable, and efficient system that yields tangible benefits for public health and environmental protection.

Keywords

Healthcare waste; waste management; environmental legislation; standards

1. Introduction

Healthcare waste (HCW) encompasses all waste generated by healthcare facilities, as defined by the National Health Surveillance Agency (ANVISA) in Resolution RDC No. 222/2018. This includes any service whose activities are related to human or animal healthcare. HCW is classified into five groups according to its characteristics and associated hazards: Group A comprises waste with potential biological agents that, due to their nature, may pose an infection risk; Group B includes waste containing chemical substances that present hazards to public health or the environment based on properties such as flammability, corrosivity, reactivity, pathogenicity, toxicity, or toxicological effects; Group C refers to materials containing radionuclides in quantities exceeding the clearance levels established by the National Nuclear Energy Commission (CNEN), for which reuse is neither appropriate nor foreseen; Group D consists of waste that poses no biological, chemical, or radiological risk to health or the environment and is comparable to municipal solid waste; and Group E includes sharps or cutting/piercing materials [1]. Within this classification, four of the five groups (A, B, C, and E) are designated as hazardous.

According to the World Health Organization [2], approximately 15% of HCWs are considered hazardous. Due to its potentially harmful nature, improper disposal of HCW poses significant risks to human health and the environment. In Brazil, HCW generation in 2021 was estimated at 289,915 metric tons, equivalent to approximately 1.37 kg per capita annually, according to data from the Brazilian Association of Public Cleaning and Special Waste Companies [3]. The most recent overview published by the Brazilian Waste and Environment Association [4] indicates a slight increase in 2024, totaling 292,762 metric tons, an increase of approximately 1% compared to 2021. Although modest, this upward trend underscores the critical need for effective management strategies to mitigate expanding socio-environmental impacts.

Inadequate management of HCW can exacerbate environmental degradation and public health risks; however, such impacts can be significantly mitigated through proactive ecological protection and public health interventions [5]. HCW management thus constitutes a comprehensive set of administrative, operational, and technical procedures for integrating, organizing, planning, and implementing waste-handling practices grounded in legal and scientific frameworks. Its primary objectives are to minimize waste generation, ensure safe and compliant disposal, safeguard the biosafety of professionals directly or indirectly exposed to HCW, and protect public health [1]. Although HCW accounts for only about 2% of total daily urban waste generation in Brazil, its proper management remains imperative. Healthcare generators are obligated to comply with environmental, public health, and occupational safety regulations and must continuously strive to enhance their waste management practices [6]. Complementary strategies may also be adopted to improve waste control, including the application of the 10Rs of the Circular Economy: refuse, rethink, reduce, reuse, repair, recondition, remanufacture, redirect, recycle, and recover [7]. Additionally, investment in environmental education for staff is a vital component of HCW management, as it equips personnel—who are in constant contact with such waste—with the knowledge and skills to handle it appropriately and respond effectively in contamination-related emergencies. HCW management must extend beyond mere regulatory compliance; it must also prioritize continuous environmental education to ensure proper handling practices [8, 9]. While these measures can reduce occupational and environmental risks, existing literature indicates persistent gaps in professional training and awareness, highlighting the urgent need for integrated regulatory and educational frameworks.

Regarding the historical context of HCW legislation in Brazil, the National Environmental Council (CONAMA) established, with Resolution No. 6, of September 19, 1991, the first guidelines for the treatment of solid waste from health facilities. This resolution permitted the incineration of such waste, provided that state environmental agencies defined specific treatment standards as a prerequisite for licensing activities related to collection, transportation, packaging, and final disposal. In 1993, the Brazilian Association of Technical Standards (ABNT) established the classification of healthcare waste through Brazilian Reference Standard (NBR) No. 12808. Subsequently, CONAMA Resolution No. 6, of August 5, 1993, was published, addressing the management of solid waste generated in ports, airports, railway and road terminals, and healthcare service establishments [10].

In 2004 and 2005, respectively, ANVISA and CONAMA published complementary and convergent resolutions, which marked a milestone for HCW management in Brazil. ANVISA Resolution - Collegiate Board Resolution (RDC) No. 306, of December 7, 2004, detailed the management of HCW according to its classification (Groups A, B, C, D, E, and subgroups A1, A2, A3, A4, and A5) and the Healthcare Waste Management Plan - HCWMP [11]. Meanwhile, CONAMA Resolution No. 358, of April 29, 2005, emphasized the treatment and final disposal of healthcare waste [10]. Notably, ANVISA RDC No. 306/2004 was later revoked by ANVISA Resolution No. 222, dated March 28, 2018. According to Portugal and Moraes [12], the 2018 resolution simplified the regulatory framework by omitting specific details previously included, as those provisions were deemed to be addressed in other existing normative instruments.

In this context, scholarly analyses suggest that the absence of national standardization, coupled with the proliferation of diverse local regulations, may simultaneously reinforce best practices and generate regulatory inconsistencies [12]. Despite the significance of this issue, there remains a

notable scarcity of systematic studies examining how Brazilian states and capital cities have regulated HCW in relation to federal norms. This academic gap is particularly salient, as international literature consistently emphasizes that adapting regulatory frameworks to local contexts is essential for effective waste management [13, 14]. Consequently, it is imperative to assess the extent to which state and municipal legislation in Brazil complements, expands upon, or diverges from national regulations.

This study therefore aims to conduct a comparative analysis of legislation enacted by Brazilian states and capitals regarding HCW management, using the ANVISA RDC No. 222/2018 and CONAMA Resolution No. 358/2005 as primary federal benchmarks. The analysis seeks to determine whether local regulations establish more stringent or specific requirements, address regulatory gaps at the federal level, and meaningfully contribute to protecting public health and the environment. By addressing a critical gap in the literature and providing updated evidence on Brazil's regulatory landscape, this study offers valuable insights to inform both operational waste management practices and the development of more coherent, integrated, and effective public policies.

2. Materials and Methods

This study adopted a comparative analytical framework, according to the flowchart presented in Figure 1 and structured into three main phases: I. Survey of state and capital city regulations concerning HCW; II. Construction of a qualitative and quantitative analysis matrix to compare the identified legislation, state and municipal, against the federal reference regulations: RDC No. 222/2018 and CONAMA Resolution No. 358/2005; and III—complementary frequency-based term analysis (Wordcloud).

