Necroleachate could be the cemetery's sewage? A panorama from Brazilian legislation

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Article

Necroleachate Could be the Cemetery's Sewage? A Panorama from Brazilian Legislation

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Abstract: Cemeteries can be compared to landfills since their leachate, also known as necroleachate, can be transported and pollute groundwater, surface waters, and soils. In Brazil, the cemeteries management is the responsibility of states and municipalities, to ensure that they do not generate negative environmental impacts and risks to public health. This article aims to discuss Brazilian sanitary-environmental legislation relating to cemetery waste management. Among the Brazilian states, half have sanitary-environmental legislation for cemeteries, and between the municipalities, only 19 have specific legislation. The legislation is broad and has many gaps, leading to environmental vulnerability and risk of contamination for the people who live in the surrounding area.

Keywords: cemetery; waste management; legislation; public health; Brazil

1. Introduction

The word cemetery comes from the Latin *Coemeterium*, which in turn derives from *cinisterium* (*cinos*: sweet and *renor:* mansion), as well as from the Greek *Koumétérion*, which means "I sleep", showing a dormitory or enclosure where the dead are kept or buried [1].

The practice of burying the dead can be done in two ways: inhumation, which consists of burying the body in an open grave 1.5 meters deep and the surface covered with earth and stone, or tombstoning, which consists of burying the corpse in masonry or concrete drawers, with a maximum depth of 5 meters, which will later receive the coffins and finally be sealed [2].

Burial rites have taken place since 100,000 BC, a period in which major epidemics occurred, resulting in countless dead people who, by being buried in unsuitable places, favored the spread of infectious agents [3]. Most historical accounts date back to the Christian era, and it is possible to observe through these the changes in burial practices, especially regarding land use in the urban space and environmental sanitation. However, it is believed that the first spaces with cemetery configurations only appeared after 10,000 years BC [1].

In Europe, in the 17th century, funeral rituals began to change; initially, they were assisted, and the sick were accompanied in their beds until the last moments of their lives. In the 18th and 19th centuries, due to the increase in the number of deaths from the epidemics that ravaged the world, such as the plague and tuberculosis, doctors began to recommend the isolation of corpses and to advocate hygiene and environmental sanitation practices, to protect the living from the evils of death [3]. This concern, along with population growth, led to the transfer of cemeteries, which were in or adjacent to ecclesiastical buildings, to areas on the outskirts of cities [4–6]. In Portugal, for example, a law was passed in 1835 banning burials in churches, and in France, one of the most important and oldest cemeteries in Paris, the Cemetery of the Holy Innocents, was deactivated and the bodies transferred to the Paris municipal ossuary, below the city streets, where it became known as "the catacombs of Paris" [4,7,8]. In 19th-century Brazil, concerns about hygiene issues involving cemeteries arose after the second half of the century with the enactment of the imperial law of October

1, 1828, which established that cemeteries were obligatory outside religious temples and that they had to be created far from urban centers by city councils. After much popular reaction, it only really came into force in 1927, with the renewal of the Code of Canon Law [9].

The concerns of the scientific community about the public health and environmental impacts of cemeteries from the 20th century onwards led the United Nations to release an introductory summary on the subject. This summary explained how the location of cemeteries was chosen without proper planning and methodology, and without analyzing the potential risks to the environment or the local community. It also addressed the impacts of cemetery leachate resulting from the product degradation of bodies and impacts on soil and groundwater and ended with suggestions [10]. In this report, Dent and Knight [11] compare cemeteries to a special type of landfill, where the organic matter is filled in with soil; in this way, they discuss the possibility of cemetery leachate being compared to landfill leachate, as it increases the concentration of organic and inorganic matter and the potential presence of pathogens, making it necessary to analyze its destination.

Cemetery leachate, also known as necroleachate, can be transported by rainwater infiltrating the graves or by the direct contact of bodies with groundwater.

The infiltration capacity of the soil will depend on various intrinsic and extrinsic characteristics of the soil, such as soil composition, hydraulic load, ion exchange capacity, number of burials, depth of the water table, and others [12]. For this reason, it is important to have environmental legislation on cemeteries to minimize the pollution potential of these enterprises, reducing the damage and risks to the environment and public health.

The rules and legislation for setting up and running cemeteries are not consensus around the world; each country has established its own laws to protect and preserve the environment. In many European countries, for example, municipalities are responsible for establishing funeral practices and standards for cemeteries, such as Denmark, where the municipality is the main manager, ensuring public funding for developments [13]. In the United States, private companies mainly manage cemeteries [14]. In Brazil, since the Proclamation of the Republic, the disposal and allocation of corpses have been managed by the town halls of each municipality, respecting religious groups and local particularities. However, it is important to consider that in most countries and Brazil, most cemeteries are old and therefore out of step in terms of technical and environmental studies [15].

The 1988 Federal Constitution, in Art. 30, items V and VIII, established that municipalities are responsible for organizing public services of local interest, promoting territorial planning, and controlling the use and occupation of urban land. Article 225 established the guarantee that everyone has the right to a balanced environment that is a common use of the people and essential to the quality of life; ensuring through paragraph 1, item IV, the existence of legislation for the installation of works or activities that potentially cause environmental degradation [16].

This article aims to discuss Brazilian sanitary-environmental legislation related to cemetery waste management.

