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GEO-ENVIRONMENTAL ASSESSMENT AND QUALITY OF GROUNDWATER IN THE COMPLEX OF CEMITERIES: QUINTA DOS LÁZAROS SALVADOR, BAHIA, BRAZIL

Geoenvironmental Diagnosis in the Cemetery: Quinta dos Lázaros

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Abstract: Cemeteries represent social facilities that deserve the attention of managers and planners of public sanitation policies with an emphasis on health, water use, soil and territorial planning. Since the products generated by cemetery activities, such as necrochorume, trace metals and pathogens, cause negative environmental impacts to soils, water, edaphic and aquatic biota and risks to public and collective health. This article aimed to investigate the level of influence of the Complex of cemiteries: Quinta dos Lázaros (CCQL), Salvador, Bahia, Brazil, on the chemical and microbiological contamination of groundwater by the product of cadaveric decomposition (necrochorum). Groundwater samples were collected in tubular wells and water from sources, measuring in situ the physical-chemical parameters, with the aid of a multiparameter probe (Horiba U-50), taking aliquots for chemical and microbiological laboratory analyses, carrying out a spatial analysis of geoenvironmental aspects such as modeling and land uses. The results of ammoniacal nitrogen, nitrate and microbiological indicators indicated the loss of water and socio-environmental quality, and local restrictions on use, including potability, in disagreement with Consolidation Ordinance No. 888/21, whose use of these waters represents a risk factor for exposure to pathogens and pollution. It is concluded that the results of the chemical and microbiological analyzes of the water and the spatial analysis of geoenvironmental aspects pointed to an environmental change associated with the activities of the CCQL, which demand environmental monitoring, health surveillance and the framing of the area of influence to the legislation, as provided for CONAMA Resolutions no. 357/05, no. 368/06, number: 402/08, NBR 10.157/87, NBR 15.495-1/07 and NBR 15.495-2/08.

Keywords: Aquifer, necrochorume, biosecurity, waterborne pathogens.

INTRODUCTION

The word cemetery, originating from the Greek: *koumeterian* and from Latin: *coemeteriun*, means dormitory, place where you sleep, place where the dead are buried (DA SILVA, SUGUIO, PACHECO, 2008). Matos (2001) points out that the cemetery assumed, from the advent of Christianity, the meaning of final rest, after death, with meaning only for places where corpses are buried. The cemetery can also be known by its synonyms, judging by necropolis, sheep, sepulchral, holy field, city of feet together and last dwelling.

Death ends the existence of the living being, the human being ceases to have legal personality and is called "corpse", in which the cemetery or necropolis translates the destiny of this organic matter, that is, of the "corpse" (SILVA & MALAGUTTI). SON, 2009). Disposing of the body of the deceased is a sociocultural and political practice that originated between the Paleolithic and Neolithic periods, in which the morphology of the "necropolis", or "cemetery", was composed of grouped graves, individual and collective tombs (CAMPOS, 2007).

In this sense, the idea of having a place of its own for the fate of the dead and preserving the memory of loved ones is very old, dating back to the cultural revolution of: *Homo sapiens*, or extinct relatives, for example: *Homo neanderthalensis*, preceding the formation of cities. Mumford (1998) understands, in this perspective, that the city of the dead precedes the city of the living, that is, that the city of the dead is the precursor, almost the nucleus, of the cities of the living.

In contemporary societies, in general, the cemetery can be considered a basic social and hygienic-sanitary equipment for society, environmental conservation and the health of the population (BATISTA, 2015). It is noteworthy, in addition to constituting a public health issue, the burial of bodies prevents the living from seeing and feeling the nauseating smell of the "corpse" that continues to decompose or even to the action of butchers (MUNFORD, 1998).

In this context, the funeral industry, which includes cemeteries, demands integrated environmental risk management plans, biosafety protocols and public health policies. Gwenzi (2021) points out that the world of environmental issues in the funeral industry includes, in addition to cemeteries, autopsy practices, thanatopraxy - embalming, funeral homes, the burial of human corpses in cemeteries and crematoria. In turn, McBean et al. (2018), K'orej et al. (2020) and Michael et al. (2020) point out that the universe of the funeral industry has sources and reservoirs of many pollutants, such as heavy metals, necrochorume, toxic organic compounds and emerging contaminants.