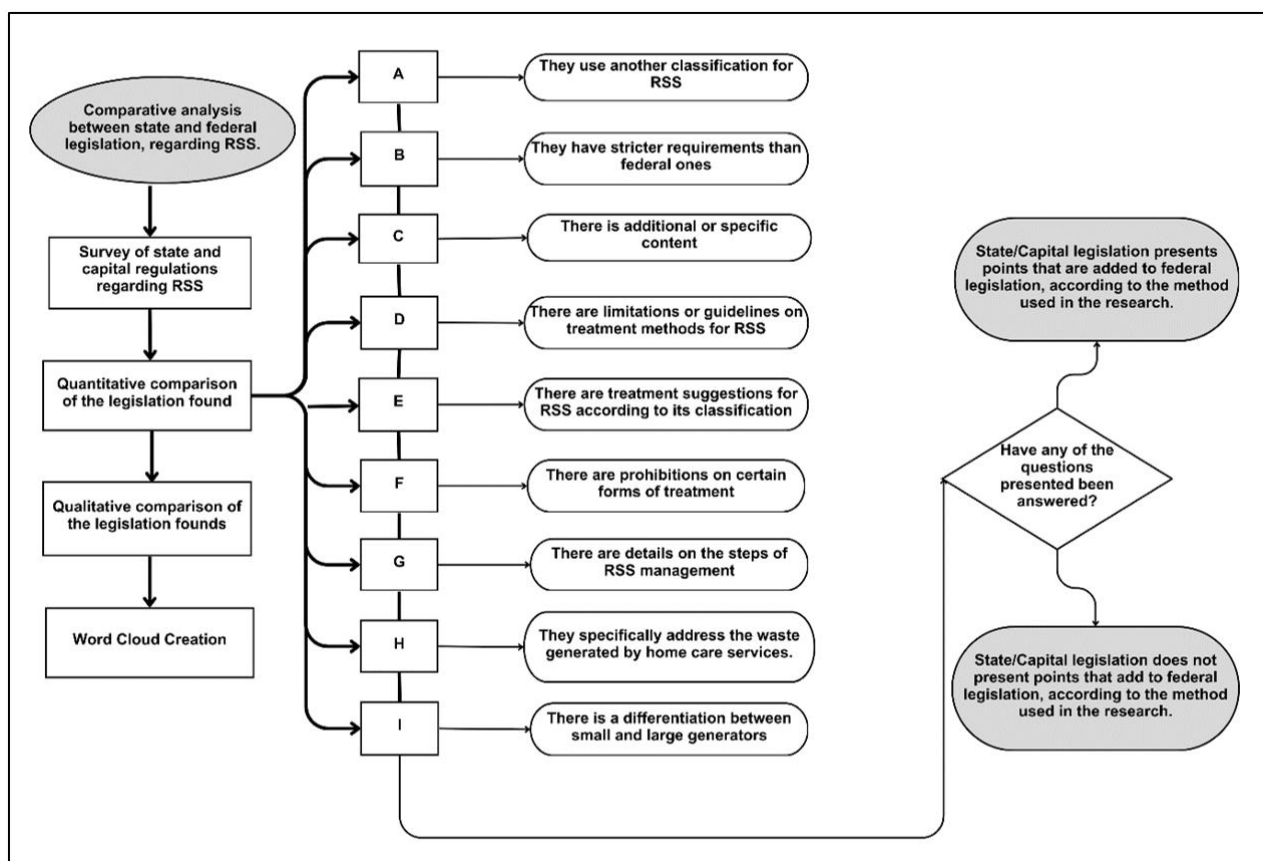


Figure 1 Flowchart used in the comparative analysis between state/capital and federal legislation on healthcare waste (RSS), highlighting the qualitative criteria applied to identify additions to national regulation. Legend: A: Does it follow a waste classification different from RDC ANVISA No. 222/2018 and CONAMA No. 358/2005?; B: Is it more restrictive than federal legislation?; C: Does it specify or include any additional topics beyond federal legislation?; D: Does it define a specific treatment?; E: Does it suggest any treatments considering the waste classification?; F: Does it prohibit any particular treatment?; G: Does it detail segregation, management, storage areas, collection, internal/external transportation, disposal, or others?; H: Does it provide for HCW generated by home care services?; I: Does it establish the option of a Simplified Healthcare Waste Management Plan?

For Phase I, the regulatory survey, the inclusion criterion was legislation specifically addressing HCW; general waste regulations were excluded. Data collection began through the Portal da Legislação Estadual, which aggregates links to official repositories for each Brazilian state. Subsequently, Google’s search engine was used with the keywords “Resíduos de Serviço de Saúde” + [name of state or capital], yielding a greater number of regulations not initially available in the official repositories. However, it was observed that specific rules identified in the first stage did not appear in subsequent keyword-based searches. Notably, São Paulo and Tocantins were not retrieved through these searches, requiring targeted retrieval of their respective regulations by official number and date. To broaden the scope of the search, the process was repeated using the following keyword combinations: “resíduos de serviços de saúde + [state name]”; “lei resíduos de serviços de saúde + [state name]”; “decreto resíduos de serviços de saúde + [state name]”, with

identical formulations applied to capital cities. This iterative process identified 14 additional regulations: 7 state-level and 7 municipal.

In Phase II, a qualitative and quantitative analysis matrix was employed to compare the collected regulations against the federal reference frameworks, following methodological approaches established in both national and international studies, including normative analyses of HCW in Brazil [12] and global regulatory assessment and waste categorization guidelines [13]. All collected legislation was read in full and analyzed article by article in direct comparison with ANVISA RDC No. 222/2018 and CONAMA Resolution No. 358/2005. The qualitative approach enabled an in-depth examination of regulatory specifics and contextual nuances, while the quantitative component was operationalized through the questions presented in Table 1. These questions were designed to evaluate whether local regulations complement, expand, or diverge from the federal resolutions, specifically ANVISA RDC No. 222/2018 and CONAMA No. 358/2005. The analysis focused on predefined key aspects, including: HCW classification; specification or prohibition of treatment methods; degree of restriction; level of additional detail; and whether differentiated HCWMPs are mandated according to the volume of HCW generated. When a regulation yielded a positive (“yes”) response to any question, it was highlighted in the analysis to facilitate the identification of relevant divergences or enhancements relative to federal legislation.

