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Analysis of the Environmental Impact on the Groundwater Quality of Cemeteries – Case of the Municipal Cemetery Located in Recife, Pernambuco – Brazil

Análise do impacto ambiental na qualidade da água subterrânea de cemitérios – Caso do cemitério municipal localizado no município de Recife, Pernambuco – Brasil

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Abstract: Among the United Nations' Sustainable Development Goals (SDGs) is the quest for universal access to quality water by 2030. SDG 6 aims to ensure the availability and sustainable management of water. According to the latest SDG progress report published by the UN (2023), 2.2 billion people still lack access to drinking water, one of the problems being water contamination. Among the sources of contamination are cemeteries, which has been aggravated by the Covid-19 pandemic. The aim of this work is to assess possible groundwater contamination in the largest cemetery in the state of Pernambuco, Brazil, the Senhor Bom Jesus da Redenção Cemetery, Recife. To assess the vulnerability of the water, laboratory and field studies were carried out to determine the levels of heavy metals, COD, BOD and pH in samples collected from the cemetery. The data is compared with water collected from the state supply system. The effect of recent burials is observed in the average phosphorus content of the soil samples tested (471, 81 mg/kg), as well as changes observed in the concentrations of heavy metals and physical-chemical parameters indicating that the groundwater in the cemetery is suffering interference in its quality due to recent burials.

Keywords: Contamination; Water contamination; Heavy metals.

Resumo: Entre os Objetivos de Desenvolvimento Sustentável (ODS) da Organização das Nações Unidas, está a busca pelo acesso universal a água de qualidade até o ano de 2030. O ODS 6, visa assegurar disponibilidade e gestão sustentável da água. De acordo com o último relatório de evolução dos ODS publicado pela ONU (2023), 2,2 bilhões de pessoas continuam sem acesso à água potável, sendo um dos problemas a contaminação de águas. Entre as fontes de contaminação estão os cemitérios, sendo agravado com pandemia de Covid-19. O objetivo desse trabalho é avaliar possível contaminação das águas subterrâneas do maior cemitério no estado de Pernambuco, Brasil, o Cemitério Senhor Bom Jesus da Redenção, Recife. Para avaliar a vulnerabilidade das águas são realizados estudos em laboratório e campo, para determinar teores de metais pesados, DQO, DBO e pH, em amostras coletadas no cemitério. Os dados são comparados com coleta de água do sistema de abastecimento estadual. O efeito dos sepultamentos recentes é observado no teor médio de fósforo das amostras de solo ensaiadas, 471, 81 mg/kg, além de alterações observadas nas concentrações de metais pesados e parâmetros físico-químicos indicando que as águas subterrâneas do cemitério sofrem interferência em sua qualidade devido aos sepultamentos recentes.

Palavras-chave: Contaminação; Contaminação de águas; Metais pesados.

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1. Introduction

Approximately 16% of the Brazilian population does not have access to public water supply, and in the northeast this figure rises to 26% of the population, making artesian wells necessary to cover the gap (ANA, 2023).

These inequalities in access to sanitation services are present in different sectors of a municipality, with the most vulnerable and deprived groups who live on the outskirts suffering most heavily from a lack of adequate basic sanitation. In addition, the correlation between access to basic sanitation and Covid-19 cases/deaths was observed, which in turn strengthens the concept of sanitation as the most important measure for preventing and spreading the virus (GUEDES *et al*., 2023).

SDG 6 aims to ensure the availability and sustainable management of water and basic sanitation for all. In order to achieve universal coverage by 2030, the current rates of progress must be increased sixfold. According to the latest published SDG progress report (UN, 2023), 2.2 billion people in the world, approximately 27%, still lack access to drinking water, one of the major problems being water pollution, which is a considerable environmental sanitation challenge affecting both human health and the environment in many countries.

In developing countries like Brazil, diseases caused by inadequate environmental sanitation result in social problems that mostly affect vulnerable regions. In short, quality sanitation services are a measure that prevents water-borne diseases, and their universality should be seen as a priority, especially in the North and Northeast regions (UHR *et al*., 2016).

Soil and water contamination in cemeteries is a significant environmental issue in Brazil, with direct implications for public health and environmental quality. This problem arises mainly due to the decomposition of human bodies, the use of metals and varnish in coffins, and inadequate cemetery management. The decomposition of bodies releases a variety of chemical substances, including nitrogen, phosphorus, ammonia, formaldehyde (used in embalming), as well as pathogenic microorganisms and increased BOD and COD. The heavy metals present in coffin materials are gradually released and these compounds can seep into the soil and reach the groundwater, causing groundwater contamination (BRYNDAL, 2015).

Studies carried out in various regions of Brazil point to alarming levels of contamination in cemetery areas (SANTOS *et al*., 2015). However, the regulation and environmental monitoring of cemeteries is still insufficient in many locations. Arguello *et al*. (2024) analyzed parameters such as DO, pH, EC, BOD, and COD which indicated contamination of water resources, with values above the limits established by international organizations.

CONAMA Resolutions nº 335/2003, nº 368/2006, and nº 402/2008 establish criteria and guidelines for the environmental licensing of cemeteries in Brazil. These criteria are fundamental to ensuring that the establishment and operation of cemeteries does not cause environmental damage, especially with regard to soil and groundwater contamination. The main criteria established by the resolutions include location, soil characteristics, minimum distance from water sources, water table level during the rainy season, and other studies that are necessary to obtain preliminary, installation, and operating licenses. Despite this, cemeteries in Brazil are often located in areas with shallow water tables, as there is little oversight by environmental agencies, increasing the risk of groundwater contamination, which can be used for human consumption and agricultural irrigation.