In cemeteries, cadaveric putrefaction begins with the microbial decomposition of tissues and results in the gradual transformation of tissues and the production of gases, including greenhouse gases, salts, necrochorume, diamines (cadaverine and putrescine) (POUNDER, 1995). Pires (2008) and Rodrigues and Pacheco (2010) emphasize that cemeteries must be well designed and managed in compliance with legislation and technical standards, avoiding the negative impacts of the products of cadaveric putrefaction in inhumation, burial and cremation on the environmental components, air, soil and water and public health.

Thus, the object of investigation characterized by the pollution of natural waters, mainly groundwater, resulting from cemetery activities, which is among the most studied environmental problems in the world associated with the issue of cemeteries, is delimited. Van Haren (1951), Marandola (2004), Aquino and Cruz (2010), Neira (2008), Romanó (2010) and Palma and Silveira (2011) investigated groundwater pollution by the product of cadaveric collision (necrochorum). In these studies, necrochorume, gases and radiation were the main polluters of groundwater from cemeteries. In relation to necrochorume, when this pollutant reaches the aquifer, it contaminates the water, whose socio-environmental consequences are aggravated if it is used as a source of drinking water.

In the context of the socio-environmental problems of necropolises, the UN (United Nations) and the WHO (World Health Organization) emphasize that the pollution of groundwater around cemeteries is a concern among the problems to human health. This is because access to drinking water reduces the prevalence of waterborne diseases, but failures in pollution control, sanitation and watershed monitoring can limit water management and the promotion of public health (MENDONÇA, 2017).

Pacheco (2002), De Almeida et al. (2006), Kim and Kim (2012), Zychowski and Brydal (2014) point out that necrochorume may contain pathogens, such as bacteria and viruses, which transmit diseases responsible for the *causa mortis*. This way, water polluted by necrochorume represents a risk factor for waterborne diseases, such as food poisoning, tuberculosis, typhoid fever, paratyphoid fever, dysentery, type "A" hepatitis. Furthermore, the management of environmental risks in the universe of necropolises can contribute to the prevention or reduction of damage from endemics, epidemics and pandemics.

As a result, necropolises demand management of risks of groundwater contamination, inside and around cemeteries, and monitoring of pollutants, such as necrochorume, cadaverine and putrescine (DENT; FORBES; STUART, 2004; LELI et al. al., 2012; PACHECO & MATOS, 2000; ŻYCHOWSKI et al. 2003). Furthermore, the application of pollution indicators, judging nitrate, heterotrophic bacteria and coliforms, can provide information for water quality management and health surveillance. Thermotolerant coliforms, enterobacteria, can be highlighted among the most used microbiological indicators in the investigation of water pollution by cemeteries. Thermotolerant coliforms, which include *Escherichia coli*, indicate recent pollution by endothermic feces and the presence of pathogenic bacteria, enteric viruses, among the pathogens (AMARAL et al., 2003).

In this sense, Batista (2014) pointed out the existence of groundwater use in the surroundings of the Complex of cemiteries: Quinta dos Lázaros, through wells and natural sources by street vendors, shopkeepers and residents. These waters are captured from the Alto Cristalino Aquifer System of Salvador, whose main form of water capture, according to Nascimento (2008), takes place locally through shallow or deep tubular wells and natural sources. This alternative use of water abstracted from the Alto Cristalino Aquifer System of Salvador is relevant in the events of shortage in the service of supply of the water system.

It is noteworthy, in this perspective, that in the city of Salvador, urbanization has integrated cemeteries into the urban fabric, creating risks of soil and natural water pollution, such as groundwater, and other sources (MORAES E NASCIMENTO, 2015). In this municipality, there was a shortage event that affected 41 neighborhoods in 2015, due to the rupture of the water main on the BR 324, which forced part of the population to seek an alternative, such as water from different sources and of unknown quality, from wells, fountains and spouts.

Porciúncula and Alencar (2020), Porciúncula, Alencar and Gonçalves (2021) point out that the suspension of the water supply service, which can exceed 24 hours, is recurrent in the Metropolitan Region of Salvador, including in the peripheral neighborhoods of the Salvador metropolis. Gonçalves et al. (2021) explained that there are inequalities in access and the non-universalization of basic sanitation services among the municipalities in the Metropolitan Region of Salvador.