Table 1 Questions designed to perform the quantitative analysis of the legislation relating to HCW in the states and capitals of Brazil.

	Key Questions	Objectives
A	Do you follow a different waste classification than RDC ANVISA No. 222/2018 and CONAMA No. 358/2005?	Assess whether the standards use another classification for HCW, which could directly impact waste management.
B	More restrictive than federal law?	Check whether the standards have stricter requirements than federal standards and what the reasons for this are.
C	Does it specify or include any topics beyond federal legislation?	Does it specify or include any additional topics other than federal legislation?
D	Does it define a specific treatment?	Analyze whether there are limitations or guidelines on the treatment methods for HCW and whether justifications are presented for this.
E	Do you suggest any treatments considering the classification of waste?	Check if there are suggestions for treatments for HCW according to their classification, guiding the generator to choose practices that are appropriate and viable for the local reality.
F	Does it prohibit any specific treatment?	Understand whether there are prohibitions on certain forms of treatment and the justifications for these restrictions.
G	Does it provide details on segregation, management, shelters, collection, internal/external transport, disposal, or others?	Assess whether there is detail on the steps involved in managing HCW, according to the classification of the waste generated.

H	Does it provide information on HCW generated by home care services?	Check whether local regulations specifically address waste generated by home care services.
I	Does it establish the option of a Simplified Healthcare Waste Management Plan?	Check if there is a differentiation between small and large generators and how this is treated in relation to the simplified HCWMP.

As an additional resource, in Step III, the Wordcloud technique was employed, which groups and visually organizes words by their frequency of occurrence in the analyzed text. This is a simple yet visually compelling analysis that facilitates rapid identification of keywords [15]. In this format, words with higher frequency appear in larger font sizes, while those with lower frequency appear in smaller fonts. Colors were also used to indicate the frequency with which words occur in the evaluated texts, following the descending order defined by the authors: red, yellow, dark green, light green, and gray.

For the analysis, four word clouds were generated using the software WordClouds.com [16], which was selected for its free, user-friendly nature. These were: I. Wordcloud of ANVISA RDC No. 222/2018; II. Wordcloud of CONAMA Resolution No. 358/2005; III. Wordcloud of the compiled state-level regulations; IV. Word cloud of the compiled capital city regulations. Additionally, the top 10 most frequent words from each of the four texts were extracted to enable a comparative quantitative analysis. The choice of this tool is justified by its potential to directly visualize central themes and highlight differences among groups of regulations, allowing for a more immediate comparative perspective. However, it should be noted that this is a complementary resource, as it relies solely on term frequency and does not capture how terms are contextually employed within the regulations, their legal weight, or their normative relevance, potentially assigning disproportionate emphasis to recurrent words while disregarding their actual meaning within the regulatory text. Thus, the word clouds were used strictly as a visual support tool and do not replace the qualitative and quantitative analyses conducted in this study.

3. Results and Discussion

The search covered 26 states, 26 capital cities, and the Federal District, identifying 33 standards. These standards pertained to 20 states, 13 capital cities, and the Federal District, as shown in Table 2, Table 3, Table S1, and Table S2. For the states of Alagoas, Bahia, Ceará, Goiás, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte, and Roraima, and for the capital cities Maceió (AL), Macapá (AP), Manaus (AM), Fortaleza (CE), Vitória (ES), São Luís (MA), Cuiabá (MT), Campo Grande (MS), Belém (PA), Curitiba (PR), Porto Alegre (RS), Boa Vista (RR), Florianópolis (SC), Aracaju (SE), and Palmas (TO), it was not possible to identify specific HCW standards using the methodology employed. For this reason, they were not mentioned in Table 2 and Table 3.

Table 2 Assessment of legislation relating to HCW in the Brazilian States.

Assessment of Legislation related to HCW in Brazil - States													
States													
	Standard Number	Year	A	B	C	D	E	F	G	H	I	Highlights by standard	
Acre	Lei Ordinária n° 1401 [17]	2001	N/A	N/A	Yes	No	No	No	Yes	No	No	2	
Amapá	Instrução Normativa SEMA n° 6 [18]	2008	No	No	No	No	No	No	No	No	Yes	1	
Amapá	Lei Ordinária n° 2505 [19]	2020	N/A	N/A	N/A	No	No	No	No	No	No	0	
Amazonas	Lei Ordinária n° 7244 [20]	2024	N/A	N/A	N/A	No	No	No	No	No	No	0	
Espírito Santo	Decreto n° 5851-R [21]	2024	N/A	No	Yes	No	No	No	No	Yes	No	2	
Espírito Santo	Lei n° 6407 [22]	2000	Yes	No	No	Yes	No	No	No	No	No	2	
Mato Grosso	Instrução Normativa n° 001 [23]	2023	No	No	No	No	No	No	No	No	No	0	
Mato Grosso do Sul	Lei n° 1.807 [24]	1997	N/A	Yes	Yes	Yes	No	Yes	No	No	No	4	
Mato Grosso do Sul	Lei n° 4474 [25]	2014	No	No	Yes	No	No	Yes	No	No	No	2	
Minas Gerais	COPAM n° 171 [26]	2011	No	No	Yes	No	No	Yes	Yes	No	No	3	
Pará	Lei Ordinária n° 6517 [27]	2002	Yes	No	Yes	No	No	Yes	Yes	No	No	4	
Paraná	Resolução Conjunta SEMA/SESA n° 002 [28]	2005	No	No	No	No	No	No	No	No	Yes	1	
Paraná	Lei Estadual n° 16322 [29]	2009	N/A	Yes	No	No	No	No	Yes	No	No	2	
Rio de Janeiro	Lei n° 6635 (Redação dada pela lei 10601/2024) [30]	2013	No	Yes	No	No	No	Yes	Yes	No	No	3	
Rio Grande do Sul	Lei Ordinária n° 10099 [31]	1994	Yes	No	No	No	No	No	No	No	No	1	
Rondônia	Lei n° 592 [32]	1994	Yes	No	No	No	No	No	No	No	No	1	
Santa Catarina	Resolução Conjunta CONSEMA e DIVS n° 02 [33]	2019	No	No	No	No	No	No	No	No	No	0	
São Paulo	Portaria CVS – 21 [34]	2008	No	No	Yes	No	Yes	No	No	Yes	No	3	
Sergipe	Lei Ordinária n° 7.913 [35]	2014	N/A	No	Yes	No	No	No	Yes	No	No	2	
Tocantins	Portaria n° 94 [36]	2025	No	Yes	No	No	No	No	No	No	No	1	
Number of highlights per question			4	4	8	2	1	5	6	2	2		
Total of highlights			34										