The control and management of contaminated areas has attracted the interest of public agencies and society in general, all around the world, with cemeteries being among the engineering structures that require attention. The implementation and operation of cemeteries in urban areas must be accompanied by geological, hydrological, topographical, and land suitability studies to be able to receive burials during their lifetime, acting in a similar manner to landfills (CAMPOS, 2007; CARNEIRO, 2009). Toscan *et al*. (2022) suggested the formation and implementation of public policies to monitor areas around vertical urban cemeteries, to reduce the spread of the SARS-CoV-2 virus from the movement of nanoparticles through the air.

With the Covid-19 pandemic, which caused more than 712,000 deaths in Brazil (FEDERAL GOVERNMENT, 2023), the number of cemetery burials increased greatly, leading to increased rates of contamination and pollution due to lack of care in sanitary aspects (ZYLBERKAN, 2020). The environmental liabilities that cemetery activities produce go beyond the visual limits of human beings, since some of the by-products that result from the decomposition process permeate the soil and can reach groundwater, resulting in health risks (FERREIRA *et al*., 2021).

During the process of degradation of organic matter in the bodies, necro-leachate is formed, a viscous, grayish liquid with a characteristic foul odor. Necro-leachate is the product of the decomposition of human bodies and for every 1 kg of body weight an average of 0.4 to 0.6 liters are produced. It is made up of around 60% water and 30% ionized salts containing phosphorus (P), nitrogen (N), chlorine (Cl), bicarbonate (HCO^{3-}), calcium (Ca^{2+}), sodium (Na^{+}) and various metal compounds, such as chromium (Cr), cadmium (Cd), lead (Pb), iron (Fe), and nickel (Ni), usually from the accessories found in coffins and funeral ornaments, with the other 10% made up of organic substances (ŻYCHOWSKI and BRYNDAL, 2015).

The aim of this study is to determine the possible potential for contamination of groundwater by cadmium (Cd^{2+}), chromium (Cr^{3+}), copper (Cu^{2+}), nickel (Ni^{2+}), lead (Pb^{2+}), and zinc (Zn^{2+}), resulting from the operation of the Senhor Bom Jesus da Redenção municipal cemetery (Figure 1) and to assess water quality by comparing BOD, COD, and pH values among samples collected from areas of the cemetery.

2. Methodology

The Senhor Bom Jesus da Redenção Cemetery, also known as the Santo Amaro Cemetery, is located in the city of Recife, in the state of Pernambuco, Brazil. It is one of the largest cemeteries in Brazil and the largest cemetery in the state, with an area of 140,000 m², and was inaugurated on March 1, 1851. After 173 years in operation, it receives an average of 18,000 visitors a month and has 9,000 ossuaries and 20,000 burial spaces distributed between tombs, graves, and vaults (PREFEITURA DO RECIFE, 2022).

Figure 1 shows a spatial view of the cemetery and the delimitated area upstream of the cemetery for the collection of the background soil used as reference material without any contamination from cemetery activities. The cemetery is located on level ground, with slopes of less than 1 meter. This is a favorable factor for earthmoving, determined by the continual need to replace excavated materials.

Figure 1 – View of the study area, Santo Amaro Cemetery.
Source: Authors, adapted from Google Earth (2024).

2.1 Collection of water samples

The methodology used in this study was developed from field work and bibliographic research, and the result is an exploratory and descriptive work, which focuses on the study of groundwater contaminants in the context of contamination from cemeteries during the Covid-19 pandemic. The study was divided into four stages: a) collection of water and soil samples from the cemetery, b) physical-chemical testing of the samples, c) geotechnical characterization of the cemetery soils, and d) physical-chemical analysis of the water from the cemetery and the public water supply network.

A total of 37 soil samples were collected for analysis and geotechnical characterization, with some points also analyzed for soil contamination (Figure 2).

