Cemeteries and the Environment: Analysis of a vertical cemetery in the Metropolitan Region of São Paulo

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ABSTRACT

Due to the growing concern about the impacts caused by cemeteries, this study aims to present and analyze the characteristics of vertical cemeteries, through a case study conducted in a vertical cemetery located in the Metropolitan Region of São Paulo (MRSP). Information about the project was collected through a questionnaire conducted with the operations supervisor. The project was built in a Permanent Preservation Area. Since the cemetery was implemented prior to CONAMA Resolution 335 of 2003, it was exempted from the installation license. It is found that all by-products generated in the processes of human body decomposition are treated, not generating impacts on air, water, and soil; the waste generated in daily activities also receives proper disposal. It is noted that, despite the need for adjustments regarding space occupation, such as the restoration of riparian vegetation, the vertical cemetery presents itself as an excellent alternative to reduce the spaces allocated to graves, making much better use of the location, besides solving the problem of overcrowding in necropolises, it also generates fewer impacts on the environment, as the corpses are placed in drawers and thus do not come into contact with the soil, and there is no risk of the main contaminant, necrochorume, contaminating the soil and groundwater.

Keywords: Environmental impacts, Necrochorume contamination, Sustainability in cemeteries, Urban environmental planning.

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INTRODUCTION

The word cemetery, from the Greek koimetérion, "dormitory", from the Latin coemeteriu, meant the place where one sleeps. This meaning is explained by Greek mythology, according to which sleeping (losing knowledge or consciousness) is something decided by Hypnous, the Greek god of sleep who does not have the power to awaken. Hypno, according to the Greeks, was the twin brother of Thanatos, the god of death (Pacheco, 2012).

The interest in cemeteries is very old because they attract our attention by virtue of their symbolic relationship with death. It is not uncommon to see this fact in museums,

where quality pieces on display do not arouse the same interest of the visitor as the reconstruction of a grave or even the presentation of a mummy or a skull (Pacheco, 2012).

Cemeteries can be classified according to the form of burial and the type of construction, as follows:

i) Traditional cemeteries: these spaces are made up of semi-buried tombs, where the body is buried directly in the ground, which can generate environmental impacts on soil and water; In addition, the strong aesthetic appeal generates a high cost in the maintenance and construction of these buildings (Kemerich, *et al.,* 2014).

(ii) Park or garden cemeteries: these are cemeteries made up of drawers in the ground covered by lawns or trees, without buildings; burials are carried out by tomb and graves are identified by a small tombstone at ground level (Campos, 2007).

(iii) Vertical cemeteries: This typology consists of buildings with one or more floors, where the bodies are placed in tombs 2 that are aerial locules 3 and, therefore, without direct contact with the earth. These locules are constructed of reinforced concrete or other material such as fiberglass, arranged in columns and rows, similar to a bookcase. it avoids the contact of the deposits with the soil, in order to hinder the environmental contamination of the soil and the water table by the product of decomposition (Rocha; Assisi; Cortizo, 2017).

According to Saraiva (2011), the buried human body is subject to processes of degradation of matter, soon after death the bodies decompose, going through phases of tissue destruction by the action of bacteria and enzymes, resulting in their transformation into gases, liquids and salts.

According to Galli (2014) *apud* Carvalho (2019), the stages of decomposition of the corpse can be segregated into 4 stages: staining period, gaseous period, coliquative period, and skeletonization period (Chart 01).

Table 01 – Stages of the decomposition of the human body, second period and characteristic.

PERIOD	CHARACTERISTICS
Coloring Period	It usually starts from 18 to 24 hours after death and lasts approximately 10 days, a period that may be altered by weather conditions. It begins with a green spot in the abdomen, the color is justified by the presence of sulfomethaemoglobin (Galli, 2014 *apud* Campos, 2019).
Gaseous Period	It starts in the first week and lasts for approximately 30 days. The gases produced by putrefaction infiltrate the muscle tissue and modify the external shape of the body and the physiognomy (Galli, 2014 *apud* Campos, 2019).
Coliquative Period	It is the period of tissue reduction that begins at the end of the first month and can last 2 or 3 years. In this phase, disintegration occurs (Galli, 2014 *apud* Campos, 2019). and softening of the tissues, converting into a mass, semi-liquid, strong odor and dark, known as putrilage.
Skeletonization Period	At the end of the coliquative period, the putrilage dries up and becomes a powder, leaving the skeleton exposed, then the skeletonization period begins. The discovered bone skeleton can be preserved for a long time (Galli, 2014 *apud* Campos, 2019).