Legend: A: Does it follow a waste classification different from RDC ANVISA No. 222/2018 and CONAMA No. 358/2005?; B: Is it more restrictive than federal legislation?; C: Does it specify or include any additional topics beyond federal legislation?; D: Does it define a specific treatment?; E: Does it suggest any treatments considering the waste classification?; F: Does it prohibit any particular treatment?; G: Does it detail segregation, management, storage areas, collection, internal/external transportation, disposal, or others?; H: Does it provide for HCW generated by home care services?; I: Does it establish the option of a Simplified Healthcare Waste Management Plan?; (Hatched in gray: emphasis given by the authors).

Table 3 Assessment of legislation relating to HCW in the capitals of Brazil.

Assessment of Legislation related to HCW in Brazil - Capitals												
Capitals												
	Standard Number	Year	A	B	C	D	E	F	G	H	I	Highlights by standard
Rio Branco	Lei n° 2.107 [37]	2001	N/A	N/A	Yes	No	No	No	Yes	No	No	2
Salvador	Decreto n° 16.592 [38]	2008	No	No	No	No	No	No	No	No	Yes	1
Goiania	Lei n° 9522 [39]	2020	N/A	N/A	N/A	No	No	No	No	No	No	0
Belo Horizonte	Decreto n° 10.296 [40]	2024	N/A	N/A	N/A	No	No	No	No	No	No	0
Belo Horizonte	Decreto n° 16.509 [41]	2024	N/A	No	Yes	No	No	No	No	Yes	No	2
João Pessoa	Lei Ordinária n° 12.735 [42]	2000	Yes	No	No	Yes	No	No	No	No	No	2
Recife	Decreto n° 18.480 [43]	2023	No	No	No	No	No	No	No	No	No	0
Teresina	Decreto n° 9.432 [44]	1997	N/A	Yes	Yes	Yes	No	Yes	No	No	No	4
Rio de Janeiro	Portaria COMLURB n° 7 [45]	2014	No	No	Yes	No	No	Yes	No	No	No	2
Natal	Decreto n° 7.168 [46]	2011	No	No	Yes	No	No	Yes	Yes	No	No	3
Porto Velho	Lei Complementar n° 136 [47]	2002	Yes	No	Yes	No	No	Yes	Yes	No	No	4
São Paulo	Decreto n° 37.471 [48]	2005	No	No	No	No	No	No	No	No	Yes	1
Distrito Federal	Lei n° 4.352 [49]	2009	No	Yes	No	No	No	No	Yes	No	No	2
Number of highlights per question			1	7	7	0	0	0	5	1	1	
Total of highlights			22									

Legend: A: Does it follow a waste classification different from RDC ANVISA No. 222/2018 and CONAMA No. 358/2005?; B: Is it more restrictive than federal legislation?; C: Does it specify or include any additional topics beyond federal legislation?; D: Does it define a specific treatment?; E: Does it suggest any treatments considering the waste classification?; F: Does it prohibit any particular treatment?; G: Does it detail segregation, management,

storage areas, collection, internal/external transportation, disposal, or others?; H: Does it provide for HCW generated by home care services?; I: Does it establish the option of a Simplified Healthcare Waste Management Plan? (Hatched in gray: emphasis given by the authors).

In the quantitative analysis, the study was guided by the questions presented in Table 1, which allowed for the following assessment: 5 regulations (15.2% of the total), of which 4 (19.1%) were state-level and 1 (7.7%) was municipal, presented a classification of HCW that differed from that of federal legislation. 11 regulations (33.3%), comprising four state-level (19.1%) and 7 municipal (53.9%) ones, were more restrictive. 15 regulations (45.5%), with 8 being state-level (38.1%) and 7 municipal (53.9%), specified or included topics not addressed by federal legislation. Two states (6.1% of the total; 9.5% of the states) defined specific HCW treatment protocols. One state regulation (3.0% of the total; 4.8% of the states) suggested treatments for HCW according to their classification. Five state regulations (15.2% of the total; 23.8% of the states) prohibited certain specific treatments. 11 regulations (33.3%), 6 of which were state (28.6%) and 5 municipal (38.5%), detailed segregation, management, storage areas, collection, internal/external transportation, disposal, or other related aspects. Three regulations (9.1%), 2 of which were state (9.5%) and 1 municipal (7.7%), provided for HCW generated by home care services. Three regulations (9.1%), 2 of which were state (9.5%) and 1 municipal (7.7%), established the option to prepare a Simplified HCWMP.

According to question A (Table 1), the regulations that followed a different classification for HCW were those before 2005, which justifies the discrepancy. No subsequent updates were identified that incorporated the new federal rules. These included: Law No. 6,407/2000 of Espírito Santo [22], Law No. 6,517/2002 of Pará [27], Law No. 10,099/1994 of Rio Grande do Sul [31], Law No. 592/1994 of Rondônia [32], and Decree No. 18,480/2000 of the city of Recife/PE [43].

