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Evaluation of the Environmental Quality of a Cemetery using the Method of the Peir Matrix - Case Study

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***Keywords*— Corpses. Impacts. Effluent.**

***Abstract*—** *Cemeteries are potential sources of environmental impact because they do not follow the various standards established by CONAMA. Most of them are not supervised or undergo periodic maintenance, being responsible for polluting the soil, subsoil and also reaching numerous groundwater from the areas where they were installed, considerably affecting the health of the local population. The study took place in the várzea cemetery, in the city of Recife, state of Pernambuco. The choice of this potential source of contamination stems from the scarcity of studies on the subject, especially in the State of Pernambuco. Local visits related to local information suggest not only non-compliance with the rules, but also possible pollution and contamination of soil and free aquifer. Therefore, the present research aims to investigate the environmental quality of the Várzea cemetery using the Pressure-State-Impact-Response Matrix (PEIR Matrix). The methodology used was the literature review, on-site visits in order to verify compliance with the legislation as well as the construction of a Matrix, also based on an analysis of soil quality. Considering the data obtained with the particle size analysis, it was verified that the sediments, in the cemetery area, showed predominance of sand grains in the surface layer of the terrain. It was possible to conclude through the matrix that the cemetery presents itself with low environmental quality and may be generating negative environmental impacts of great proportions.*

I. INTRODUCTION

It is not only during life that the human body undergoes transformations. In fact, with the occurrence of death, the human body decomms, contributing to pollute the environment (ABIA et al., 2019) and becomes an ecosystem, composed of arthropods, bacteria, pathogenic microorganisms, and organic matter destroyers.

It occurs that, in some cases, when decomposition starts to occur in places where there is no adequate infrastructure, as well as the absence of hydrogeological studies, it can

generate significant environmental impacts, especially the contamination of water, both surface and underground, by microorganisms that proliferate along the decomposition of bodies (NASCIMENTO, 2020).

Cemeteries, in their early days, were seen as a place to sleep. After numerous problems due to the lack of organization of the places where the bodies were deposited after death, they became necessary, due to the fact that they were places with great potential for environmental impact. When they are not properly maintained. In addition to causing bad smell, the process of saponification of bodies and the flow of water passing through the graves to nearby communities can occur, which can generate serious risks to the health of the population (LINS et al, 2018).

Despite the damage they can cause to the environment, research related to the subject is still scarce. In the studies that could be verified, such as Lins et al (2018) and Pinheiro, et al (2018), the biggest problems pointed out by the researchers were the contamination of soil, air, and groundwater, in addition to non-compliance with the laws in force.

Therefore, the present research aimed to evaluate the environmental quality of the Várzea cemetery using the technique of the Pressure-State-Impact-Response Matrix (PEIR Matrix), where data were obtained through field visits and particle size analysis of the soil.

II. METHODOLOGY

The research method adopted was the hypothetical-deductive, since a set of information will not be sufficient to explain a phenomenon. To try to explain the problem, several hypotheses were created, which were tested for its validity. This way if a truth is accepted, it does not mean that it is considered true. It's just a truth that hasn't been distorted yet.

The first hypothesis considered was that being the surface soil with sandy characteristic, the possibility of negative environmental impact in the subsoil is high. The second hypothesis is that the soil has homogeneous and uniform characteristics. The third hypothesis considered is that necrochorum has equal density and viscosities.

Another method also used was the investigative method, aiming to make the deductive method more real where only loco surveys were performed associated with particle size analysis of the soil.

2.1 Area of Study

The study area chosen was the Várzea Cemetery, located on Av. Prof. Artur de Sá, s/n, being one of the five municipal cemeteries of Recife, Pernambuco, Brazil, which are administered by the city hall, from the Municipality of Maintenance and Urban Cleaning of Recife (EMLURB).

Founded in 1867, initially as municipal public cemetery of the parish of Várzea, since it was connected to the parish of the neighborhood, from the donation of the land, made by Major José Antônio de Brito Bastos. The cemetery has a total area of 21,700m², distributed in three blocks of catacombs, in which 3,159 tombs are distributed (Figure 1).