Source: Modified from Carvalho, 2019.

In the process of decomposition of the corpse, the necroleachate is released, according to Campos (2007), the necroleachate is a solution rich in mineral salts and degradable substances, aqueous, which is the result of the process of decomposition of bodies buried in cemeteries, as stated by Franco (2005). Its constitution is 60% water, 30% mineral salts and 10% organic substances, two of which are highly toxic to cadaverine and putrescine, which can also contain pathogenic microorganisms (Pacheco, 2012).

According to Pacheco and Matos (2005), cemeteries can be a source of environmental impacts. The inadequate location and operations of necropolises in urban areas can cause the contamination of water sources by microorganisms that proliferate in the process of decomposition of bodies. If the groundwater aquifer is contaminated in the internal area of the cemetery, this contamination can flow to nearby regions, increasing the risk of contamination of the water that will be captured through shallow wells, for example.

In this context, CONAMA Resolution No. 335/2003 (Brasil, 2003) provides for the environmental licensing of horizontal and vertical cemeteries, so that

establishes appropriate procedures and documentation for the licensing of these projects in a specific manner, covering several issues, such as: technical location with indication of accesses and road system (article 3, I, a); technical studies on groundwater levels (Article 3(I)(c)); studies of fauna, flora (Article 5, VI); minimal setbacks in burial areas in horizontal cemeteries (Article 5, IV); adoption of techniques that enable gas exchange for adequate decomposition of bodies in horizontal cemeteries (Article 5, III); environmentally appropriate treatment for any gaseous effluents in vertical cemeteries, etc.

CONAMA Resolution No. 368 of 2006 also provides for prohibitions on the installation of cemeteries in Permanent Preservation Areas (PPAs) or in other areas that require deforestation of primary and secondary Atlantic Forest:

> (...) in a medium or advanced stage of regeneration, in predominantly karst terrains, which have caves, sinkholes or underground rivers, as well as in those whose use is restricted by current legislation, except for the legal exceptions provided for (Brasil, 2006).

Subsequently, CONAMA Resolution No. 368, of March 28, 2006, modified, in Resolution No. 335/2003, the article that prohibited the construction of cemeteries in areas of water source for human supply, in order to allow the municipalities inserted in these areas, and without space for the implementation of new cemeteries, to build their new Necropolises there. These must meet items to ensure that there will be no contamination of the preservation area (Pacheco, 2012).

In order to mitigate environmental impacts, vertical cemeteries appear as a promising option since there is control of the by-products generated in the decomposition of the human body.

Thus, this research aims to present and analyze the characteristics of vertical cemeteries, through a case study in a vertical cemetery located in the Metropolitan Region of São Paulo (RMSP), in which the techniques used and the identification of compliance with the current legislation are pointed out.

METHODOLOGY

For the development of the research, fieldwork was carried out in a cemetery unit. In order to preserve the identity of the enterprise, the cemetery was named with a fictitious name "Alpha".

CHARACTERIZATION OF THE STUDY AREA

Alpha Cemetery is a private enterprise and is located in the Metropolitan Region of São Paulo (RMSP); Construction began in 1997 and was completed in 1998. The cemetery has a total area of 14,776 m², and 4,342 m² of built area and approved by the Fire Department Inspection Report (AVCB). According to the manager, the project has 5 floors and has 3,800 tombs, of which 176 are intended for the remains and currently the estimated occupancy is 2,900. There are 19 employees working on site.

Regarding prices, a locule in this vertical cemetery can cost from six to nine thousand reais.

Part of the project area is part of a Permanent Preservation Area (next to the watercourse); around there is the presence of irregular occupations and the region has shops and residences, being a mixed zone according to the Municipal Master Plan (Guarulhos, 2019).

TECHNICAL AND OPERATIONAL PROCEDURES

The characterization and location of the area was carried out with the help of the geospatial data system made available by the city of Guarulhos – GuaruGEO (Guarulhos, 2024), the platform allowed the download of cartographic bases as well as the characterization of land use and occupation and urban zoning.