2. Materials and Methods

This study used a qualitative and exploratory approach. From this perspective, a documentary review of Brazilian legislation was used to develop the research.

For the selection of federal, state and municipal legal instruments, we used the databases available on the federal government's Legislation Portal (https://www4.planalto.gov.br/legislacao/portal-legis) and the State Laws (https://leisestaduais.com.br/) and Municipal Laws (https://leismunicipais.com.br/) platforms, using the keyword "cemetery" to locate legislation on the proposed topic.

The inclusion criteria adopted were: legal instruments enacted between 1970 and 2022; available in full. The delimitation of the beginning of the research period was justified by the fact that the legislation was enacted after the Proclamation of the Republic, to find as many laws as possible. Bills were excluded as they are not currently being processed or have not been approved.

The search was conducted in July 2023. After this search, the legal instruments were read in full and selected, based on the inclusion and exclusion criteria, and then analyzed.

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3. Results and Discussion

- Environmental legislation for cemeteries

Before the institution of specific environmental legislation for cemeteries established by the National Environment Council (CONAMA) of the Ministry of the Environment, two legal instruments indicated the need for licensing of establishments that used natural resources and could potentially pollute:

- Federal Law No. 6.938 of August 31, 1981, which established the National Environmental Policy aimed at environmental protection. Article 10 states that [17]:

The construction, installation, expansion, and operation of establishments and activities that use environmental resources, are effectively or potentially polluting, or capable, in any way, of causing environmental degradation will depend on prior environmental licensing.

However, this law did not specify cemeteries as establishments that could potentially pollute or cause environmental degradation.

- With the promulgation of the Federal Constitution in 1988, the organization of public services of local interest, for the planning and control of the use and occupation of urban land became the responsibility of the municipalities.

Thus, until 2003, at the federal level, there was no specific legislation or technical standard regulating the implementation and operation of cemeteries in environmental and sanitary terms. Thus, CONAMA's legislation presented cemeteries as polluting sources of the environment and began to demand criteria for their construction and operation, aimed at environmental protection of both soil and groundwater [18], minimizing environmental contamination from cemetery facilities (Table 1).

Table 1. Environmental legislation specific to cemeteries.

Legislation	Date	Article	Menu
CONAMA Resolution 335 [19]	2003		Provides for the environmental licensing of cemeteries and issues involving construction aspects and cemetery regulations
CONAMA Resolution 368 [20]	2006	Art. 1	It deals with the environmental licensing of horizontal and vertical cemeteries, based on the particularities existing in areas of protection of water sources located in metropolitan regions.
		Art. 2	It establishes that cemeteries existing on the date of publication of this Resolution will have a period of up to 2 years to adapt to the rules contained in this Resolution, counting from the date of its publication.
CONAMA Resolution 402 [21]	2008	Art. 1	Amends articles 11 and 12 of Resolution no. º 335. It establishes that state and municipal environmental agencies must establish, by December 2010, criteria for adapting cemeteries that existed in April 2003.

Some of the requirements of CONAMA Resolution 335 are [19]:

horizontal and vertical cemeteries must be submitted to the environmental licensing process;

horizontal cemeteries must have a minimum distance of 1.5 meters from the maximum level of the aquifer and, when this is not possible, burials must be conducted above ground level;

techniques and practices must be adopted to allow gas exchange, providing suitable conditions for the decomposition of bodies;

the bodies buried may be wrapped in blankets or the urns may be made of biodegradable materials, but may not use plastics, paints, varnishes, heavy metals, or other impermeable materials; and

non-human solid waste resulting from the exhumation of bodies must be disposed of in an appropriate environmental and sanitary manner.

In 2006, CONAMA Resolution 368 [20] amended Resolution 335 [19], due to the impossibility of building new cemeteries (or expanding existing ones) in some municipalities in the states of São Paulo, Rio de Janeiro, Minas Gerais and Bahia; installed in areas protected by water sources and on small plots of land, which had been causing overcrowding. This reformulation established [20]:

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a ban on the construction of cemeteries in areas of permanent preservation, in cavernous terrain or with caves nearby, sinkholes, or underground rivers, and in areas where the water table is less than 1.5m from the bases of the graves, to guarantee the non-contamination of these preservation areas and of the water supply sources used for human consumption.

State and municipal bodies are obliged to license and inspect the construction and implementation of new cemeteries.

However, two years after its publication, CONAMA Resolution 368 was updated by Resolution 402 of 2008, which set a new deadline for state and municipal environmental agencies to establish criteria for adapting cemeteries set up before the publication of Resolutions 335 and 368 to the new standards [21]. However, most Brazilian states and municipalities do not have adequate tools for managing cemeteries, using CONAMA resolutions as the main tool for cemetery environmental control.

Table 2 shows the state legal frameworks that were identified and that had some guidelines for cemeteries.

Table 2. State legislation.