Fig.1: Aerial view of várzea cemetery. Source: Googlemaps (2022).

Inside the cemetery it is possible to observe that, in the blocks, although, the shallow pits (coffins placed directly on the ground) with excavations from 0.6 to 0.8 meters deep, there are also tombs in precast blocks, consisting of

two compartments coated with masonry plates without plaster, which reach the depth of 1.5 meters. In catacomb blocks, tombs comprise drawers coated internally by cement and, for the most part, above the surface of the ground. For the most part, the graves are not perpetual, and there is reuse after a minimum period of two years, when the remains are removed and then proceeded new inumção – the remains are packed in a new container and placed in the lower part of the tomb, while a new coffin is deposited at the top of the tomb.

2.2 Surroundings of the cemetery

In general, cemeteries were initially implanted outside the urban perimeters. However, urban sprawl over the years has narrowed the gap between cemeteries, such as Várzea Cemetery. Currently, the surroundings of the cemetery are completely urbanized, including constructions that use part of its wall to make up its buildings.

It is also possible to observe the lack of infrastructure in the residential areas around the cemetery, such as lack of sanitary sewage and regularity in the water supply. The housing units were built without any type of urban planning, given the occurrence of alleys, streets without exit and advance of buildings on the streets, without meeting minimum urban parameters. The residences are mostly low-income, and it is also observed the existence of small commercial units.

2.3. The PEIR Matrix

In order to enable the interpretation and analysis of the data in a complete and objective way, a matrix of pressure-state-impact-response (IRP) model indicators was applied. This methodology made it possible not only to identify, but also to identify the possible negative impacts generated and its consequences on the environment, especially in the vicinity of the locality where the Várzea cemetery is located.

The PEIR Matrix methodology, as carvalho (2020) shows, is a means of research used to evaluate the state of the environment under study, in order to present proposals that may mitigate or avoid environmental impacts that the potentially polluting activity developed in it can cause. The definition of this analysis model is clarified in a synthetic way, but quite assertive Still according to the author, the matrix of pressure-state-impact-response (IRP) model indicators seeks to establish a logical link between its various components that can be materialized from "cycles", in order to guide the evaluation of the state of the environment, from the factors that exert pressure on natural resources (which can be understood as the "causes" of their current state, which may consist of direct pressures that society exerts on the environment), through the current state of the environment ("effect" in the face of pressures and responses exerted by society) and the impacts of this effect on the environment (consequences arising from the state of the environment), to the responses (reactions) that are produced to address environmental problems in each locality.

Thus, it is possible to understand that the model consists of feedback of your data, to arrive at the necessary answer to solve the problem that was first identified. This feedback can be observed more clearly in Figure 2:

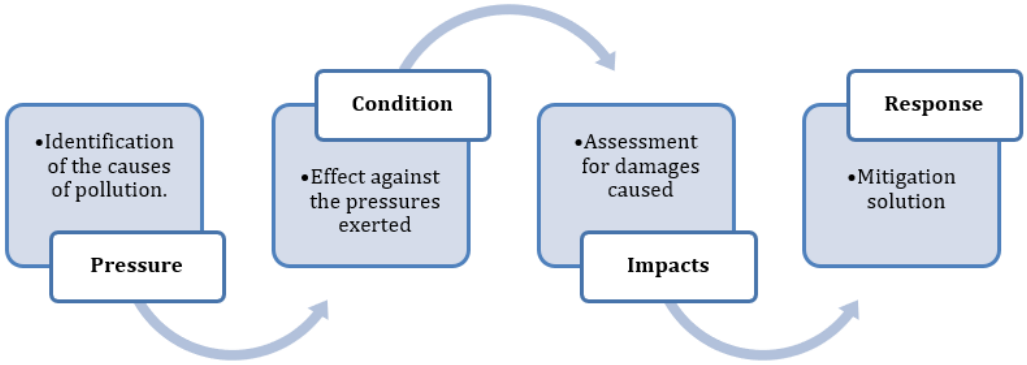

Fig.2: Flow of construction of the PEIR Matrix.