The cartographic bases obtained from GuaruGeo (2024) and *Google Maps* (Google, 2024) were processed with the aid of the QGis software (QGis, 2024), generating a location map of the area.

In order to identify the burial and handling practices employed in the enterprise, on-site visits and interviews with the operations supervisor were conducted.

The questionnaire used (Chart 02) was structured according to CONAMA Resolution 335/2003 (Brasil, 2003). The answers were documented using handwritten notes.

Table 02 – Environmental questionnaire applied to the vertical cemetery.

No.	QUESTIONS
1	Which year of Inauguration?
2	What is the area of the development and the area occupied?
3	How many employees work in the venture?
4	Is the operating license up to date?
5	Is there any kind of environmental compensation?
6	Is there a need for waterproofing of the tomb? If so, how is it carried out?
7	What method or destination is used for the disposal of common solid waste?
8	What method or destination is used for the disposal of Liquid Waste (necroleachate)? Is it collected and treated inside or outside the cemetery?
9	Is there gas collection and treatment? How is it carried out?
10	After exhumation, are the bones cremated or do they go to the ossuary?

Source: Prepared by the authors.

The answers obtained through the interview are presented in the form of discursive text in the results and discussion section.

RESULTS AND DISCUSSION

The Alpha project is privately owned and located in an area of high population density in the Metropolitan Region of São Paulo (Figure 01). It appears that the project was exempt from the installation license and the operating license is in the process of being regularized.

Parts of its facilities are part of a Permanent Preservation Area (APP) of a 1st order stream according to Strahler's hierarchical fluvial classification, a factor that indicates that this channel does not have any tributaries. It should be noted that according to Article 3 II of Federal Law 12.651/12 (Brasil, 20212), the Permanent Preservation Area is a protected area, covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability and biodiversity, facilitating the gene flow of fauna and flora, protecting the soil and ensuring the well-being of human populations. It is still possible to observe the presence of green area in the surroundings of the development, as well as signs of degradation and a very urbanized environment.

Figure 01 – Delimitation of the study area and its immediate surroundings.

Source: Prepared by the authors.

It should be noted that the areas that include the parking lot, the bathroom of the wake room and a wall of the cemetery are in the PPA area, as shown in Figure 02. It should be noted that the parking floor is interlocked, a factor that allows greater infiltration of rainwater; according to studies carried out by Benittez (2021) in which the infiltration capacity of pavements with interlocking floors in parking lots was analyzed, medium and low permeability degrees were identified, which can be compared to natural materials such as gravel sand, clean sand and fine sand, sand, dirty sand and sandy silt, presenting itself as an effective measure with regard to rainwater infiltration, contributing to less surface runoff and reduction of flooding intensity.

The entrance to the development has flowerbeds with permeable and landscaped areas and the parking lot, followed by the building with 5 floors, where the burials take place (Figure 03).

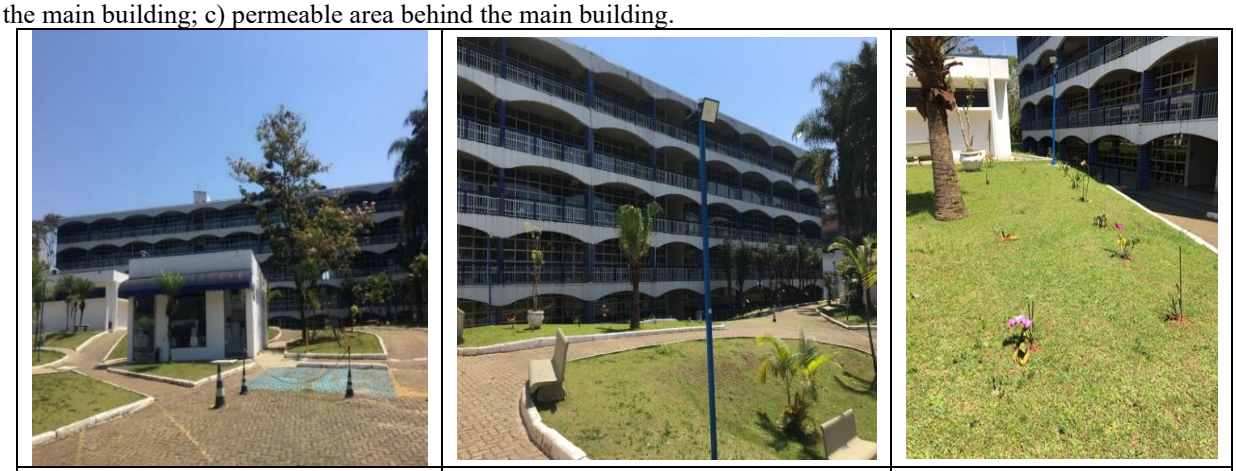
As for the burial, as it is a vertical cemetery, the grave is not in contact with the soil and does not harm the environment, so the necroleachate does not present a risk of crossing into the lower layers of the soil and subsoil and causing contamination. This type of burial is not very common, by way of comparison in the city of São Paulo, there are 22 traditional cemeteries and 4 vertical cemeteries. It is noted that vertical cemeteries present a new concept on the subject.