State	Legislation	Year	Menu
Acre	Law No. 1117 [22]	1994	Provides for the state's environmental policy
Bahia	Law No. 12.932 [23]	2014	Establishes the state's solid waste policy
Federal District	Law No. 2.424 [24]	1999	Provides for the construction, operation, use, administration, and supervision of cemeteries and the performance of funeral services
Goiás	Law No. 13.583 [25]	2000	Provides for the conservation and environmental protection of groundwater deposits in the state
Maranhão	Law No. 7.587 [26]	2001	Prohibits the installation of projects located on the banks of water sources
Minas Gerais	Law No. 20.017 [27]	2012	Provides for sanitary and environmental conditions for burial in the state
Mato Grosso	Law No. 9.612 [28]	2011	Provides for the administration and conservation of groundwater in the state's domain.
Mato Grosso do Sul	Law No. 1.293 [29]	1992	Provides for the state sanitary code
Pernambuco	Decree-Law No. 268 [30]	1970	Establishes general rules on health promotion, protection, and recovery
Rio de Janeiro	Decree "E" No. 3.707 [31]	1970	Establishes guidelines for the establishment and operation of cemeteries
Rondônia	Law No. 1.878 [32]	2008	Provides for the installation of projects in water source basins
Santa Catarina	Law No. 6320 [33]	1983	Provides for general health standards
	Decree No. 30.570 [34]	1986	Regulates articles 48, 49, and 50 of Law No. 6.320
Tocantins	Law No. 261 [35]	1991	Provides for the state's environmental policy

Of the 26 Brazilian states, 12 and the Federal District have some approach to the health and environmental issue of cemeteries and the rest have no reference to cemeteries in any legal instrument. In addition, only one of the laws found is related to cemeteries, the others deal with the environment, health, and solid waste.

The states of Rio de Janeiro and Pernambuco have the oldest legislation. The Pernambuco Decree-Law established general rules on health promotion, protection, and recovery, and a single paragraph stipulated that all cemeteries should be under the supervision of the state health authority [30]. The Rio de Janeiro Decree was a specific instrument for the establishment and operation of cemeteries. It defined that graves needed to be controlled to prevent the release of gases or odors so as not to contaminate the air, the underground water table, rivers, ditches, canals, and public roads. However, it did not describe what these measures would be. It also determined that the final constructions for burials should be previously approved by the state authority so that they take place in "conditions of public hygiene" [31].

Another state that also has specific legislation for the construction and operation of cemeteries is the Federal District (DF). In a 1999 law, the Federal District established location guidelines, stipulating that cemeteries should be built on high ground facing the water supply to cisterns, that they should be isolated from public places, and that the water table should be at least 2 meters deep.

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It also stipulated that ornamental vases must be prepared so that they do not become repositories of water and do not allow mosquitoes to breed [24].

In 1983 and 1986, the state of Santa Catarina enacted a law on general health regulations, three articles of which address specific criteria for cemeteries. It stipulates that a cemetery can only operate after approval from the health authority, complying with the rules of this regulation regarding the construction project, installation, location, topography and nature of the soil, general hygiene and sanitation conditions, access roads, and urban planning. It established building requirements, such as being in elevated areas, away from water that could feed wells and other sources of supply; isolation from public places or other open areas and distance from the water table at least 2 meters deep. It also stipulated that construction projects must be accompanied by specialized studies proving the suitability of the soil and the water table [33,34].

Five Brazilian states (Acre, Maranhão, Mato Grosso, Rondônia and Tocantins) had a general article in their legal instruments on environmental policy or the administration and conservation of groundwater regarding the installation of cemeteries on the banks of springs that could compromise minimum water quality standards; or which required the approval of health and environmental agencies about the location, construction, installation and operation of cemeteries, crematoria and morgues [22,26,28,32,35]. The law in the state of Rondônia was a little more specific when it came to the location of cemeteries in water catchments. It prohibited their construction, installation, and operation within a radius of 40 meters from the banks of springs, waterholes, and water basins [32]. The state of Mato Grosso, in a legal instrument on the conservation of groundwater, addressed aspects of the transfer of corpses in the state territory and dictated the need for health authorization [28].

In a law on the conservation and environmental protection of groundwater deposits, the state of Goiás established criteria for preventing and monitoring the pollution of groundwater resources in cemeteries. It determined the implementation of water quality monitoring wells, establishing their constituent elements, and determining requirements for the construction and operation of cemeteries, such as environmental licensing, describing the local geology, and determining the direction and direction of groundwater flow. It defined the need for a report to be submitted to the environmental supervisory body, with information on the geological profile of the monitoring wells, as well as their casing, filters and pre-filters; buffer; operating system; and description of the monitoring and sanitary protection system. He also pointed out that, if necessary, the environmental inspection body may require the use of geophysical methods that prove applicable to the prevention of pollution of underground water resources for the storage or disposal of liquid and solid waste [25].

In a law establishing the state's solid waste policy, Bahia classified cemetery waste as solid waste and classified it separately from health service waste [23].

Two states, Mato Grosso do Sul and Minas Gerais, have enacted laws that deal with the burial, cremation, embalming, exhumation, transportation, and display of corpses; in 1992 and 2012 respectively [27,29].

The Mato Grosso do Sul law establishes the state's health code. It stipulates that the deposit and handling of corpses for any purpose, including necropsies, embalming, or any other procedures for the preservation of corpses, can only be conducted in establishments authorized by the Health Department. The cremation of corpses and burial can only take place in cemeteries licensed by the health authorities, who exercise health surveillance over funeral facilities and services. These authorities can order the execution of works for the sanitary improvement of cemeteries, as well as their temporary or definitive banning. It also defined that the transfer and deposit of human remains, or their ashes requires a health permit [29].