Source: The Authors (2022).

With a matrix of indicators, it is possible to obtain the means to structure the sets of indicators, so as to facilitate their interpretation and thus ensure that all aspects are taken into account, besides being able to help in understanding how different issues are interrelated.

It is worth mentioning that, before the construction of a data matrix itself, it is necessary to carried out field research in such a way that the data necessary for the evaluation of social and environmental impacts are collected. However, the collection of these data cannot be

performed randomly, otherwise the construction of the matrix would be impaired, which, despite presenting a range of data, these same data would not have a correlation, which is at the core of the adopted model. In this sense, an adapted methodology of Carvalho (2020) was used in his research since it allows the replication of this method in the Várzea cemetery, Pernambuco, Brazil.

Table 1: Description of the indicators observed in the field. Source: Carvalho (2020).

Indicator	Points to note
Pressure Indicators	They should be mainly associated with the assessment of the environmental function, and are also linked to issues related to the functioning of the basic sanitation system;
State Indicators	They are predominantly related to issues relating to the evaluation of sanitary and environmental realities
Impact Indicators	Representative of situations regarding the level of preservation of natural resources and impacts on the population, thus observing a diversity of indicators regarding the classification of environmental dimension conditions
Response Indicators	It refers to the scope of instruments, methodologies and policies that can act on the municipality and, mainly, on the area, in relation to sanitary and environmental functions, in a corrective or preventive manner

2.2. Soil Granulometric Analysis

There are two assays for the determination of soil granulometry. In one of them is done the thick and fine sieving. In the other, sedimentation is carried out in distilled water.

a) Sieving method: Separating particles up to 0.074 mm.

b) Sedimentation method in distilled water: for particles smaller than 0.074. The test can be performed in up to three different ways.

- Only sieving for granular material.

- Sedimentation for fine soils.

- Joint particle size analysis, which comprises both sieving and sedimentation (soils with coarse and fine particles).

These tests were all performed based on the standards NBR 7181 - ABNT - "Soil - Particle Analysis", NBR 5734 - ABNT - "Sieves for testing - Specification" and NBR 6457 - ABNT - "Soil Samples - Preparation for Compaction Tests and Characterization Tests".

III. RESULTS AND DISCUSSION

3.1. Visit *In Loco*

In the on-site visit to the cemetery,it was possible to observe that neither the administration of these necropolises, nor the City of Recife, through the Urban Cleaning Maintenance Company (EMLUB), responsible for its maintenance and administration, comply with environmental legislation, which aims to preserve the environment and avoid the impacts generated by the installation of a cemetery in the urban environment.

It is notethat for the installation of a cemetery, especially in urban areas, it is necessary, in addition to the study of environmental impact, the implementation of measures to prevent negative impacts, such as installation of drainage systems and treatment for necrochorum, to avoid soil contamination and, consequently, the proliferation of diseases to the population.

Although the tombs presented inFigures 3 and 4 present apparent good state of conservation, it is possible to identify cracks and cracks, which are capable of releasing necrochorum and gases, thus observing the need for periodic maintenance of the tombs being a way to mitigate the possible damage caused to the environment.

Fig.3: Drawer tomb (osuary). Source: The Authors (2022).

It was possible to verify that, according to Figuras 3 and 4, the construction of tombs and graves in the várzea cemetery did not occur in the correct way, according to what is provided in Article 6 of the resolution of

CONAMA 335/03, which establishes that the tombs must be built with specific material, which does not allow the leakage of liquids and the passage of gases from the decomposition phases of the bodies.

It is notorious that the deposits present structural problems, which can lead to the leakage of necrochorum and gases to the environment, where, according to Santos (2013), it is classified as a secondary physical impact, which are linked to the quality of the materials used in their construction.