Figure 02 – Partial view of the parking lot of the Alpha development in the vicinity of the APP. a) emphasis on the end of the parking lot near the watercourse; b) highlight the other points of the parking area.

(a) (b)

Source: Prepared by the authors.

Figure 03 – Partial view of the entrance to the Alpha project. a) view of the entrance and parking guardhouse; and b) view of the main building; c) permeable area behind the main building.



(a) (b) (c)

Source: Prepared by the authors.

In the Alpha project, burials are carried out in drawers/vaults, associated with the building, which has a ground floor and four upper floors (Figure 04).

Figure 04 – View of the building of the Alpha development where the burials take place: a) Tombs – highlighted in red a unit, and b) general view of the 4 floors.

(a)

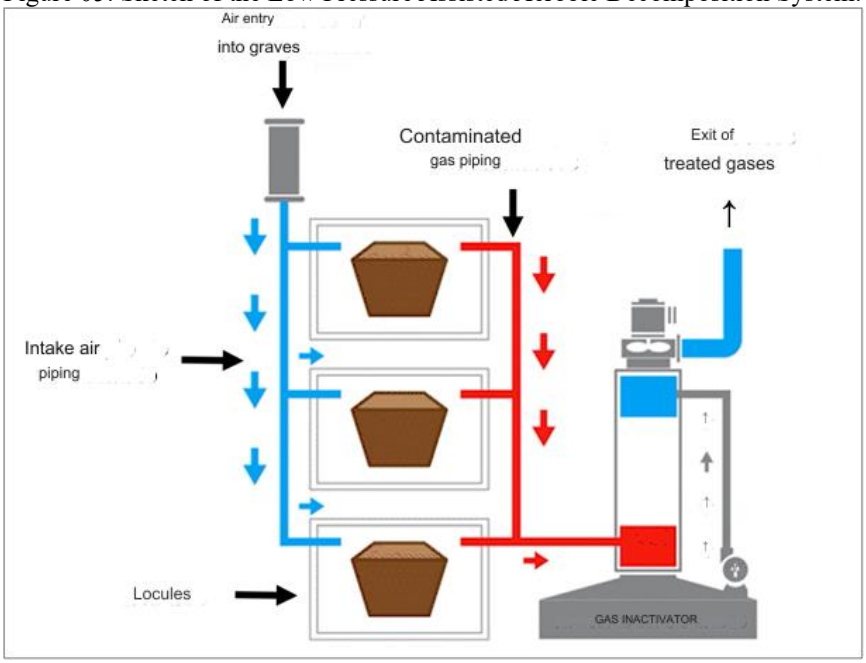
(b)

Source: Prepared by the authors.

The pollutants generated in cemeteries are associated with the anaerobic decomposition of matter, which results in gases and liquids (necroleachate). For the Alpha project, the technology employed presents a process based on the dehydration and evaporation of the necroleachate as soon as it is generated, obtaining a natural body decomposition system, predominantly aerobic.