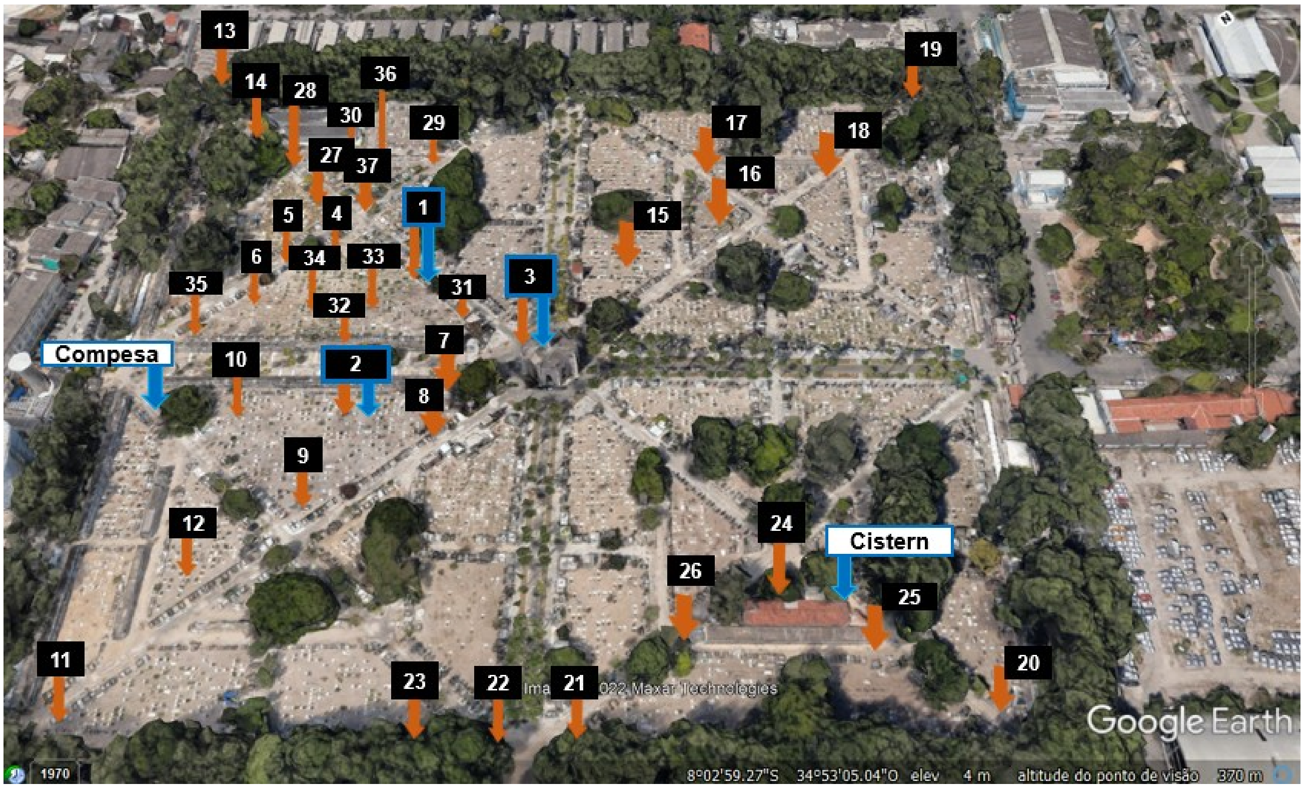


Figure 2 – Location of soil and water sampling points.
Source: Authors, adapted from Google Earth (2024).

Three wells were drilled to collect water samples (Points P1, P2, and P3, shown in Figure 2). To determine the interference of burials on the contamination of groundwater samples, water samples were collected from areas without burials and from the external water supply from the state water company (Compesa) and from the cistern located at the cemetery, which were used as references.

Laboratory analyses were carried out to determine the following physical-chemical parameters: pH, COD, BOD, and heavy metal content. The materials used (glassware) were cleaned and prepared by immersing them in a solution of hydrochloric acid and distilled water for 24 hours, then washing them with distilled water and drying them in an oven.

2.2 Physico-chemical analysis of the water

Water quality monitoring was carried out during two collection campaigns, in the months of November (30/11/2022) and December (07/12/2022), 2022. Samples were collected at points P1, P2, and P3, located in the burial courts at an average depth of 1.5 meters, at the cistern located in the administrative area with a depth of approximately 14 meters, and at the tap that comes from Compesa's external water supply.

The pH values of the water samples collected from the Senhor Bom Jesus da Redenção cemetery were obtained in the field using a portable pH meter, with three repeat readings per sample.

Following collection, the water samples were kept refrigerated at the Environmental Sanitation Laboratory of the Federal University of Pernambuco (UFPE), where COD, BOD, and heavy metal tests were carried out. The samples were named Collection 1 for Well P1; Collection 2 for Well P2, and Collection 3 for Well P3.

COD was measured using the titrimetric methodology recommended by Standard Methods: 5220D: Chemical Oxygen Demand. A heating block was used for digestion and the samples were titrated in triplicate. After obtaining the COD results, BOD was determined using Method A of the SABESP Internal Technical Standard NTS 003 BOD - Biochemical Oxygen Demand.

The levels of cadmium, chromium, copper, nickel, lead, and zinc were measured in all the water samples collected. The methodology adopted was that contained in Method 3010 A - Acid digestion of aqueous samples and total metal extracts for analysis by FLAA or ICP spectroscopy (USEPA, 1992). The digestion aliquots were read using inductively coupled plasma optical emission spectrometry (ICP-OES). The results obtained were compared to the reference values for the concentration of metals in water recommended by Resolution 357/2005 of the National Environment Council (CONAMA, 2005).

To analyze the data, an initial statistical treatment was carried out. Descriptive statistics were first used to explore the behavior of the data. The Student's t-test was then applied, with a 95% confidence interval, to assess if the differences between the means of the parameters investigated was significant. The statistical treatment aimed to ensure the validity and accuracy of the conclusions derived from the analysis, enabling a robust discussion of the results obtained in this study.

2.3 Geotechnical characterization of the soils

Geotechnical characterization analyses were carried out at all points shown in Figure 2. At points P1, P2, and P3 (Figure 2), in addition to collecting water samples, soil samples were collected for every 50 cm (0-0.5 m; 0.5-1.00 m; 1.00-1.50 m, and 1.50-2.00 m).

The soil samples were prepared and the physical tests carried out at the laboratories of the Federal University of Pernambuco (UFPE). For the granulometric characterization of the samples, ABNT NBR 7181/2016 was followed and ABNT NBR 7180/2016 and ABNT NBR 6459/2016 were used to obtain the Atterberg Limits. The density of the soil particles, or specific mass of the solids, was obtained using the pycnometer method described in ABNT NBR 6458/2016.

Based on the results of the geotechnical characterization, the soils were classified using the tables of the Unified Soil Classification System - SUCS, which is based on granulometry, soil plasticity, and physical attributes (ASTM, 2020).