These shortages, even those of low frequency, due to failures in sanitation and land occupation in the metropolis, can expose, above all, to low-income populations, in social vulnerability, in the search for alternative access to water, the a source contaminated by pathogens and waterborne infections. This scenario can be critical, from an epidemiological point of view, to low-income populations that reside or seek alternative access to water from wells, fountains and spouts around the cemeteries.

This way, this article aimed to investigate the level of influence of the Complex of cemiteries: Quinta dos Lázaros on the quality of groundwater due to the threat of chemical and microbiological contamination of these waters by necrochorume, among others, since some households use water from wells, or sources, which makes the user population vulnerable to exposure to pathogenic microorganisms and waterborne diseases. It is also noteworthy that the aforementioned contamination of groundwater restricts its uses, including as an alternative supply in cases of shortages.

MATERIALS AND METHODS

AREA OF STUDY

The Complex of cemiteries: Quinta dos Lázaros is located in the municipality of Salvador, State of Bahia, more precisely between the neighborhoods Dois Leões, Macaúbas (to the south), Barbalho (to the west), Cidade Nova (to the east) and Caixa D'Água. (to the north), with an active residential and commercial structure (Figure 1). This municipality is part of the hot and humid tropical climate domain, Af according to Köppen and Geiger, without a dry season, with an average annual temperature around 25 °C, minimum and maximum of 22.2 and 28.2 °C. The rainfall rate approaches 2000 mm/year, with rains distributed in a wettest four-month period (April to July) and two less rainy four-month periods (August to November; December to March), with predominant winds from the Southeast and relative humidity. annual average of 81% (INEMA, 2014), which are related to the coastal proximity, and air masses of tropical maritime currents.

The CCQL was built in the geological context of the Alto Cristalino of Salvador that is represented, according to Barbosa et al. (2005), by medium and high grade metamorphic lithotypes, deformed in a polyphase way and frequently cut by monzo-syenogranitic bodies and mafic dykes. It is noteworthy that the Salvador fault separates and delimits the Alto de Salvador from the Recôncavo Sedimentary Basin. The rocks that support the area are located in the so-called Salvador-Esplanada Belt (BARBOSA & DOMINGUEZ, 1996).

Regarding the modeled, the regional geomorphological evolution can be related to the pediment process, which produces the progressive retreat of the slopes in the elevated areas called Colina de Salvador. Thus, a gently undulating topography predominates, with flat parts, U-shaped valleys and an altitude of around 100 m (NASCIMENTO, 2008). The confluence between the compartmentalized block structure of the relief and the hot