The Minas Gerais law deals with sanitary and environmental conditions for burial. It determined the use of techniques and practices in cemeteries that allow gas exchange and prevent the passage of these gases to the place of circulation of people and the leakage of liquids from colliquation, to minimize damage to the environment. It determined a minimum distance for graves of 1.5 meters above the highest level of the water table. It also stipulated that funeral blankets or urns be made of biodegradable materials [27].

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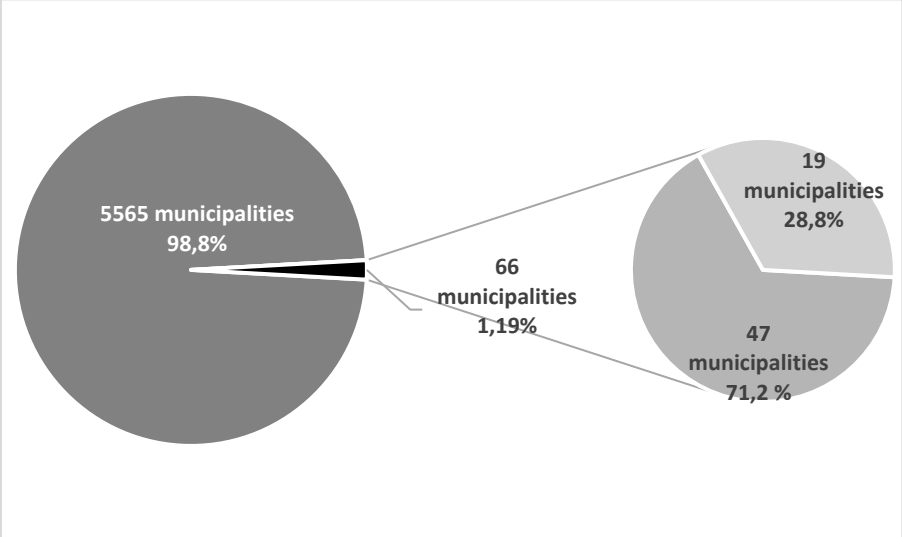
As CONAMA Resolution No. 368 of 2006 established the obligation of state and municipal bodies to license and inspect the construction and implementation of new cemeteries, another search was made to identify the municipal legal framework for cemeteries [20].

According to the 2010 Census, Brazil has 5,565 municipalities, of which only 38 have more than 500,000 inhabitants [36]. It was only possible to retrieve specific legislation on cemeteries from 66 municipalities, or 1.19% of the total. This result is due to the difficulty of accessing the data and the absence of specific legislation (Graph 1).



Graph 1. Number of municipalities with specific legislation on cemeteries.

Of these 66 municipalities, 47 in their legislation do not mention specific articles for health and environmental issues, leaving the legal guidelines to CONAMA resolutions alone; the other 19 municipalities, in addition to following CONAMA resolutions, have legal instruments from the municipal environmental secretariats, where specific articles are described in Table 3.

Table 3. Municipal legislation.

Municipality	State	Legislation	Year	Menu
Sorocaba	São Paulo	Law No. 5.271 [37]	1996	Provides for the operation of cemeteries in the municipality
Diadema		Municipal law No. 3.048 [38]	2010	Provides for the conduct to be observed concerning cemeteries
Praia Grande		Supplementary Law No. 606 [39]	2011	Provides for the installation and operation of cemeteries
Americana		Law No. 5.750 [40]	2015	Regulates the establishment, management, and use of cemeteries in the municipality
São Paulo		Decree No. 59.196 [41]	2020	Regulates funeral, cemetery and cremation services in the municipality, following the provisions of Laws No. 11.083, of September 6, 1991, No. 14.268, of February 6, 2007, and No. 11.479, of January 13, 1994, as well as article 282 of Law No. 16.050, of July 31, 2014, and Laws No. 17.180, of September 25, 2019, and No. 17.582, of July 26, 2021.
Araraquara		Supplementary Law n No. 971 [42]	2022	Provides for the installation, organization, and operation of cemeteries and crematoria
Rio de Janeiro	Rio de Janeiro	Decree No. 39.094 [43]	2014	Establishes the cemetery and funeral regulations, regulating local legislation on cemeteries and the performance of funeral services
Teresópolis		Municipal law No. 4.079 [44]	2021	Provides for the establishment, administration, operation, and use of public and private cemeteries located in the municipality of Teresópolis
Montes Claros	Minas Gerais	Law No. 3.800 [45]	2007	Provides for the construction, operation, use, administration, and supervision of cemeteries and the performance of funeral services
Caratinga		Law No. 3.626 [46]	2017	Provides for the use of the municipal cemetery of Caratinga
Dom Viçoso		Supplementary Law No. 1.149 [47]	2020	Provides for facilities, standards, and procedures to be followed in cemeteries and mortuary chapels
Santa Terezinha de Itaipu	Paraná	Law No. 75 [48]	1984	Provides for cemetery services
Quedas do Iguaçu		Law No. 945 [49]	2013	Provides for cemeteries and funeral services
São Francisco de Paula	Rio Grande do Sul	Law No. 2.757 [50]	2011	Consolidates legislation regulates activities, use, and provision of cemetery and funeral services, and repeals laws
São Borja		Law No. 5.810 [51]	2021	Provides for the regulation of funeral, cemetery, and cremation services
		Decree No. 19.353 [52]	2022	Regulates provisions of Law No. 5.810, of November 10, 2021
Cuiabá	Mato Grosso	Law No. 2.339 [53]	1985	Regulates the creation, construction, and operation of public and private cemeteries
Colíder		Law No.167 [54]	1990	Regulates the creation, construction, and operation of public and private cemeteries
Planalto da Serra		Law No. 558 [55]	2020	Provides for the regulation and regularization of municipal and private-public cemeteries
Rio Branco	Acre	Law No. 1.809 [56]	2010	Regulates and establishes rules for the provision of cemetery and funeral services