For question B (Table 1), some state and municipal regulations were indeed more restrictive. While CONAMA Resolution No. 358/2005 allowed up to 2 years for adaptation, and ANVISA RDC No. 222/2018 establishes 180 days for new generators, local regulations significantly reduced these periods. Among them, those that reduce the deadlines for submitting the HCWMP stand out, such as the decree of Salvador/BA [38], which establishes a deadline of 60 days, counted from the date of publication of the decree, for HCW generators to comply with the provisions according to RDC ANVISA No. 306/2004 and CONAMA No. 358/2005 [38]. In Recife/PE, Decree No. 18.480/2000 establishes a deadline of 120 days for submitting the HCWMP and 60 days, counted from the date of its approval, for its implementation [43]. In São Paulo/SP, Decree No. 37.471/1998 establishes that establishments that generate HCW, after being summoned by the Municipal Secretariat for Green Areas and the Environment, will have a period of 30 days to present the HCWMP [48]. Law No. 4,352/2009 of the Federal District establishes a period of 60 days to show the HCWMP and a period of 90 days, counted from the date of approval of the HCWMP, for its implementation [49]. Some rules impose penalties, such as Complementary Law No. 136/2001 of Porto Velho/RO, which provides for a fine of 10,000 Fiscal Standard Units for violators [47]. Another rule restricts the target audience, such as Ordinance No. 94/2025 of the state of Tocantins, which limits it to HCW-generating units under the responsibility of the Health Secretariat of the State of Tocantins [36]. Law No. 6,635/2013 of the state of Rio de Janeiro and Decree No. 7,168/2013 of Natal/RN are restricted to Healthcare Solid Waste [30, 46], and Municipal Urban Cleaning Company (COMLURB) Ordinance No. 7/2024 of Rio de Janeiro/RJ, which provides for the certification of legal entities for the collection and removal of HCW, determined, for the ordinance, as the waste described in groups A and E of RDC No. 222/2018 [45].

Regarding question C (Table 1), some standards address additional topics or greater specificity, such as reverse logistics for expired medications. In this example, we have Ordinary Law No.

1,401/2001 - Acre, which requires that medications must be temporarily stored in containers distinct from those used for sale, until their collection [17]; Law No. 4,474/2014 of Mato Grosso do Sul, which details how the campaign should be carried out with pharmacies and drugstores for the collection of expired or unfit for use medicines, cosmetics, pharmaceutical inputs, and related products, making the collection of drugs mandatory [24]; and Decree No. 5,851-R/2024 of Espírito Santo, which provides for the reverse logistics of medicines for home use and how distributors and industries should act, making medicine manufacturers responsible for the final and adequate disposal of the products sold, in addition to instructing how the temporary storage of expired or unfit for use medicines should be done until their collection [21]. There is also Law No. 16,322/2009 of Paraná and Complementary Law No. 136/2001 of Porto Velho/RO, which establish the return to the manufacturer of expired medicines [29, 47]; while Law No. 7.913/2014 of the state of Sergipe requires pharmacies and drugstores to maintain containers for the collection of deteriorated or expired medicines, cosmetics, pharmaceutical supplies, and related products, which must be sent to institutions that have an HCW Management Plan and Program, in addition to establishing a fine in case of non-compliance with the law [35]. Another requirement beyond those of federal standards was found in COPAM standard No. 171/2011 of Minas Gerais, which establishes structural and equipment requirements for the HCW Treatment Plant, according to the type of waste to be received [26]. There are also requirements, such as those observed in Ordinary Law No. 6.517/2002 of Pará, which require the registration of HCW generators with the State Executive Secretariat for Science, Technology, and Environment [27]. Other requirements that go beyond federal standards are: Ordinance CVS - 21/2008 of the state of São Paulo, which specifically provides for the Management of Hazardous Waste from Medication in Health Services [34]; Law No. 9,522/2014 of Goiânia/GO, which determines the charging of a public fee for the collection and final disposal service, in addition to determining the amount of a fine in case of non-compliance with the provisions of the law [39]; Decree No. 10,296/2000 of Belo Horizonte/MG, which details to generators of group C the following establishes that establishments that generate HCW, after being summoned by the Municipal Secretariat for Green Areas and the Environment, will have a period of 30 days to present the HCWMP [40]. Law No. 4,352/2009 of the Federal District establishes a period of 60 days to show the HCWMP and a period of 90 days, counted from the date of approval of the HCWMP, for its implementation [49]. There are rules imposing penalties, such as Complementary Law No. 136/2001 of Porto Velho/RO, which provides a fine of 10,000 Fiscal Standard Units (UPF) for violators [47]. Another rule restricts the target audience, such as Ordinance No. 94/2025 of the state of Tocantins, limiting it to HCW generating units under the responsibility of the Health Secretariat of the State of Tocantins [36]. Law No. 6,635/2013 of the state of Rio de Janeiro and Decree No. 7,168/2013 of Natal/RN are restricted to Solid Waste from Health Services, and COMLURB Ordinance No. 7/2024 of Rio de Janeiro/RJ, which provides for the certification of legal entities for the collection and removal of HCW, determined, for the ordinance, as the waste described in groups A and E of RDC No. 222/2018 [30, 45].

For question D (Table 1), some standards establish specific treatments for HCW. Law No. 6,407/2000 of the state of Espírito Santo establishes, in its Art. 8, the following order of priority for environmentally appropriate final disposal: I - incineration; II - co-processing; and III - final disposal in a Class I landfill, intended for hazardous products [22]. Law No. 1,807/1997 of the state of Mato

Grosso do Sul mandates incineration as the mandatory disposal method for hospital waste, thereby applying to hazardous HCW [24].

According to question E (Table 1), Ordinance CVS-21/2008 of the state of São Paulo provides treatment recommendations based on waste classification, recommending incineration for Type 1 Hazardous Medication Waste in units licensed for Class I hazardous waste, but allowing alternatives with environmental authorization [34].

Regarding question F (Table 1), some regulations prohibit specific treatments. In the state of Mato Grosso do Sul, Law No. 1,807/1997 requires incineration for all HCW, and Law No. 4,474/2014 prohibits the following destinations: I - crude dumping in the open air, both in urban and rural areas; II - burning in the open air or in inappropriate, unlicensed containers, facilities, or equipment, not in accordance with current legislation; III - dumping into the sewage system; IV - in sanitary landfills (hazardous waste landfills) [24, 25]. In Minas Gerais, COPAM No. 171/2011 prohibits the disposal of HCW in dumps, controlled landfills, pits, ditches, pipes, or open burning [26]. In Pará, Law No. 6,517/2002 prohibits the final disposal of HCW by establishments that are not correctly registered with SECTAM [27]. Law No. 6,635/2013 of the state of Rio de Janeiro prohibits the recycling or reuse of Group A and E waste [30].