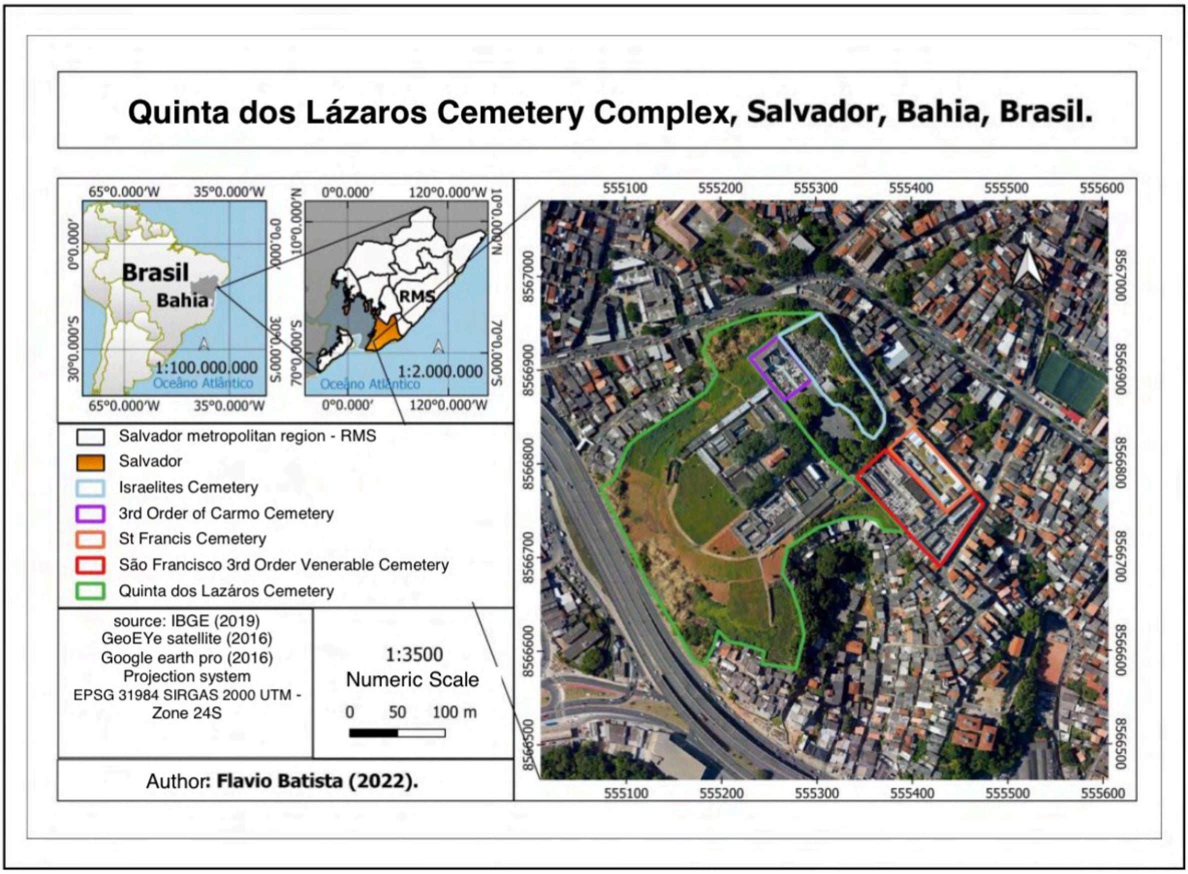

Figure 1 - Map of location and situation of the Cemetery Complex: Quinta dos Lázaros, Salvador.

Source: Own elaboration.

and humid tropical climate, with high temperatures and rainfall and excess water, provides recharge and the development of crystalline-fissural aquifers and granular units. The latter result from the chemical weathering of crystalline rocks, that is, from the regolith. Also, recharge and water table variation depend on storage capacity, which is more limited and restricted to the most fractured zones in crystalline-fissural aquifers.

Furthermore, the infiltration of water in the aquifer profile and the runoff (runoff) promotes chemical weathering of the minerals that form crystalline rocks, and pedogenesis, influencing the distribution of pedological horizons, the mineralogical composition of these horizons and the physical-physical properties. chemicals, fundamental to soil management in CCQL. It is expected that the influence of time and climate on the intensity of weathering of the crystalline rocks of Alto de Salvador and the predominance of oxide-hydroxides, followed by clay minerals from the vermiculite group (1:1). It is noteworthy, in this sense, that the entire hill, where the CCQL is located, is made up of regolith and mobilized soils, clayey orange-brown, called Alic Red-Yellow Latosols (Al saturation > 50%), with a moderate A horizon. and clayey texture, in a model with a flat to wavy tendency (EMBRAPA - SNLCS, 1981).

SPATIAL ANALYSIS

The spatial analysis of the water quality and the displacement of the surface flow of the Complex of cemiteries: Quinta dos Lázaros was based on the maps of the Cartographic System of the Metropolitan Region of Salvador, CONDER/ SEPLANTEC (1995). The dimensions of the topographic map SD24-XA-IV-4-SE were used, at a scale of 1:25,000 (CONDER, 1976), with the aid of the Surfer 8.0 software for its preparation, which resulted in a surface flow map in 3D, being plotted the directions and direction of the surface water flow, applicable in the spatial analysis for choosing the groundwater collection points and geoenvironmental diagnosis.

Points of internal comparison were established between the results of measurements of physical-chemical, chemical and microbiological variables of groundwater, according to the influence of CCQL, considering point P2 as the one with the greatest influence and point P5 as the one with the least influence. The latter (P5) is located in the opposite direction of the necrochorume and water flow displacement area, in accordance with the geomorphology and land uses and CCQL activities. The results of the physical-chemical and chemical analyzes in the surroundings of the CCQL, obtained by Nascimento (2008), were adopted in the external comparison. Furthermore, the spatial analysis integrated the results of the physical-chemical, chemical or microbiological variables of the water and the geo-environmental aspects.