2.4 Phosphorus content in the soils

In soils, the total phosphorus (P) content varies, on average, between 200 and 3,000 kg ha^{-1}, although only approximately 0.1% of this total is available for absorption by plants (IFTIKHAR et al., 2024). This study analyzed the concentrations of available phosphorus in the soil samples collected, using the Mehlich extraction method, also known as the North Carolina or double acid method, due to the use of two acids for phosphorus extraction: sulfuric acid and hydrochloric acid.

The procedure for extracting phosphorus from the soils used Mehlich extractions (Figure 3a), after which an aliquot of the extract was pipetted with the addition of ascorbic acid and ammonium molybdate for color development (Figure 3b) and subsequent reading of its optical density on a UV-Vis spectrophotometer, at a wavelength of 660 nm. Some samples were diluted due to their high phosphorus content and the process was repeated (EMBRAPA, 2017).

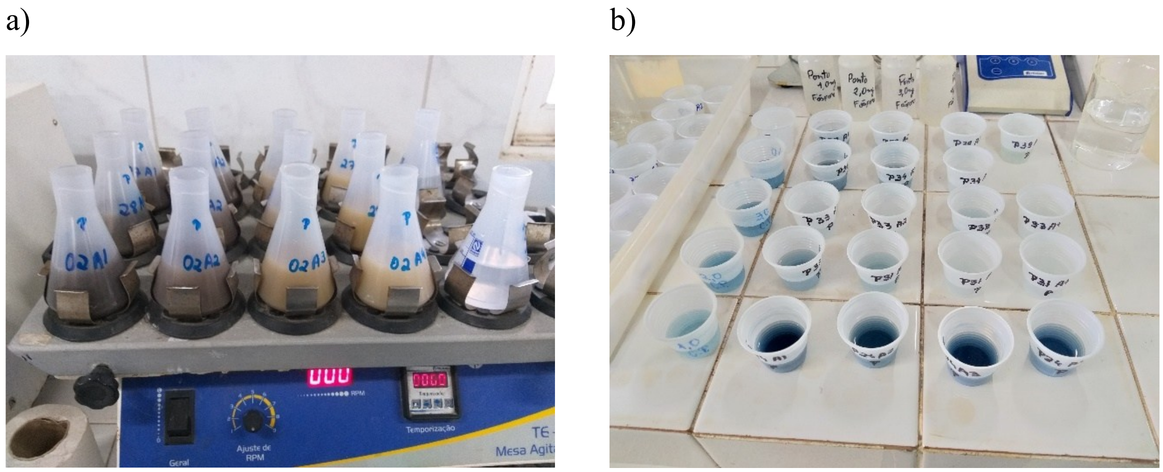


Figure 3 – a) Extraction of aliquots with Mehlich, b) Samples with ascorbic acid and ammonium molybdate to develop color.
Source: Gonçalves (2023).

3. Results and discussion

3.1 Water quality of the monitoring wells

The potential of hydrogen (pH) is one of the indicators of potability. The values found ranged from 5.2 to 6.9, a similar range to that found by Kemerich et al. (2014) in a cemetery in Rio Grande do Sul, showing the relationship between the parameter and the surface and subsurface flow of the water. According to legislation from the Brazilian Ministry of Health (Ordinance No. 518/04), it is recommended that water in the distribution system for public supply have a pH between 6.0 and 9.5.

The results obtained from the averages of the COD analyses are shown in Figure 4.

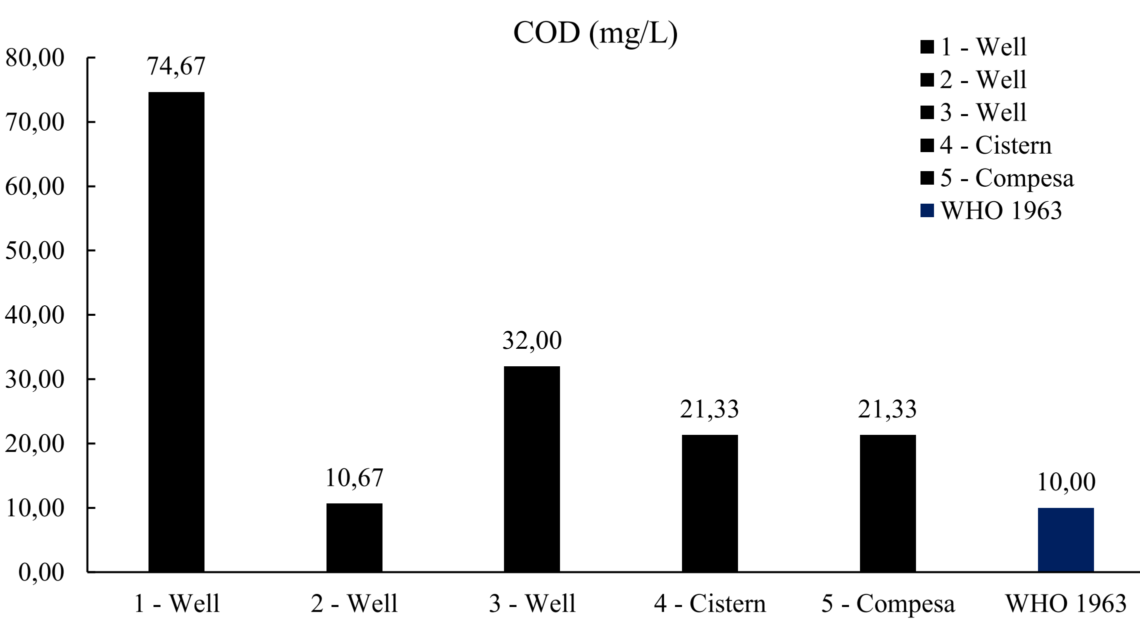


Figure 4 – Chemical Oxygen Demand (COD) values.
Source: Authors (2024).