When comparing the Brazilian context with the international context, through scientific literature, it is recommended that infectious and sharp waste be treated primarily through non-incinerator technologies, due to their potential to emit toxic atmospheric pollutants if operated inappropriately, with treatments such as autoclaving with steam under pressure, microwaves, and chemical treatments being recommended in specific contexts [50, 51]. According to the WHO technical guide, the autoclave used with mechanical fragmentation is considered an efficient, widely validated option for treating infectious waste [51]. Incineration is currently recommended for anatomical and pharmaceutical waste when no viable alternatives are available. The choice of technology must consider environmental, economic, and operational criteria, always seeking alternatives that minimize risks to health and the environment [13, 51, 52]. In the study by Rafiee et al. [53], eight treatments for infectious HCW were evaluated: autoclave, autoclave with shredder, chemical treatment, hydroclave, demolisher, microwave, chem-clave, and central incineration. The objective was to determine which of the analyzed treatments would yield the best results, taking into account technical, economic, social, and environmental factors. The study concluded that the hydroclave, a variant of the autoclave method that uses hot water and, in some cases, chemical processes to sterilize waste, obtained the best score in the evaluated criteria. The other treatments followed the following ranking order: autoclave with shredder, autoclave, central incineration, and chemical treatment [53]. However, in studies that considered volatile organic compound emissions, the autoclave with shredder obtained better results than the hydroclave [54]. Despite recommendations to prioritize non-incinerator technologies, incineration remains widely used in Brazil, where approximately 43.4% of HCW is treated by this method [3]. At the international level, according to Fadaei [55], 91% of countries also use incineration to treat HCW.

For question G (Table 1), standards with greater detail on steps such as segregation, handling, storage areas, collection, transportation, and disposal included: Law No. 6,517/2002 of the state of Pará, which specifies the correct packaging in plastic bags or appropriate containers, according to the type of waste [27]; Law No. 16,322/2009 of Paraná, which details the obligation of pharmaceutical distributors to collect expired medications [29]; Law No. 6,635/2013 of Rio de

Janeiro, which details that radioactive waste must be treated based on Resolution CNEN-NE 6.05 [30]; and Law No. 7,913/2014 of Sergipe, which provides information on what containers should be used to collect the material and how it should be stored until it is collected by the responsible party [35].

Regarding regulations in capital cities, decree No. 10,296/2000 of Belo Horizonte/MG details the floor plan that must be in place at the stage of collection and internal transportation of Group A waste, and also indicates the final storage areas for Groups A and D [40]. In Rio de Janeiro, COMLURB Ordinance No. 7/2024 stipulates the minimum number and type of vehicles required for collecting HCW [45]. In Teresina, Decree No. 9,432/2009 allows the collection of Group A waste, which is easily putrefying, to be stored for more than 24 hours, provided it is refrigerated or subjected to conservation methods [44]. In the Federal District, Law No. 4,352/2009 establishes that Groups A, B, D, and E waste must be sent to controlled landfills [49].

To be an impartial source of health information and guidance on safe waste management practices, WHO has developed the guide "Safe management of waste from health-care activities - 2nd edition (2014)" [13], which provides details on the segregation, storage, and transportation of HCW, highlighting the importance of proper management to minimize risks and reduce contamination of other waste [13, 56-59]. The guide also provides guidance on the use of colors and symbols to identify HCW, to ensure that they are correctly identified, thereby avoiding environmental contamination and incorrect disposal. Furthermore, it discusses how health professionals should act during care to contribute to correct segregation, highlighting the importance of educating professionals on proper segregation [13, 60-62]. The WHO [13] establishes that vehicles used to transport HCW should not be used for any other purpose and that there should be a specific routine to ensure that the storage time does not exceed the recommended period, depending on the type of waste. However, the study by Raji and Adeogun [63] found that the region's culture directly influences how waste is handled. Even if the environments had correctly identified containers, correct use was not always observed. In developing countries, the situation was more serious due to the lack of knowledge and resources for the use of modern treatment techniques [64-66]. In developed countries, the authors observed a better situation, in which the WHO guidelines were generally followed and access to more modern and efficient treatments was available.

In response to question H (Table 1), standards on HCW from home care services include Espírito Santo through Decree No. 5851-R/2024, which provides for expired or unused industrialized and compounded medications for home use, and their packaging [21]. In the state of São Paulo, Ordinance CVS-21/2008 covers RPM (hazardous drug waste) from home care/assistance services [34]. In Belo Horizonte, Decree No. 16509/2016 provides for HCW generated in condominiums [41].

The presence of medications in the environment is primarily a consequence of their disposal in homes, which is one of the most common incorrect disposal methods among the population, as they mix medication waste with common solid waste [67]. The proper disposal of household waste is of great importance for reducing risks associated with health and the environment. According to the EPA (Environmental Protection Agency), there are several guidelines in the United States for the disposal of medicines, including take-back programs, that facilitate the return of household medicines to reduce improper disposal [68]. Medicine collection programs are an essential solution to the problem of medicine disposal. Good coordination between the

government and other authorities is necessary to ensure that medicine collection helps address issues of use, storage, and disposal [69]. The rapid advances in medicine and the lack of awareness among the population have resulted in a significant increase in medical waste, as well as improper disposal of HCW by households. The lack of awareness among the population regarding the disposal of HCW can lead to environmental damage and health risks, as reported by Banjar et al. [70].

For question I (Table 1), standards that provide for the Simplified Healthcare Waste Management Plan aimed at small HCW generators include: State of Amapá: SEMA Normative Instruction No. 6/2008, which defines small waste generators (in accordance with Art. 4, § 2 of the standard) as those that generate up to 30 liters/week (not applicable to establishments that generate chemotherapy and radioactive waste) [18]. State of Paraná: Joint Resolution SEMA/SESA No. 002/2005 for generators of up to 30 liters per week [28]. Belo Horizonte: Decree No. 16509/2016 for condominium units and generators of subgroups A1, A3, A4, and groups B, D, and E [41].