The geoenvironmental characteristics, such as pedological aspects, displacement of surface and groundwater, and the patterns of land use in the CCQL's area of influence are important for soil management and the analysis of the pollution mitigation potential, the assessment of the vulnerability of the aquifer to pollutants (necrochorum, pathogens and trace metals) and the management of environmental risks and health risks from the spatial analysis of the environmental problem of the cemetery.

LABORATORY ANALYSIS - HYDRO-GEOCHEMICAL

The total of 3 groundwater samples and 2 spring water samples were collected, arranged in the host rocks of the Alto Cristalino Aquifer, in November 2013, at sampling points distributed around the Complex of cemiteries: Quinta dos Lázaros, Salvador (Figure 1). Measures were taken *in situ* of the physicochemical variables (pH, ORP, EC, STD, OD and DT), with the aid of a multiparameter probe (*Horiba U*-50), as well as aliquots were taken for laboratory analysis of chemical variables (Ca^{2+}, N-NH_3^-, N total, N-NO_3^-, N-NO_2^-, SO_4^{2-}, Cl^-, P total), in polyethylene containers (0.5 L, 1.0 L), according to the guidelines of the *Standard Methods fot the Examination of Water na Wastewater* APHA (2008) (Table 1).

In this context, the decontamination and identification of the sample collection recipients were previously carried out. Regarding the conservation of the samples, it remained *in natura* aliquots destined for anion analysis (1L), refrigerated at ±4 °C. Chemical and microbiological analyzes were carried out in the laboratories of the National Service for Industrial Learning (SENAI) or the Pedro Ribeiro Industrial Technology Center (CETIND).

LABORATORY ANALYSIS - MICRO-BIOLOGICAL

Aliquots of water were taken for microbiological analyses, with 100 ml sterile plastic collectors, containing 0.1 ml sodium thiosulfate (Na2S2O3), which were refrigerated in a styrofoam box with ice (±4 °C)

Testing	Unit	Method	Method Quantification Limit - MQL
N-Nitrate (N-NO3-)	$mg.L^{-1}$	EN 138 QGI (EPA 300.1-1)	0,003
N-Nitrite (N-NO2-)	$mg.L^{-1}$	EN 138 QGI (EPA 300.1-1)	0,007
Ammoniacal nitrogen (N-NH3-)	$mg.L^{-1}$	EN 039 QGI (SMEWW 4500 NH_3^- F)	0,03
Total nitrogen (N total)	$mg.L^{-1}$	EN 050 QGI	1,60
Total phosphorus (P total)	$mg.L^{-1}$	EN 013 QGI (SMEWW 4500-P E)	0,013
Chloride (Cl-)	$mg.L^{-1}$	EN 138 QGI (EPA 300.1-1)	0,03
Sulfate (SO42-)	$mg.L^{-1}$	EN 138 QGI (EPA 300.1-1)	0,03
Calcium (Ca2+)	$mg.L^{-1}$	EN 005 QGI (SMEWW 2340 A, B, C)	0,65
Hardness (DT)	$mg.L^{-1}$	EN 301 (EPA 6010B/3010A)	1,0

Table 1 Methods of quantification of chemical indicators of water quality.

Own elaboration, based on the data of the reports delivered by the laboratories: SENAI/CETIND.

Testing	Unit	Method	Method Quantification Limit - MQL
Heterotrophic bacteria	$UFC.mL^{-1}$	EN 002 MIC (SMEWW 9215 A, B)	1
Total coliforms	$UFC.100\ mL^{-1}$	EN005 MIC (SMEWW 9222 A,B, C)	1
Thermotolerant coliforms	$UFC.100\ mL^{-1}$	EN 005 MIC (SMEWW 9222 A,B, C)	1
Escherichia coli	$UFC.100\ mL^{-1}$	EN 021 MIC (SMEWW 9213 D)	1
Mesophilic aerobic bacteria	$UFC.100\ g^{-1}.mL^{-1}$	EN 044 MIC (AOAC – 990.12)	-
Enterococcus faecalis	$UFC.100\ mL^{-1}$	EN 019 MIC (SMEWW 9230 A, C)	-
Salmonella sp.	P/A 100 mL	EN 006 MIC (IN 62)	-

Table 2 – Methods of quantification of water quality indicator microorganisms.