Another problem observed was the lack of rainwater drainage system, generating some grooves in the local soil. A similar situation was the subject of a study conducted by Petsch, Monteiro & Bueno (2011) in the Municipal Cemetery of Sussuí, state of Paraná, Brazil, where the erosive processes were identified bringing a series of damages to the site. Through local measurements it was possible to measure differences of a level greater than 20 cm between the graves of the Cemetery of Drowned Ingazeira, Pernambuco, Brazil. In turn, CETESB (1999) states that the perimeter and interior of the cemetery should be provided with an adequate and efficient drainage system, in addition to other devices designed to capture, route, and dispose of rainwater flow safely and prevent endues, flooding and land movements.

Fig.4: Tomb with masonry perimeter presenting malfunctions. Source: The Authors (2022).

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2.3. Soil Research Analysis

The geological and subsoil analysis was performed based on the information obtained in the literature and local organs. Through information obtained from CPRM (Geological Service of Brazil), ITEP (Technological Institute of Pernambuco) and EMLURB (Urban Maintenance and Cleaning Company of Recife) it was possible to obtain enough data to obtain the PEIR matrix.

The Boa Viagem aquifer, where theVárzea cemetery is established, for example, has a groundwater level close to 6.0 meters, an average thickness of 50 meters in the neighborhoods of Várzea and Cidade Universitária, an average flow rate of 17 m^3/h and an average specific flow rate of 4.5 $m^3/h/m$, data obtained from the CPRM (2003). Through studies conducted by Costa (1998) it was possible to obtain the hydrodynamic parameters related to transmissivity (T), hydraulic conductivity (K) and porosity (ρ) of the Aquifer Boa Viagem, whose mean values correspond, respectively, to 7 X 10^{-3} m^2/s, 1.7 X 10^{-4}m/s and 0.10. The author also points out that aquifer is because it is free, has its main recharge from rainwater, in addition to rivers, leaks from sewage networks and losses in the public supply network.

Geotechnical studies carried out by ITEP (2001), inside the várzea cemetery, indicated that the level of the groundwater surface was not reached up to 4.0 meters deep and that the construction of an observation well, manual lye, inside this cemetery, in February 2003, made it possible to determine the level of water in subsurface, which was 6.0 meters deep, confirming Costa (1998).

Through Espíndula (2004), in his master's thesis, it was possible to obtain information in the area around this cemetery, where the occurrence of residential shallow wells is high. In general, they presented depth ranging from 9 to 15 meters and were used, in general, as a complement to the public supply carried out by the Pernambuco Sanitation and Supply Company – COMPESA, occurring less frequently in cases in which such wells are the only source of supply.

After a new local analysis in 2022, there was an increase in the use of shallow wells in the surrounding areas due to the population increase and the water rotation imposed by COMPESA due to the low in the dams. It is notepoint that

when observing the waters, they are still darkened, brackish and with unpleasant odor. According to several authors (MIGLIORINI et al., 1994; MARINHO, 1998;MATOS& PACHECO, 2002) the waters of the groundwater aquifer in cemetery areas may have some of its chemical parameters altered due to contamination from the decomposition of the bodies.

Based on the particle size analysis of the surface soil (considered the most critical – the one that, during visual tactile analysis, found predominance of granular soils), the sands presented percentages ranging from 60 to 93% on the surface. Among the sands, the classification specified from very coarse sand to very fine sand, whose percentages ranged from 0.17 to30.2%, for very thick sands, and 0.5 to 20%, for very fine sands.

2.4. PEIR Matrix

Thus, with all the information and records obtained, it was possible to assemble the matrix of PEIR para analysisof the ambient quality of the cemetery. Seeking to understand the cause and effect of anthropic actions on the environment will be fundamental for decision-making that can contribute to the orientation of environmental diagnosis and what can be done to prevent and mitigate current and future negative environmental impacts.

The violation of technical standards in the operation and adequacy of cemeteries, lack of supervision, lack of planning and environmental management, serve as characteristics of the pressures exerted by anthropic activity, factors that can lead to contamination and pollution of the areas where the cemetery is implanted.

The state of the environment, which result from the pressures are release of liquid and gaseous cadaveric effluents, production of solid waste without proper management, burning of bones due to lack of ossary, lack of drainage of rainwater. The impacts are produced on different aspects such as environment, quality of life and economy, which generates negative impacts such as: contamination of surface and underground water bodies and soil, air pollution, spread of diseases, hospital costs, visual pollution, proliferation of vectors of diseases, air pollution, soil erosion and saponification.