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All the municipal laws identified point to issues related to the possible contamination of water and groundwater by decomposing bodies. The laws of Sorocaba (SP), Araraquara (PR), Caratinga (MG), Dom Viçoso (MG), Planalto da Serra (MT), and Rio Branco (AC) also detail the need to adopt necessary and sufficient measures to avoid such contamination, such as the application of technical studies, characterization of the area where the cemetery will be located (location, topographic survey, aquifer level study, mechanical drilling to characterize the soil), plan for implementing and operating the project, environmental licensing, groundwater monitoring and a neighborhood impact study [37,42,46,47,55,56].

To prevent these problems from occurring, the laws of the municipalities of Sorocaba, Diadema, Praia Grande and Americana (SP); Santa Terezinha de Itaipu, Quedas do Iguaçu (PR); Planalto da Serra (MT) and Rio Branco (AC) stipulate that cemeteries cannot be built above reservoirs, water supply systems or springs. These reservoirs must be at least 2 meters away from the deepest point used for the grave [37–40,48,49,55,56]. The Praia Grande (SP) law also points out that if the above specifications are not possible, the groundwater level should be lowered through drainage and if drainage is not possible, the thickness of the chamber that makes up the pit should be increased by raising the surface of the land through earthworks [39]. The laws of Sorocaba (SP), Caratinga (MG), and Planalto da Serra (MT) also oblige cemetery grounds to be sufficiently elevated to prevent the possibility of graves flooding [37,46,55].

The laws of the municipalities of Montes Claros (MG), Cuiabá, and Colíder (MT) point out that so-called "shallow graves" can be used if they have a minimum depth of 1.55m in a flat section of the cemetery [45,53,54]. In addition, the laws of Rio de Janeiro and Teresópolis (RJ), along with those of Cuiabá and Colíder (MT) point out that burials in traditional cemeteries in drawers, consoles, or shelves, below or above ground level, will only be allowed when done in "satisfactory conditions of public hygiene" [43,44,53,54].

- Waste generated in cemeteries

Cemeteries are establishments that can generate waste from the construction and maintenance of graves, dry and green waste from floral arrangements and the like, wood waste from skiffs; waste from the decomposition of bodies (bones and others), and those from the exhumation process. Due to its characteristics, the management of cemetery waste is important, since its improper management can result in environmental and public health impacts, due to the possibility of spreading pathogenic biological agents, affecting the health and quality of life of several people, from those who work in these places to those who live around these establishments [5,57–62].

In 2010, Federal Law No. 12.305 was enacted, establishing the National Solid Waste Policy and laying down guidelines for the management of solid waste in Brazil, including the dangers and responsibilities of generators [63].

According to the National Solid Waste Policy, solid waste is defined as:

discarded material, substance, object, or good resulting from human activities in society, the final disposal of which is proposed to be carried out or is obliged to be carried out, in solid or semi-solid form, as well as gases contained in containers and liquids whose particular characteristics make it impracticable to discharge them into the public sewage system or bodies of water, or require solutions that are technically or economically unfeasible given the best available technology (Article 3) [63].

Article 13 of this policy classifies solid waste as hazardous and non-hazardous and uses the Brazilian Standard (NBR) No 10.004 of 2004, from the Brazilian Association of Technical Standards (ABNT) as a reference. It classifies hazardous waste as that which, due to its characteristics of flammability, corrosivity, reactivity, toxicity, pathogenicity, carcinogenicity, teratogenicity, and mutagenicity, presents a significant risk to public health or environmental quality. And non-hazardous waste is waste not classified as household waste, which originates from domestic activities in urban residences [64].

This same article also classifies solid waste according to its origin and establishes that household waste and urban cleaning waste, originating from sweeping and cleaning public places and roads and other urban cleaning services, should be classified as solid urban waste [64]. However, this policy

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does not specify what hazardous and non-hazardous waste is, nor does it include cemetery waste in solid urban waste.

However, in 2004 the ABNT already dealt with this issue and defined solid waste as any solid or semi-solid waste resulting from "industrial, domestic, hospital, commercial, agricultural, service and sweeping activities". It also included sludge from water treatment systems, sludge generated in pollution control equipment and installations, as well as certain liquids whose particularities make it unfeasible to discharge them into the public sewage system or bodies of water or require solutions that are technically and economically unfeasible given the best available technology. Next, a classification of waste was established, based on hazardousness, characterized according to the physical, chemical, or infectious properties present, which can pose risks to public health, generating deaths and/or incidences of disease, and risks to the environment when the waste is managed improperly. There are two types of waste: class I (hazardous) and class II (non-hazardous). Class I waste is the type covered by Law No. 12.305 of 2010 [63]. Class II or non-hazardous waste is waste that is not classified as household waste and originates from domestic activities in urban residences [64].