Source: Own elaboration, from the analytical methods of the SENAI/CETIND laboratories, which were based on the *Standard Methods fot the Examination of Water Wastewater* (APHA, 2008).

until the laboratories from SENAI/CETIND. In these aliquots, the heterotrophic bacteria, thermotolerant coliforms, *Escherichia coli*, mesophilic aerobic bacteria *Enterococos faecalis*, from what the *Standard Methods fot the Examination of Water na Wastewater* (APHA, 2008), in which the results were expressed in colony forming units – CFU (Table 2). The Presence-Absence method was applied with enzyme substrate in the analysis of *Salmonella spp*.

STATISTICAL ANALYSIS

In the statistical analysis, descriptive and inferential approaches were adopted, as well as measures of position or dispersion and the performance of tests to evaluate the normality of data distribution (*Shapiro-Wilk*). Then, multiple comparison tests were applied in the analysis of parametric data (*One-Way* - ANOVA), or in the analysis of non-parametric data (*Kruskal-Wallis*), to identify significant differences, with a 5% confidence level.

RESULTS AND DISCUSSION

HYDROGEOCHEMICAL CHARACTERIZATION

Slightly acidic waters were dominant, whose pH values ranged from 5.3 to 6.7, with a mean of 6.0 and a median of 6.1 (Table 3). The pH values of points P1 and P4 were lower than the minimum value recommended by CONAMA Resolution number: 396/08 for all freshwater classes. The hydrogenic potential (pH) in water bodies is influenced by changes in temperature, biological activity and effluent discharge (FRANCA, 2006). Furthermore, in the CCQL universe, the pH of groundwater, and other variables such

Point	Location	°C		mV	mg.L^{-1}								
		Temp.	**pH**	**ORP**	**STD**	**Ca^{2+}**	**OD**	**DT**	Cl^-	SO_4^{2-}	N-NH_3^-	N-NO_3^-	P Total
P01	Fountain of Stones	25.20	5.30	355.00	453.05	33.80	4.20	119.00	67.4	51.90	0.03	16.80	<0.04
P02	Mechanical Workshop I	26.50	6.10	291.00	515.45	50.30	3.92	153.00	68.0	56.40	0.09	14.20	<0.04
P03	Source	28.80	6.70	377.00	425.75	31.00	5.99	121.00	49.0	44.50	0.03	21.40	<0.04
P04	Mechanical Workshop II	26.60	5.40	415.00	458.25	33.90	6.36	107.00	67.1	60.90	0.02	18.80	0.07
P05	Reseller	28.00	6.50	375.00	246.35	19.50	7.33	71.50	47.5	20.00	0.02	0.05	<0.04
	V.M.P.	-	6-9.5	-	1000.00	75.00	-	500.00	250.00	250.00	1.50	10.00	-
Minimum		25.20	5.30	291.00	246.35	19.50	3.92	71.50	47.50	20.00	0.02	0.05	-
Maximum		28.80	6.70	415.00	515.45	50.30	7.33	153.00	68.00	60.90	0.09	21.40	-
Average		27.02	6.00	362.60	419.77	33.70	5.56	114.30	59.80	46.74	0.04	14.25	-
median		26.60	6.10	375.00	453.05	33.80	5.99	119.00	67.10	51.90	0.03	16.80	-
Standard deviation		1.40	0.63	45.50	102.29	11.01	1.46	29.37	10.56	16.13	0.02	8.36	-
Standard Error		0.63	0.28	20.70	45.75	4.92	0.65	13.13	4.72	7.21	0.01	3.74	-
Coefficient of variation (%)		5.20	10.54	12.60	24.37	32.66	26.21	25.69	17.66	34.51	77.62	58.69	-
SW (p value)		0,82 [A]	0,38 [A]	058 [A]	0,15 [A]	0,56 [A]	0,50 [A]	0,81 [A]	0,02 [B]	0,26 [A]	0,01 [B]	0,15 [A]	-

V.M.P.: maximum value allowed by Ordinance number: 888/2021 (BRASIL, 2021), or value recommended by W.H.O (2006); [A]: Gaussian distribution; [B]: Non-Gaussian distribution.