The HCW poses a significant challenge for governments, particularly in developing countries, where waste management systems often have limited capacity to address the issue [14]. Understanding the importance of HCW is crucial, given the profound environmental impacts and secondary effects associated with improper disposal. It is of utmost importance that a more comprehensive waste management model be implemented, enabling countries not only to thrive but also to take responsible control over this waste [64]. To this end, it is essential to establish an organized and integrated system for HCW management. This system should cover all stages of the short, medium, and long-term processes, including identification, segregation, packaging, transportation, disposal, and storage of waste. To optimize HCW management, it is necessary to incorporate strategies to prevent and minimize the generation of this waste, as well as to improve the handling, reuse, and recycling of these materials at all possible stages [71].

Good waste management through an effectively implemented HCWMP, even if the establishment is considered a small generator, brings several positive impacts to the institution. These benefits include cost reduction through reduced energy consumption and waste quantity, increased recycling, minimization of adverse environmental effects resulting from waste handling and treatment, and a better public image [13]. Minimizing waste quantity and toxicity should be a growing priority at all stages of the production cycle. At the same time, greater recycling of non-hazardous waste and broader use of efficient, less-polluting waste-disposal practices should reduce environmental and community health impacts while also maintaining protection against the transmission of infections [13].

Finally, the most recurrent words in the legislation were evaluated, as shown in Figure 2. The word clouds produced are highly similar, as expected, since they are legislative documents that address the same topic. For this reason, when Table 4 was prepared with the ten most recurrent words extracted from the word clouds, it was observed that five of them appear simultaneously among the different documents. However, when evaluating the other highlighted words, it is possible to identify the focus given by the standards in the context of HCW management. From the visual analysis of the word clouds, it is clear that CONAMA Resolution No. 358/2005 presents a more evident focus on the stages of treatment and adequate final disposal of HCW. In turn, ANVISA RDC No. 222/2018 also highlights the risks associated with waste according to its classification. Regarding state standards, there is a greater focus on HCW management guidelines



Table 4 List of the 10 most frequent words in ANVISA n° 222/2018, CONAMA n° 358/2005, in the norms of the States and in the norms of the Capitals.

The highlighted cells indicate words that are among the ten most frequent in both federal regulations and in groups of state and municipal regulations, emphasizing commonly used and highly relevant terms.

4. Discussion

According to WHO [13], supportive regulations for HCW management typically emerge after the establishment of a national policy, and the importance of this progression is emphasized. This is because legislation must be adapted to the local reality it is intended to address. States and municipalities, upon identifying gaps in federal regulations, may develop their own rules tailored to regional needs and contexts, thereby adapting HCW management accordingly. Another point highlighted by WHO [13] is the need to establish penalties and effective enforcement mechanisms targeting HCW generators. Although penalties for non-compliance are provided for in CONAMA Resolution No. 358/2005 and ANVISA RDC No. 222/2018, direct oversight by states and municipalities can contribute to stricter and more effective control.

In analyzing the identified regulations, it was observed that most reference federal norms—CONAMA Resolution No. 358/2005 and ANVISA RDC No. 222/2018—and incorporate complementary rules. As evidenced by Portugal and Morais [12], although ANVISA RDC aims to define good practices for HCW management, it does not explicitly reference other complementary legislation, such as CONAMA Resolution No. 358/2005 itself. Thus, the use of multiple complementary norms regarding HCW management represents a positive aspect.

Moreover, ANVISA RDC No. 306/2004 previously established specific indicators to be produced annually, such as: rate of injuries caused by sharps waste; variation in waste generation, indicating proportions for Groups A, B, D, and E; and variation in recycling percentage. However, these indicators were not included in ANVISA RDC No. 222/2018—a decision possibly intended to simplify the new version of the resolution and encourage compliance by generators. Nevertheless, this omission represents a significant loss of essential data for HCW management and governance [12]. Notably, none of the analyzed regulations incorporated the aforementioned indicators, which may be considered a negative point, as it hinders the acquisition of more precise data regarding the current state of HCW management.

Overall, this study stands out by offering an unprecedented, comparative view of state and municipal legislation on HCW, contrasted with current federal regulations. By systematically compiling and analyzing the diverse regulations, it was possible to highlight regional particularities and potential advances that may serve as models for other localities, as well as to identify limitations that weaken integrated management of the issue nationwide. This comparative approach adds distinctive value to the study, broadening understanding of Brazil's normative diversity and providing practical insights for formulating more consistent public policies that align HCW management with local specificities while maintaining coherence with national policy.

Finally, as limitations, it should be noted that during the research, challenges arose in locating regulations on the official websites of states and capitals. Most regulations were only available on third-party legal databases such as LegisWeb [72], which provides updated normative content at federal, state, and municipal levels, but not necessarily on official government portals. Consequently, it was not possible to confirm with states and municipalities whether the regulations remain in force or whether the texts retrieved represent the most current versions.

Thus, the possibility of additional specific legislation not identified due to methodological limitations cannot be ruled out.

4.1 Comparative International Overview

In Germany, waste management, including HCW, is highly structured. The country follows the Abfallverzeichnis-Verordnung (AVV), a regulation that incorporates into national law the European Union's Decision 2000/532/EC, which established the European Waste Catalog (EWC) and defined waste classifications to ensure standardization, traceability, control, and management [73]. The six-digit coding system used is similar to the waste coding system established by ANVISA and CONAMA in Brazil. German environmental culture is powerfully shaped by legislation, such as the Packaging Ordinance (1991), which created the "Green Dot" (Grüner Punkt) system, a pioneering model of extended producer responsibility that reshaped citizen and corporate behavior [74], and the Circular Economy Act (1996), which institutionalized shared responsibility between citizens and companies, prioritizing prevention, reuse, recycling, and final disposal (as a last resort) [75]. This legal and cultural foundation has resulted in disciplined and efficient waste management, including HCW, further reinforced by complementary guidelines such as the Vollzugshilfe zur Entsorgung von Abfällen aus Einrichtungen des Gesundheitsdienstes (LAGA M18), which explicitly guides healthcare waste management [76], and the Technische Regeln für Biologische Arbeitsstoffe 250 (TRBA 250), which establishes biosafety measures to protect workers against biological agents [77].