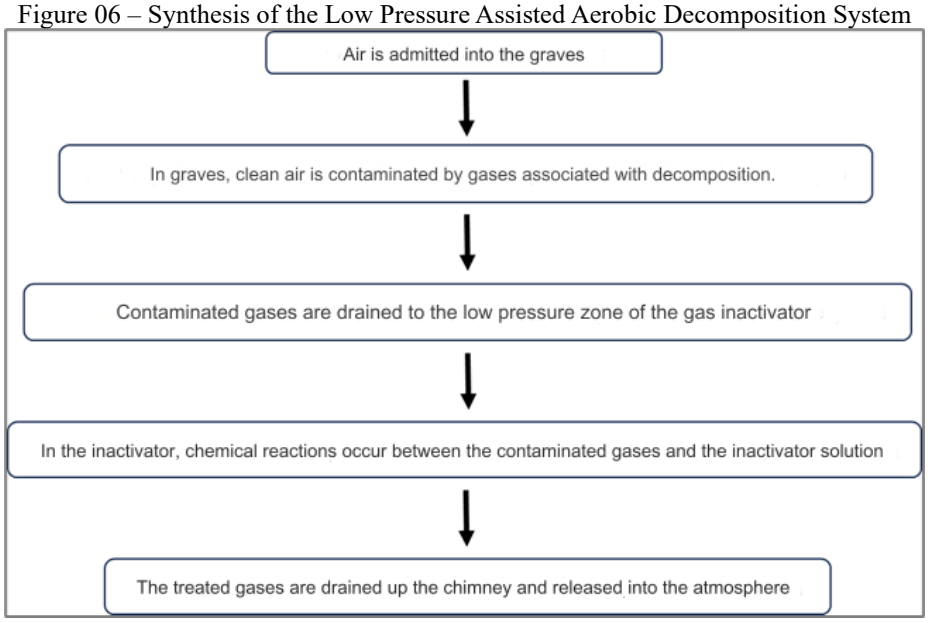
The burial system was implemented by the company VALFER Tecnologia, which presents a technique of Aerobic Assisted Decomposition at Low Pressure. In this system, three factors come together, exothermic decomposition, the negative pressure created inside the locules, and the presence of oxygen, which allow a faster evaporation of the necroleachate, enabling the acceleration of the decomposition process, which on average in the traditional system lasts 2 to 3 years and in this system takes 8 months (VALFER Tecnologia, 2024). The gases and vapors generated in this process are conducted to a device called Gas Inactivator, where Carbon Dioxide (CO2) and hydrogen sulfide gas (H2S) are transformed respectively into odorless and non-contaminating sodium carbide and sodium sulfide, figure 05 exemplifies the operation of the gas inhaler (VALFER Tecnologia, 2024) (Figure 05 and 06).

Figure 05: Sketch of the Low Pressure Assisted Aerobic Decomposition System.



Source: Adapted from Valfer Tecnologia, 2024.

Figure 06 – Synthesis of the Low Pressure Assisted Aerobic Decomposition System



Source: Adapted from Valfer Tecnologia, 2024.

As for the solid waste generated in the project, it occurs as follows: the waste is separated and properly packaged inside the project (Figure 07) according to the type of waste; After exhumation, waste such as coffins and clothes is collected and disposed of by a partner company, which sends the contaminated waste to a landfill. Class II-A and II-B waste (ABNT, 2004), such as wood, bricks, mortars, paper, plastics, metals, glass, if not contaminated, are sent for recycling.

Figure 07 - Partial view of the primary packaging of recyclable solid waste in the Alpha project.

Source: Prepared by the authors.

FINAL THOUGHTS

By analyzing the Alpha cemetery, it is verified that it has an efficient system of burial, collection and treatment of by-products associated with the decomposition of the human body, presenting itself as an environmentally appropriate alternative for the disposal of the human body.

The project also has a Solid Waste Management Plan, which includes common and hazardous waste.

Due to the current decomposition and treatment system, the main environmental impacts of the area consist of the generation of gases (which do not cause damage because they are treated correctly), and the physical allocation of the project, which is located on the water banks.

Thus, it is suggested the recovery of the riparian forest in the areas of the project as a form of environmental compensation and improvement of the physical and ecological stability of the area. Subsequently, the recovery of the riparian forest can be used as publicity for the area, which in addition to following an environmentally appropriate burial technique, also has a proactive stance towards environmental issues.

In short, vertical cemeteries are excellent solutions for burial, when compared to traditional techniques, because they occupy smaller physical spaces and have efficient treatment systems, but the system must be periodically monitored to ensure its efficiency.

Another way to minimize the impacts generated is the restoration of riparian forest to ensure the protection of water resources.

It is believed that the main contribution of this research lies in the systematic presentation of the burial processes and destination of by-products in a vertical cemetery.

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