Table 3 - Statistical summary of hydrogeochemical variables of groundwater samples and sources.

Source: Own elaboration.

as calcium, chloride and sulfate ions, can be influenced, in addition to soil uses and occupation, and pollution by necrochorume, on the infiltration of water into the soil and in the aquifer, the water-rock interaction, the minerals that make up the rocks that host the aquifer and its attributes.

The analysis and interpretation of the redox potential (ORP) values allowed the characterization of the oxidizing environment, so that the ORP values oscillated between 291.00 and 415.00 mV, with a mean of 362.60 and a median value equal to 375.00 mV (Table 3). This oxidizing condition of the medium favors the hydrochemical evolution of the nitrogenous compounds of ammoniacal nitrogen (NHO3-) until they accumulate as nitrate ions (NO3-), a more oxidized form, from the beginning of the decomposition of organic matter, in the context of cadaveric putrefaction. associated with the CCQL cemetery. Batista (2015) points out that in the putrefactive process, the deceased generates necrochorume, which is rich in nitrogenous compounds such as diamine, cadaverine and putrescine that undergo hydrolysis, oxidize ammonia and produce nitrate ions in an oxidizing medium.

Regarding the levels of nitrate (N-NO3-) in the water samples, values that ranged from 0.05 (P5) to 21.8 mg.L-1 (P2) were obtained, with an average of 14.25 mg.L-1 and median of 16.8 mg.L-1 (Table 3), exceeding in 80% of the samples the potability limit recommended by Ordinance No. 888/21 (BRASIL, 2021). There is also a contrast between the levels of dissolved oxygen at point P2, under greater influence of CCQL pollution, when compared to the levels of this variable at point P5, under less influence of CCQL pollution. Thus, it is inferred that failures in the containment of cadaveric decomposition products, such as necrochorume, resulting from CCQL activities, may represent a source of soil pollution, whose leaching of these pollutants dissolved in the water that infiltrates the aquifer profile, or by infiltration of necrochorume, in this same profile, these waters can pollute these waters with different pollutants, such as metals, solvents, drugs, endocrine disruptors and nitrogenous compounds from cadaveric decomposition, diamines (cadaverine and putrescine).

The presence of the highest levels of NH3- in the samples indicates a recent contribution of organic load from a polluting source (Table 3), but the accumulation of nitrate, in an oxidizing medium, indicates the existence of a continuous source of pollution, which is relate, in this work, to a large extent, to the deviations that result from the ineffectiveness of CCQL's environmental risk management. The relevance of point P2 is highlighted in the assessment of the environmental impacts resulting from the CCQL, which promote the compromise of groundwater chemistry and risks to public health. In addition, pollution associated with cemeteries activities must be treated as a priority, because they have environmental and epidemiological relevance, highlighting the threat of avoidable exposure of the population to water contaminated by microbial pathogens carried by necrochorume.

Regarding the mineralization of the waters, the TDS contents ranged from 291.00 (P2) to 415.00 mg.L-1 (P5), with an average of 362.60 mg.L-1, median of 375.00 mg.L-1 (Table 3). These values of the STD of the water samples were not an impediment to its use, even if considering what is recommended by Ordinance No. 888/21 (BRASIL, 2021), however it is indicated that the definition of uses of these waters depends on a broader assessment consider other hydrochemical variables, judging by nitrate levels found, or microbiological variables. In this sense, it is considered that the uses of these waters by the low-income population in the CCQL's area of influence represent a way of exposing this population to health risks.

Calcium ion concentrations in groundwater samples ranged from 19.50 (P05) to 50.30 mgL-1 (P02), with a mean of 33.70 mgL-1 and a median of 33.80 mgL-1 (Table 3). It is verified the presence of analytical contents of the measures of the physicochemical variables (STD and OD) or of the chemical variables (nitrate, sulfate, calcium, DT) in the sampling points P1, P3 and P4 are located in an intermediate position to the analytical contents of the points of internal comparison, although they are closer to the concentrations of point P2, under a greater influence of CCQL.