Figure 4 shows that all water samples, including the water supplied by Compesa, had COD values above the maximum value recommended by the World Health Organization (WHO) of 10.0 mg/L, which indicate possible pollution in the water present in the cemetery. Well 1, in the burial court, had the highest COD value in the study, at 74.67 mg/L. The presence of recent burials in that area may be responsible for the high concentration. Areas with high concentrations of COD may indicate some level of toxicity. For water sources, chemical oxygen demand is an indicator of water quality and reveals its unsuitability for human consumption (HAN *et al*., 2022).

The physico-chemical parameters (COD, BOD, and some heavy metals) obtained were above the limits established by national and/or international legislation in at least one of the samples. The average BOD values obtained are shown in Figure 5.

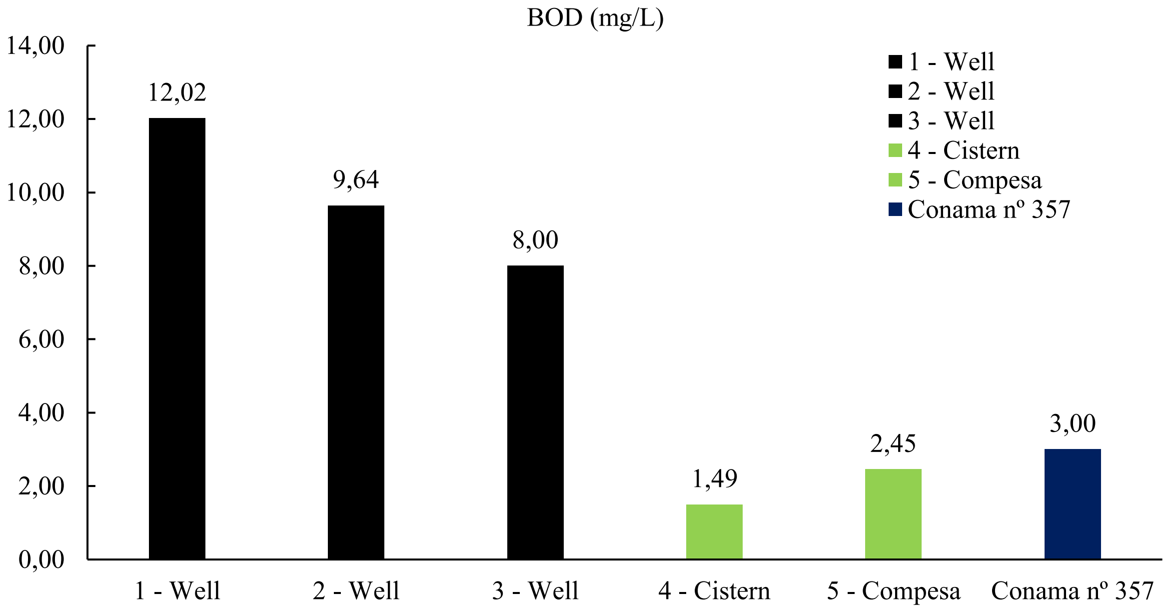


Figure 5 – Biochemical Oxygen Demand (BOD) values.
Source: Authors (2024).

Figure 5 shows that only the samples from the cistern and the public water supply network had BOD concentrations below that established by CONAMA No. 357, while the samples from the inspection holes (P1, P2, and P3) located in areas encompassed by the cemetery had BOD values above the maximum allowable.

CONAMA resolutions state that water intended for human consumption that receives simple disinfection and is classified as Class I must have BOD 5 days at 20° C below 3 mg/L, while BOD values for Class II freshwater (water intended for human consumption after conventional treatment) must not exceed 5 mg/L.

Values higher than the limits established by the Maximum Permitted Values (MPV) in CONAMA Resolution 357/2005, indicate that the water is unsuitable for human consumption. It can therefore be concluded that the quality of water in cemeteries is affected by the presence of necro-leachate released on site, or by other sources of contamination in the vicinity.

The concentrations of heavy metals obtained were compared with the MPV concentrations recommended by national legislation (CONAMA Resolution 357/2005) for Class II fresh waters, as shown in Table 1.

Table 1 – Heavy metal concentrations and Maximum Permitted Values - MPV (mg/L).

Sample	Cd	Cr	Cu	Ni	Pb	Zn
CONAMA nº 357/2005	0.001	0.050	0.009	0.025	0.010	0.180
P1	0.000	**0.101**[a]	**0.156**[a]	0.002	0.002	0.006
P2	**0.050**[a]	0.000	0.002	0.004	0.000	0.000

P3	**0.100**[a]	0.000	0.002	0.005	0.000	0.000
4 - Cistern	0.000	0.026	**0.130**[a]	0.007	0.002	0.019
5- Public Water Supply	0.000	0.037	0.004	0.003	0.001	0.001

[a] *Above reference values.*
Source: Authors (2024).

Among the metals analyzed, cadmium, chromium. and copper were found to be higher than the maximum permitted values in some wells. Chromium and copper were detected above the maximum permitted values in well P1, and cadmium in wells P2 and P3. In the water samples collected from the cistern, copper was detected above the MPV. From the analyses carried out, according to the comparisons made between samples, and in accordance with Brazilian legislation, CONAMA Resolution No. 357/2005, it can be determined that groundwater is being contaminated by the Senhor Bom Jesus da Redenção Cemetery.