In this equation, solid cemetery waste can be classified as class II waste, i.e., non-hazardous, which makes it economically viable to manage its disposal due to the possibility of environmental reuse; but also as class I waste, hazardous.

Class II cemetery solid waste can be assimilated into construction waste and municipal solid waste, as it contains waste resulting from the construction, renovation, repair and demolition of civil works in cemeteries and burial grounds, as well as waste resulting from the preparation and excavation of grave plots; and also recyclable materials, such as plastic from artificial flowers, vases; fabrics and those from sweeping and tree pruning, leaves and natural flowers, generated in urban cleaning activities [65,66]. However, according to the pathogenicity criterion, where waste is characterized as containing or suspected of containing biological agents, recombinant DNA or RNA, genetically modified organisms, or toxins capable of producing diseases in humans, animals, or plants, cemetery waste can also be classified as belonging to class I, depending on the type.

In 2004, the National Health Surveillance Agency (Anvisa) established health legislation, Collegiate Board Resolution (RDC) n^0 306 [67], on health service waste, which was updated in 2018 by RDC n^0 222 [68]. It should be noted that in 2005 the publication of CONAMA Resolution n^0 358 used the same technical criteria but addressed environmental aspects [69].

According to these laws, cemetery waste is classified as health service waste.

Health services are all those whose activities are related to human or animal health care, including home care services; (...) morgues, funeral homes, and services where embalming activities are conducted (thanatopraxia and somatoconservation); forensic medicine services; (...)" [67–69].

This waste can be classified into 5 groups [68]:

Group A: may contain possible contamination from biological agents (leftover laboratory samples, human body parts, etc.). Group A is subdivided into:

A1: cultures and stocks of microorganisms; disposal of vaccines of live or attenuated microorganisms; waste from genetic manipulation laboratories; waste resulting from the health care of individuals or animals, with suspected or certain biological contamination by risk class 4 agents, microorganisms with epidemiological relevance and risk of dissemination or causing an emerging disease that becomes epidemiologically important or whose transmission mechanism is unknown; transfusion bags; leftover laboratory samples containing blood or body fluid.

A2: carcasses or any bodily waste from animals subjected to experimental processes.

A3: anatomical parts of the human being; the product of fertilization without vital signs.

A4: arterial line kits when discarded; air filters and gases aspirated from contaminated areas, leftover samples from laboratories and containers containing feces, urine, and secretions; bodily waste (adipose tissue) from plastic surgeries; waste from health care that does not contain blood; anatomical parts and other waste from surgeries; carcasses or any bodily waste from animals that have not been subjected to experimental processes.

A5: organs, tissues, organic fluids, sharp or scarifying materials, and other materials resulting from the health care of individuals or animals, with suspected or certain contamination with prions.

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Group B: waste containing chemical products that are dangerous to public health or the environment, depending on their characteristics of flammability, corrosiveness, reactivity, toxicity, carcinogenicity, teratogenicity, mutagenicity, and quantity.

Group C: waste that contains radionuclides higher than those determined by the standards of the National Nuclear Energy Commission and for which reuse is inappropriate or not foreseen.

Group D: waste that does not present a biological, chemical, or radiological risk to health or the environment and can be assimilated into household waste.

Group E: sharp or scarifying waste (needles, glass ampoules, etc.).

Based on this classification, the main waste found in cemeteries is described in Table 4.

Table 4. Solid waste from cemeteries.

Waste classification	Waste
Group A	waste from the exhumation of bodies and the cleaning of graves, both the product of dry settling and other materials that come into contact with it (decaying wood, bags, blankets, quilts and coffin lining materials, bones, jewelry, leftover clothing, protective equipment used such as gloves, etc).
Group B	cans of paint and/or varnish and other flammable waste; fluorescent lamps, batteries
Group D	natural flowers, wreaths, arrangements, ornamental objects, plastic vases; landscaping waste, sweeping and tree pruning, plastic cups, paper, packaging, plastic, candle wax, and construction debris (bricks, ceramic blocks, concrete in general, mortar, stone, wood, soil, rocks, glass, plastic, pipes, electrical wiring, etc.).
Group E	glass vases, ceramic images, and metal objects.

Cemetery waste can fall into Group D waste, which poses a lower risk to the environment, or even into Groups A and B, where it poses a higher risk due to the presence of biological and chemical agents that are contaminating and harmful to the environment if not treated correctly, whether they are liquids or solid waste [70].

Only 1 piece of state legislation has addressed the issue of cemetery waste, Law No. 12.932 of 2014, from the state of Bahia; where it subdivides cemetery waste into human (derived from cadaveric exhumation) and non-human (derived from the periodic cleaning and maintenance of cemeteries) [23].

Among the municipal laws, that of the municipality of Planalto da Serra (MT) only states that the solid, non-human waste resulting from the exhumation of bodies must be disposed of in an appropriate environmental and sanitary manner [55].