In India, although a consolidated legal framework exists, based on the Bio-Medical Waste Management Rules, 2016, updated in 2025 to strengthen monitoring of treatment facilities, the effectiveness of HCW management remains limited [78]. Implementation challenges, insufficient enforcement, inadequate infrastructure, and lack of training compromise adherence to regulations [79]. Additionally, cultural factors, such as traditional disposal habits, underestimated perception of biological risk, and institutional hierarchies, hinder proper segregation and treatment of waste [13, 80], despite the existence of color-coding systems and specific treatment methods.

In Brazil, HCW management is primarily regulated by ANVISA RDC No. 222/2018 and CONAMA Resolution No. 358/2005, complemented by some state and municipal regulations. Similar to India, effectiveness depends on enforcement, infrastructure, and professional training [79]. Although detailed classification and traceability systems exist, environmental awareness is still developing in many regions, impacting practices related to segregation, treatment, and final disposal [81, 82]. Thus, while Germany combines stringent legislation with a consolidated culture to achieve efficiency, both India and Brazil possess robust legal frameworks but face institutional and cultural challenges that limit the full effectiveness of HCW management [76, 83].

5. Conclusions

The analysis showed that there are advantages to having specific state and/or municipal legislation for HCW, provided it is developed to address potential gaps in federal regulations, such as CONAMA Resolution No. 358/2005 and ANVISA RDC No. 222/2018, and is aligned with local realities. Of the 33 rules found, only six did not present points for highlighting in relation to federal laws, reinforcing the importance of local regulation as a means to improve HCW management.

Regulations that establish their own oversight bodies and clear penalties tend to promote more effective control over HCW management. In addition, the implementation of HCWMPs adapted to small generators is seen as positive, as it may facilitate adherence and broaden the reach of waste management policies, favoring more complete mapping of the regional situation. Another noteworthy point is the existence of regulations focused on HCW generated by home care services, an aspect not yet addressed by federal laws. This initiative represents a significant advance, primarily as it promotes the circular economy of waste, particularly regarding medications, and is an essential step toward eventually encompassing other types of HCW.

Another relevant point is that, although eight Brazilian states still lack specific legislation for HCWs, five of their capitals have already implemented their own regulations. Given this reality, the following question arises: could municipal regulation encourage states to develop their own guidelines on the subject?

Finally, the research demonstrates that well-formulated local legislation can yield concrete gains for HCW management by taking local needs into account. However, these initiatives must remain aligned with federal regulations to contribute to a more integrated and efficient system.

Socioeconomic, political, and institutional factors can partially explain the variations identified between state and municipal legislation. Localities with greater financial and administrative capacity tend to develop more detailed regulations, as they have the technical structure and resources for oversight. In addition, local political pressures, such as the action of more engaged environmental agencies or health sector stakeholders, influence the development of regulations. In regions with strong social mobilization or a history of environmental problems related to HCW, there is a greater tendency to adopt restrictive rules. On the other hand, in states with lower institutional capacity or greater dependence on federal guidelines, legislation tends to be more generic, reproducing guidelines already set out in national resolutions. These differences reflect the Brazilian context, where normative autonomy coexists with structural inequalities among federative units.

Thus, it becomes essential that state and municipal legislators understand local realities and identify the gaps to be addressed, transforming them into opportunities for improvement. It is recommended to adopt HCW generation indicators included in the version before ANVISA RDC No. 222/2018, as mentioned earlier, to enable quantitative analyses that support better public policies adjusted to the real scenario. In addition, it is suggested to: establish HCWMPs focused on small generators, ensuring them simplified management tools; implement reverse logistics focused on medications and home care waste, serving as a starting point for the inclusion of other HCW when possible; strengthen local oversight, establishing proportional sanctions aimed at discouraging improper practices; encourage the adoption of less polluting HCW treatment technologies, while aligned with international recommendations; and promote environmental education campaigns and continuous training for health professionals and the population. These measures can make local regulations more effective, contributing to an integrated, sustainable, and efficient HCW management system.

Moreover, future research on HCW management should emphasize the critical role of digital technologies. Integrated platforms that use big data, fuzzy information systems, and artificial intelligence can improve monitoring, optimize decision-making, and support coordination among multiple stakeholders. Similar to recent advances in the assessment of clean energy systems, which have adopted Pythagorean fuzzy approaches for stakeholder coordination [84], and in

partner selection for rural energy internet projects using fuzzy AHP [85], these studies, while focused on energy systems, illustrate the potential of fuzzy-based digital tools for multi-stakeholder coordination, which could be adapted to HCW management. The incorporation of such digital tools into the regulatory and operational context of HCW management can promote more adaptable, transparent, and efficient systems.

5.1 Managerial Implications

The findings suggest that state and municipal legislators should not only identify gaps in federal regulation but also transform them into opportunities for improvement. Practical measures include adopting indicators for healthcare waste generation to support evidence-based policymaking, implementing simplified HCWM plans for small generators, strengthening local enforcement with proportional sanctions, and promoting environmentally safer treatment technologies aligned with international recommendations. These strategies can enhance the effectiveness of regional regulations and foster a more integrated management system.

5.2 Practical and Social Implications

Beyond regulatory adjustments, the study highlights direct benefits for healthcare professionals and the population. Initiatives such as reverse logistics for medicines and home-care waste, environmental education campaigns, and continuous training programs contribute to safer handling practices, reduced infection risks, and increased public awareness. By aligning local regulations with social realities, these actions can promote greater community engagement, advance circular economy practices, and strengthen public health protection.

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Author Contributions

Isadora Muller de Oliveira and Letícia Caroline de Oliveira Vital were responsible for the methodology, data collection, formal analysis, and writing – original draft. Marcos Paulo Gomes Mol contributed to conceptualization and writing – review and editing, as well as supervision. Izabela de Siqueira Reis Regueira contributed to text validation and writing – review and editing.

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Competing Interests

The authors have declared that no competing interests exist.

AI-Assisted Technologies Statement

During the writing process of this article, the authors used artificial intelligence-assisted tools, specifically ChatGPT (OpenAI) and Gemini (Google), solely to enhance the readability and linguistic clarity of the manuscript. These tools were not employed to generate original ideas or to analyze data or results. All intellectual content and scientific contributions are the sole responsibility of the authors, in accordance with the research and publication ethics guidelines established by LIDSEN.

Additional Materials

The following additional materials are uploaded at the page of this paper.

1. Table S1: States.
2. Table S2: Capitals.

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