Baum *et al*. (2022) assessed the quality of groundwater in the areas of two cemeteries located in the urban area of the municipality of Lages, Brazil, and detected contamination by components of necro-leaching, such as mineral salts, NH_3, total phenols, Cd, Cr, and Ni.

Because the data was collected during the rainy season, between May and July, the contaminants present were diluted, and because of this, the concern related to their environmental impact caused is even greater. Figure 6 shows the weather conditions in the city of Recife, PE in the year 2022 during the collections. The data was observed hourly, with color-coded categories (in order of severity).

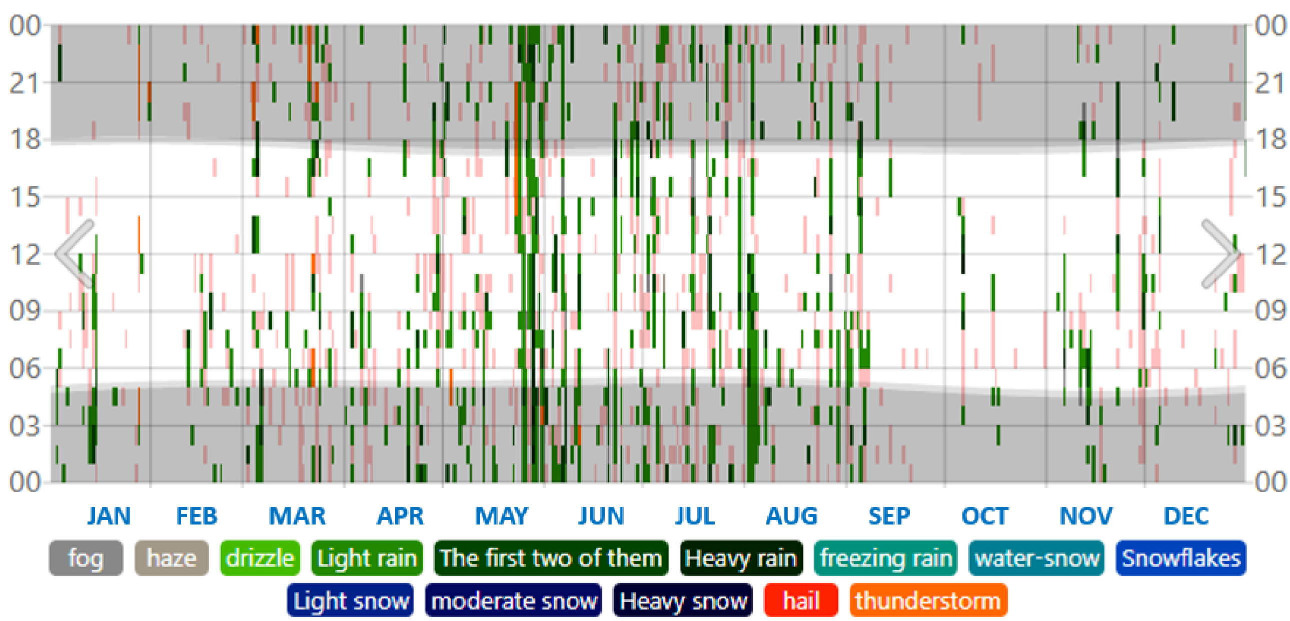


Figure 6 – Weather conditions in the city of Recife, PE in the year 2022.
Source: WeatherSpark.com (2022).

The ingestion of these elements at high levels contributes to worsening the quality of life of residents. High levels of zinc can cause liver disease (MORILLAS *et al*., 2019). According to Husejnovic *et al*. (2018), excess cadmium in the human body can cause osteoporosis, chromium can cause lung cancer in humans (FU *et al*., 2020) and lead is a neurotoxin whose accumulation can lead to central nervous system problems (KORTEI *et al*., 2020).

3.2 Soil characterization

The attributes of the soil samples, expressed by the texture and granulometry of the particles, influence fundamental characteristics such as density, permeability, presence of organic matter, and void ratio, among other factors. Although more than 100 soil samples were characterized, taken from along 37 boreholes distributed throughout the cemetery, as shown in Figure 2, the results presented refer to three specific points where water samples were also collected. The characteristics of the soil samples analyzed were very similar.

The results obtained from the 12 soil samples were used to investigate the relationship between grain size and the adsorption and leaching of contaminants in the municipal cemetery. The data related to these parameters is presented in Figures 7, 8, and 9, in order to illustrate the contaminant dispersion and retention dynamics in the cemetery environment.

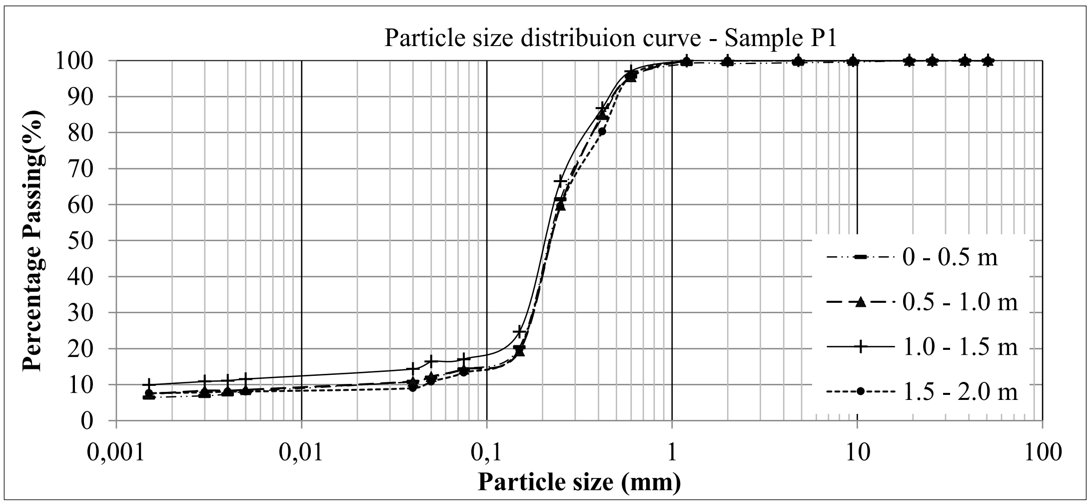


Figure 7 – Particle size composition, point P1.
Source: Authors (2024).