Necroleachate

Necroleachate is a colored sludge that doesn't adhere to bones; it has a strong unpleasant smell; it results from the process of decomposition of bodies and is usually formed three weeks after death but can last for months. A decomposing human body weighing between 70 kg and 80 kg can release around 30 liters of necroleachate. This percolate is made up of water, mineral salts, and degradable organic substances along with pathogens. It is a liquid with mineral loads that are released and by-products such as carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), ammonium (NH4), and nitrate (NO3), as well as biogenic amines such as putrescine and cadaverine, which have a high pathogenic load. It is also known that, in addition to pure and simple decomposition, there may be other components in the process that come from corpses, such as radiological, chemotherapeutic, and embalming elements (e.g., arsenic, formaldehyde, and methanol), make-up (e.g., cosmetics, pigments, and compounds), which can be used to make up the body [58,62,71–77]. There are some microorganisms associated with the decomposition of bodies that can cause diseases, such as tetanus (*Clostridium tetani),* gas gangrene (*C. perfringens*), toxic contamination of food (*E. coli*), *tuberculosis (Mycobacterium tuberculosis),* paratyphoid fever (*Salmonella paratyphi),* bacterial *dysentery (Shigella dysenteriae)* and cholera (*V. cholerae*) [73]. In this way, necroleachate alters the physicochemical and biological characteristics of soil and groundwater in places where there is no system for collecting and treating this liquid [74,76] and for this reason, cemeteries represent a source of health and environmental liability [57,58,72,78,79].

In addition, cemeteries have historically been in areas where the geoecological, hydrological, and geotechnical conditions are inadequate from a legal point of view, increasing the socio-environmental health vulnerability of the areas where they are located [80–82].

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It is important to note that in addition to the necroleachate from the decomposition of the bodies, there are by-products from the decomposition of the coffins and their props, the fabrics used to dress the body, and the coffin bed. The fabrics used are made from materials that are difficult to degrade and are treated with chemical binders. The wood used for coffins is usually treated with preservatives such as polyvinyl chloride, creosote, or insecticides, as well as varnishes and sealants which, when they degrade, release harmful toxic substances [62,74,76,83,84]. Several authors point to the presence of heavy metals in these leached contaminants, which puts the population living in the vicinity of a cemetery at risk. High levels of metallic elements in the bloodstream can cause damage, such as Cu, which causes problems in the human neurological system; Zn: ingestion can cause liver disease; Fe: can cause corrosion in the gastrointestinal tract and cirrhosis of the liver); Pb: is a potent neurotoxin and can cause problems in the central nervous system; Cr: can generate lung cancer in humans; Cd: excess can cause osteoporosis; Ni: has been classified as a human carcinogen [12,62,73,85–89]. For this reason, necroleachate is classified by ABNT/2004 as class I hazardous waste and is health service waste. It is essential to establish criteria and requirements for the proper construction and maintenance of cemeteries since necroleachate cannot be discharged into the public sewage system or bodies of water without prior treatment [64].

Of the 13 Brazilian states that address the possibility of contamination of the water table by necroleachate, 10 discuss aspects related to the construction of graves concerning the location of the water table (AC, DF, GO, MA, MG, MT, RJ, RO, SC e TO) [22,24–28,31–35]. The states of SC, DF, and MG point out the need for graves to be a minimum distance from the water table. DF and SC indicate 2 meters [24,33,34], while MG determines 1.5 meters [27]. GO is the only state that has addressed issues related to the system for monitoring pollution of groundwater resources [25].

Point sources of contamination, such as cemeteries, usually produce defined and concentrated plumes of contamination, which makes them easier to identify [73].

Contamination consists of the introduction of substances that cause harmful alterations to the use of the aquatic environment, thus characterizing the occurrence of pollution. The most important contaminants are organic matter, pathogenic organisms, organosynthetic compounds, and heavy metals [90].

Because it is denser than water, necroleachate has excellent mobility and dispersion, crossing the aquifer up to its impermeable layer, and being partly carried in the direction of the underground flow, contaminating the entire region. The severity of groundwater contamination depends partly on the characteristics of the waste or leachate, i.e., its volume, composition, concentration of the various constituents, rate of contaminant release time, size of the area from which the contaminants are derived, and the density of the leachate, among others. The mechanisms for dispersing and slowing down the migration of chemical and microbiological contaminants in the soil cover and rock environment also depend on factors such as the local climate and geology, the type of soil, its hydraulic conductivity, and its cation exchange capacity; the depth of the water table and the flow patterns of its waters; and the nature of the contaminating agents. In addition, the chemical reactions that occur such as chemical precipitation, chemical, radioactive, and biological degradation, volatilization, biological consumption, and adsorption can interfere with infiltration to deeper soil zones, preventing or degrading contaminants [12,91].

The water affected by necroleachate is microbiologically contaminated with heterotrophic bacteria, proteolytic bacteria, sulfite-reducing clostridia, enteroviruses, and adenoviruses. There is also a large consumption of oxygen due to biological decomposition and chemical transformations, of products containing nitrogen, phosphorus, and sulfur, among others. Graves cause an increase in the number of mineral salts, increasing the electrical conductivity of these waters [92]. The analysis of these contamination parameters will guide the possible alteration or contamination of groundwater by necroleachate. In addition to these, there are bioindicators such as *Streptococci*, *Salmonella*, total *coliforms*, *E. coli*, sulfite-reducing clostridia such as *Clostridium perfringens*, as well as *Pseudomonas aeruginosa* and proteolytic bacteria. Of these, *Clostridium spp*, *Streptococcus*, and enterobacteria are colonizers of human corpses [10,58,73,93,94], and can be important indicators of necroleachate.