The answers are the component of the matrix that corresponds to actions that will mitigate or prevent negative environmental impacts, and that conserve natural resources contributing to the improvement of the quality of life of the local population. They are: Environmental Risk Prevention Program (PPRA), Immediate recovery of graves to prevent leakage of liquids from colliding and treatment of possible gaseous effluents, using, for example, activated carbon, as shown in Table 2.

Table 2: PEIR Matrix for Várzea Cemetery, Recife/PE. Source: The Authors (2022).

PRESSURE	CONDITION	IMPACT	RESPONSE
Non-compliance with the standards determined by CONAMA resolutions.	Depredation of the graves, graves, drawers, and mausoleums of the cemetery. Residences very close to the cemetery.	Pollution of surface and groundwater, causing communicable diseases, causing impacts on public health.	Treatment and conservation of tombs, pits, drawers to prevent the expulsion of contaminant liquid gases, both in the flora and in the local fauna.
Omission of the supervision and management of the City of Recife.	Lack of cleanliness of the pits and non-observance of the minimum distance between them.	Direct and indirect contamination of the environment of those who perform activities in the cemetery and visit the burials.	Build drainage systems for the discharge of necrochorum esum that carries the greatest environmental impact, through the leakage of the tombs and graves of those who were buried.
Absence of environmental studies and training for environmental management.	No drainage of surface and groundwater reaching the groundwater.	Pollution of the tombs through the cracks found. There is a great passage of water bodies, resulting infectious diseases such as hepatitis "A", typhoid fever, amebas and	Implantation of biodegradable coffins and blankets to contain the leakage of toxic gases and necrochorum, causing infectious diseases.

PRESSURE	CONDITION	IMPACT	RESPONSE
		problems to the population that resides in the surroundingarea.	
Lack of maintenance and conservation of the tombs and graves of the cemetery.	Infiltration of the soil, causing contamination of groundwater and surface water due to the cracks of the tombs.	With the shedding of necrochorum, especially in the rainy season, there is contamination of the lenients and, consequently, the spread of infectious diseases, such as hepatitis "A", typhoid fever among others.	Build a correct drainage system for the passage of necrochorum without harming the local population.

The matrix built in this research is like that built in the São Luiz Cemetery, in the municipality of Escada/PE, carried out in the scope of the research by Lins et al (2018). It was not possible to notice the non-compliance with environmental standards, which is the starting point of the negative impacts caused by the cemetery analyzed here.

In the question of the analysis of the "condition", the leakage of liquid effluents (such as necrochorume) was identified. This leak is later identified at the "impact" point of the matrix, where contamination of surface water bodies is identified.

On the "response" point identified in the matrices, although some differences are observed, see the particularities of each cemetery, the common point is the suggestion of the construction of drainage system for effluents that are released into the soil and, consequently, in the groundwater (According to Hypothesis 1) without proper treatment, mitigating the problem of water pollution that will later be used by the population living around the cemetery.

IV. FINAL CONSIDERATIONS

Through the present study it was possible to verify that the problems generated by the Várzea cemetery in the locality where it is located, especially about the environmental impact, are due to the lack of application of the norms and guidelines that establish the minimum measures necessary for soil preservation and the surface of such localities.

Although the physical structure, which was the point of analysis of this research, already demonstrates that it is very likely that the environment of that area is contaminated, it is necessary to evaluate more thoroughly the impacts generated, through analysis of the current level of pollution, especially the soil and groundwater of the cemetery area and its surroundings.

The present research applied the PEIR Matrix, at a time of pandemic, which, despite the difficulties to collect the necessary data, was constructed from the information collected in the cemetery object of our research.

Given its objective, the use of the Pressure-State-Impact-Response (IRP) matrix proved effective in identifying problems and solutions that are capable of, if not completely correcting the problems encountered, significantly reducing the negative impacts generated by Várzea cemetery, Pernambuco, Brazil.

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