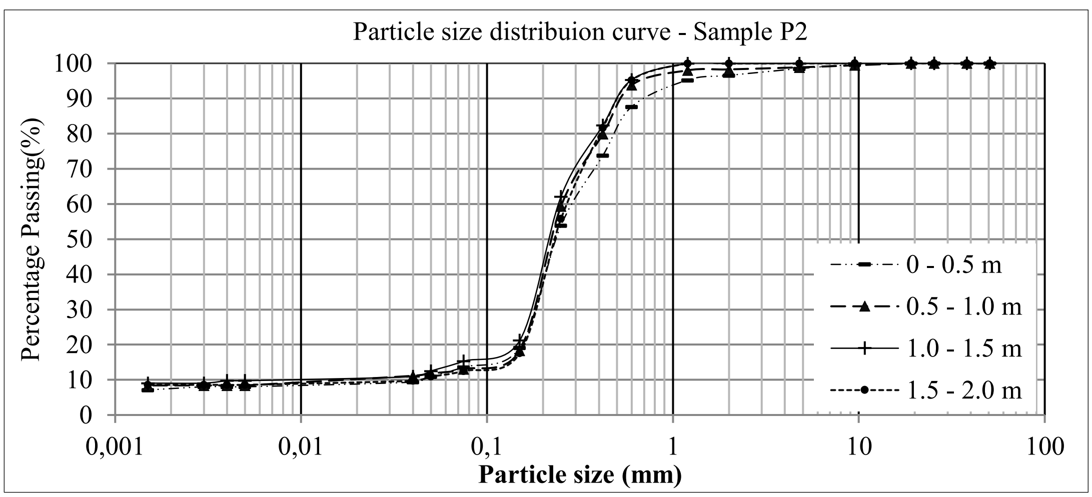


Figure 8 – Particle size composition, point P2.
Source: Authors (2024).

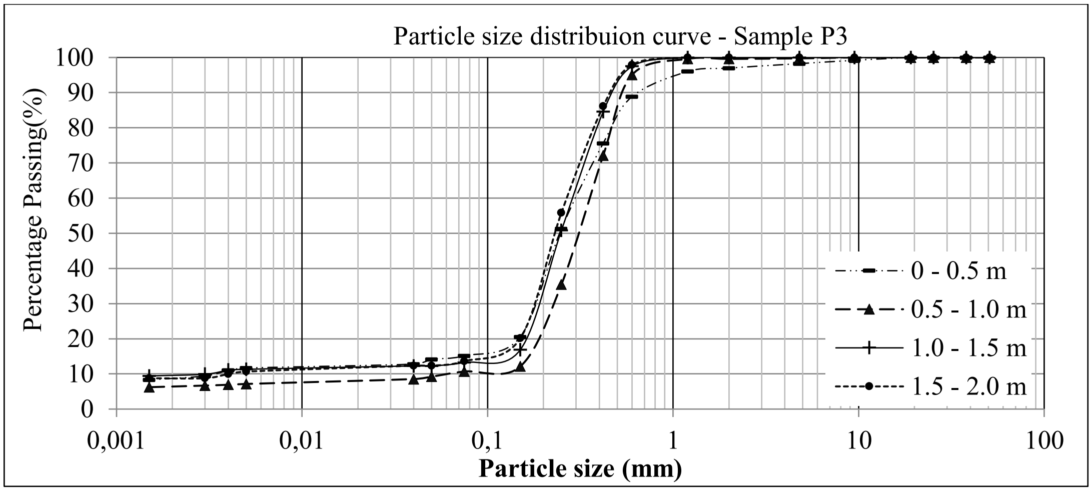


Figure 9 – Particle size composition, point P3.
Source: Authors (2024).

In all of the samples, the percentage of sand in the composition of the soils was greater than 60%, which means that contaminants leach out more easily because of the low capacity of sandy soils to adsorb contaminants, as well as their high permeability, which allows heavy metals to move freely into the water. In the Nova Hartz cemetery, Morandi *et al.* (2024) observed a soil with a sand content of 78.34%, favoring greater movement of necro-leachate in the porous medium and consequently increasing the risk of diseases transmitted by the water used for public supply. In this study, the water table was high during certain months of the year, while in the Nova Hartz cemetery it was less than 7 m deep.

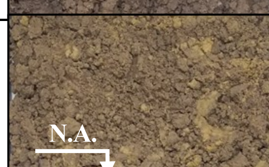
Depth	Soil layer profile	Percentage of material per layer			SUCS - ASTM Classification
		Fines	Sand	Gravel	
0.0 m - 0.5 m		15.20%	84.50%	0.30%	Silty sand (SM)
0.5 m - 1.0 m		12.60%	87.40%	0.00%	Silty sand (SM)
1.0 m - 1.5 m		16.10%	83.80%	0.00%	Silty sand (SM)
1.5 m - 2.0 m		14.00%	86.00%	0.00%	Silty sand (SM)

Figure 10 – Schematic profile of the soil layers in collection well P2.
Source: Authors (2024).