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Another important aspect of guaranteeing health and environmental control concerns the requirement for infrastructure to drain necroleachate. This is a subject that is rarely addressed in legislation. Depending on the region, high levels of rainfall and lack of maintenance increase the spread of necroleachate [61]. This effect could be avoided with adequate drainage conditions, thus reducing the runoff of necroleachate [95]. The only two municipal laws that address this issue are those of São Francisco de Paula (RS) and Sorocaba (SP). The former stipulates that all graves or overlapping drawers must have an individual drainage system and describes specifications for the installation of PVC pipes, or similar, with a diameter of 40mm, leading from the grave to a drainage box with dimensions of 40cm long, 40cm wide and 40cm deep and filled with gravel. Legislation in Sorocaba (SP), on the other hand, requires the installation of drainage system pipes with a minimum diameter of 50mm and a septic tank to receive the liquid waste from decomposition and the washing water from the drainage system.

Some of the municipal laws indicate the type of material that should be used in the manufacture of urns and coffins so that there is no contamination of the soil and groundwater when they decompose. The municipalities of Sorocaba (SP), Teresópolis (RJ), Montes Claros (MG), São Borja (RS), Planalto da Serra (MT) and Rio Branco (AC) have indications prohibiting the use of metal coffins or wooden coffins covered internally or externally with metal, except in cases of embalming, exhumation, and autopsied corpses. Autopsied corpses, limbs, or viscera must be deposited in zinc or tinplate coffins. In addition, they determine that inhumed corpses must be wrapped in necroleachate-absorbing wrappings and funeral urns must be made of biodegradable materials and hermetically sealed. Inside these urns, decomposition-accelerating materials or purification filters must be present, along with devices that prevent the effects of gas pressure inside [37,44,45,51,52,55,56].

The possibility of air contamination can occur through the combined action of autolysis and putrefaction of the bodies, leading to drastic physical and chemical changes. Macromolecules are degraded, resulting in the emission of hundreds of different volatile organic compounds (VOCs), such as dimethyl sulfide, dimethyl disulfide, toluene, hexane, and dimethyl trisulfide [96,97]. Studies have emphasized the influence of several factors on the release of volatile compounds from corpses, including environmental conditions (temperature, humidity, air currents), soil types, the presence of scavenging insects, and stages of decomposition [98]. In addition to pollution, cadaveric odor plays a key role in attracting scavenging insects and other vertebrate scavengers [99]. Houseflies (*Musca domestica*), like many other species of necrophagous insects, are considered worldwide pests. In addition to being irritants, they are also vectors that can transmit numerous human and animal diseases caused by many antibiotic-resistant zoonotic pathogens [100,101].

Odor and air quality impacts can reach several hundred meters downwind and result in inflammatory and immunological effects or irritation to the eyes, nose, or throat [102,103]. The release of bioaerosols, particulates, or volatile organic compounds and the possible harmful or health effects have not been widely assessed and may be an area for further study [104].

The laws of the municipalities of Sorocaba, São Paulo (SP); Rio de Janeiro, Teresópolis (RJ); Dom Viçoso (MG); São Borja (RS); Cuiabá and Colíder (MT) state that graves must be in such a way that there is no release of putrid gases or odors that could pollute or contaminate the air, and the use of impermeable material that prevents the gaseous exchange of the buried body with its surroundings is prohibited [37,41,43,44,47,51–54].

4. Final Considerations

In Brazil, there is no control over the construction of cemeteries, which is aggravated by the lack of monitoring by the different spheres of the competent public authorities, who push the problem onto each other. As an increase in the controversial discussion on the subject, it is believed that the problem lies not only in the activity itself but also in the mistaken and careless choice of areas for cemeteries. Many of them are environmentally vulnerable, which entails a risk of contamination for the soil, groundwater, and the people who live around them. However, the literature on the subject is limited.

Groundwater contamination is a major global concern. In developing countries, groundwater is subject to contamination due to poor sanitation associated with high population growth rates. In rural areas of developed countries, groundwater contamination is attributed to fertilization, the use of pesticides and herbicides, and inadequate irrigation habits from the point of view of the amounts of groundwater pumping and quantities of water used for irrigation. In urban areas of developed countries, groundwater contamination is attributed to a variety of species (chemical pollutants and microorganisms), coming from urban development and domestic and industrial waste.

Brazil has legislation on water quality, which sets out the microbiological standards for drinking water and bathing water: Ordinance n 2.914/2011, of the Ministry of Health, and Conama Resolutions n 357/2005 and 396/2008) [105–107]. The presence of *C. perfringens* is not a parameter considered in this legal framework, which poses a potential risk to water users in the area near cemeteries. This demonstrates the need to include specific parameters for the analysis of water samples for human consumption in environmentally vulnerable areas such as cemeteries.

The results of this study show that Brazilian state legislation, as well as federal legislation, has many gaps. On the one hand, bodies buried in cemeteries can lead to contamination of soils and surface and underground water, and require care and control, both environmental and sanitary; and perhaps because it borders on these two areas, the legislation is not specific. The criteria needed to manage cemeteries are sometimes covered by environmental legislation, to control, prevent, and monitor pollution of water resources, and sometimes by health legislation. However, most of these laws are too broad. It was hoped that the states would present a more detailed legal framework than the national one, since there are regional aspects that should be considered when designing cemetery projects, such as hydrogeological issues, for example. But this is not what can be seen in this analysis.

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