Rego *et al*. (2021) found that the natural vulnerability to groundwater contamination is intrinsically associated with the lithology of the site, whose material is predominantly sandy with a heavy amount of rainfall. In the study by Bezerra *et al*. (2023), the potential risk of aquifer contamination was classified as “Very High” because it involved lithologies with high porosity and hydraulic conductivity, geologically represented by fine to medium, well-rounded, and selected sands.

Based on the physical indices (soil moisture, specific mass of soil grains, and hygroscopic water) and Atterberg limits, the sample was classified as sandy soil. According to the Unified Soil Classification (SUCS), the cemetery soil had a SW-SM classification and is non-liquid and non-plastic. Although the particle densities varied depending on the depth of the inspection hole, the variation was small, between 2.58 and 2.64. The data on the specific mass of the grains showed values similar to the relative density of some minerals, such as quartz, which has a density of between 2.59 - 2.65, an expected value for a soil with a sand content of over 60%.

The full characterization of the cemetery's soils classified them as sandy with very little clay and silt, which is extremely worrying as it favors surface water contamination. Born *et al*. (2014) found a relationship between the vulnerability of groundwater and permeable areas that facilitate the percolation of effluents into deeper layers in cemeteries in Curitiba, Paraná.

Another factor highlighted by this study was the presence of a higher groundwater level, often found during the rainy months, which favors contamination of groundwater by human decomposition.

The soils in Recife's municipal cemetery have physical and granulometric characteristics that favor poor retention of contaminants, allowing for the the percolation of leachate and necro-leachate through the porous medium to the site's groundwater. They are therefore not suitable for the surface layers of the cemetery or for the burial layers in graves.

3.3 Phosphorus concentrations in soils

Areas near the burial sites have higher concentrations of nitrogen and phosphorus compounds from the decomposition of organic matter (Figure 11). The presence of these materials induces an increase in pH, alkalinity of the soil solution, and electrical conductivity (MATOS *et al*., 2001).

Figure 11 – Organic matter (skull) visible on the surface.
Source: Authors (2024).

The soils in the Senhor Bom Jesus da Redenção Cemetery has an average concentration of 471.81 mg/kg of phosphorus, higher values than the data observed by Marques *et al*. (2004) in soils from the municipal cemetery of Betim, MG, who obtained phosphorus contents from two samples within the cemetery of 90.85 mg/kg and 51.95 mg/kg and in five samples outside the cemetery with values of 89.48 mg/kg, 45.74 mg/kg, 58.81 mg/kg, 102.28 mg/kg, and 133.98 mg/kg.

In this study, the highest levels of phosphorus were found in soils at point P1 and in inspection wells located in blocks where current burials were taking place. It is estimated that the body of an adult has approximately 700 g of phosphorus, with 85% present in the form of hydroxyapatite [$Ca_{10}(PO_4)_6(OH)_2$], 14% in soft tissues and only 1% extracellularly, including organic (70%) and inorganic (30%) forms of phosphate (BIRD and ESKIN, 2021). The high phosphorus content in a cemetery therefore comes from the decomposition of bodies.

The sections of the cemetery with recent burials (less than three months) had the greatest changes in soil quality and the highest phosphorus levels.

Table 2 – Phosphorus concentration in cemetery soils.

Samples	Depth (m)	[P] ($mg.kg^{-1}$)	[P] ($g.kg^{-1}$)
P1	0.0 – 0.5	1200.89	1.20
	0.5 – 1.0	1111.24	1.11
	1.0 – 1.5	757.04	0.76
	1.5 – 2.0	272.03	0.27
P2	0.0 – 0.5	758.50	0.76
	0.5 – 1.0	710.00	0.71
	1.0 – 1.5	280.84	0.28
	1.5 – 2.0	236.75	0.24
P3	0.0 – 0.5	592.18	0.59
	0.5 – 1.0	604.62	0.60
	1.0 – 1.5	246.29	0.25
	1.5 – 2.0	393.14	0.39

Source: Authors (2024).

4. Final Considerations

Analysis of the water data collected from three monitoring wells and a cistern located within the Senhor Bom Jesus da Redenção Cemetery area showed changes in the concentrations of heavy metals that indicate contamination of the cemetery's groundwater. There is a greater disturbance in water quality when closer to burial areas, influencing the physico-chemical parameters (BOD and COD), which had concentrations above the limit established by Conama/Brazil.

The water used as control, collected from the public water supply network, had all the heavy metal concentrations below the limit set by Brazilian legislation. The results obtained from the water samples collected in the cemetery area indicate possible groundwater contamination.

In the Senhor Bom Jesus da Redenção Cemetery, burial time and depth influenced the potential for soil pollution, with higher levels of phosphorus being observed, and areas close to the graves presenting a greater risk of environmental water pollution, especially from chromium and copper.

In the Senhor Bom Jesus da Redenção Cemetery, burial time and depth influenced the potential for soil pollution, with high levels of phosphorus being observed, and areas close to the graves presenting a greater risk of environmental water pollution, especially from chromium and copper.

With this in mind, it is important to emphasize the need for public agencies to guide and supervise projects that are common to all Brazilian municipalities and that have the potential to pollute, as is the case with cemeteries. Public environmental policies should be more strongly encouraged, especially with regard to cemeteries, as the health of the population is at risk and greater attention to cemeteries in Brazil is urgently needed.

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