The contents of the hydrochemical variables of the present study, under the influence of CCQL pollution, were compared with the contents of these variables obtained at the external comparison points (I -Crystalline Aquifer and II - Porous Aquifer), selected from wells disposed in the Aquifer of the Alto Cristalino de Salvador, provided they are located in the vicinity of the CCQL, being taken from the hydrogeochemical research by Nascimento (2008) (Table 4). It can be noted, therefore, that the median levels of calcium in the CCQL samples exceeded the median levels found in the external comparison points, except at point P2, under a lesser influence of the CCQL. It is inferred, therefore, that the products of cemetery activities, especially necrochorume, possibly influence the calcium contents of groundwater in the CCQL's area of influence.

It is noted that the median pH values in groundwater samples from the CCQL's area of influence differed significantly from the pH values of groundwater from the Porous Aquifer or the Alto Cristalino Aquifer (Figure 2 a). Furthermore, the pH values of the water samples in the present study are between the pH values of the more acidic waters of the Porous Aquifer and the slightly acidic to alkaline waters of the Crystalline Aquifer. The pH of groundwater in the CCQL's area of influence can be influenced by the chemical demand and the biochemical demand associated with the products of

Sample Estimator	pH			STD			SO_4^{2-}			Ca^{2+}		
	Actual	I	II	Actual	I	II	Actual	I	II	Actual	I	II
Minimum	5,30	6,50	4,90	246,35	78,00	120,00	47,50	42,10	53,20	19,50	8,20	6,70
Maximum	6,70	7,30	5,40	515,45	455,00	700,00	68,00	60,80	118,00	50,30	46,00	27,00
Average	6,00	6,90	5,26	419,77	263,47	405,33	59,80	50,66	67,82	33,70	23,44	15,74
median	6,10	6,80	5,30	453,05	260,65	401,00	67,10	49,40	55,30	33,80	14,00	15,00
Standard deviation	0,63	0,34	0,21	102,29	167,88	258,27	10,56	8,43	28,10	11,01	16,56	7,78
Standard Error	0,28	0,15	0,09	45,75	68,53	105,44	4,72	3,77	12,57	4,92	7,41	3,48
Coefficient of variation (%)	10,54	4,91	3,94	24,37	63,72	63,72	17,66	16,64	41,43	32,66	70,65	49,43
Shapiro-Wilker (p-value)	0,38 [A]	0,56	0,023 [A,B]	0,146 [A]	0,11 [A]	0,11 [A]	0,02 [B]	0,38 [A]	0,001 [B]	0,56 [A]	0,22 [A]	0,95 [A]

I - Crystalline Aquifer (Fissural), data provided by Nascimento (2008).

II - Porous Aquifer (Regolith), data provided by Nascimento (2008).

[A]: Gaussian distribution; [B]: Non-Gaussian distribution.

Table 4 – Statistical summary and comparison of the results of the analysis of the hydrogeochemical variables of samples from the CCQL's area of influence and from the hydrogeological investigation of Birth (2008).

Source: Own elaboration.

cadaveric putrefaction.

In this context, it is observed that the calcium content, in addition to the sulfate ion content, in the groundwater samples from the CCQL's area of influence were higher than the calcium content of the water samples from the external comparison points listed. to the Alto Cristalino Aquifer (Fissural) or to the waters of samples from the Porous Aquifer (Regolito) (Figure 2 cd). It is assumed that the cemetery activities represent relevant sources of necrochorume, calcium, sulfate and chloride for soils and groundwater in the CCQL's area of influence. The products of cemetery activities and cadaveric decomposition represent sources of soil and groundwater pollution by calcium, chloride, sulfide, ammonia nitrogen and nitrate ions. This highlights the importance of the environmental impacts of cemeteries on the quality of soil and water, even in areas under the influence of urbanization and sanitation failures.

The ionic activities of calcium and sulfate are more expressive in the CCQL's area of influence when compared to the external comparison points, providing key indicators for the assessment of the environmental impacts of the cemetery activities on water quality (Figure 2c-d). Furthermore, there is a contrast between the concentrations of the total dissolved solids variables and the ionic activities of the calcium cation and the sulfate anion between the internal comparison points,

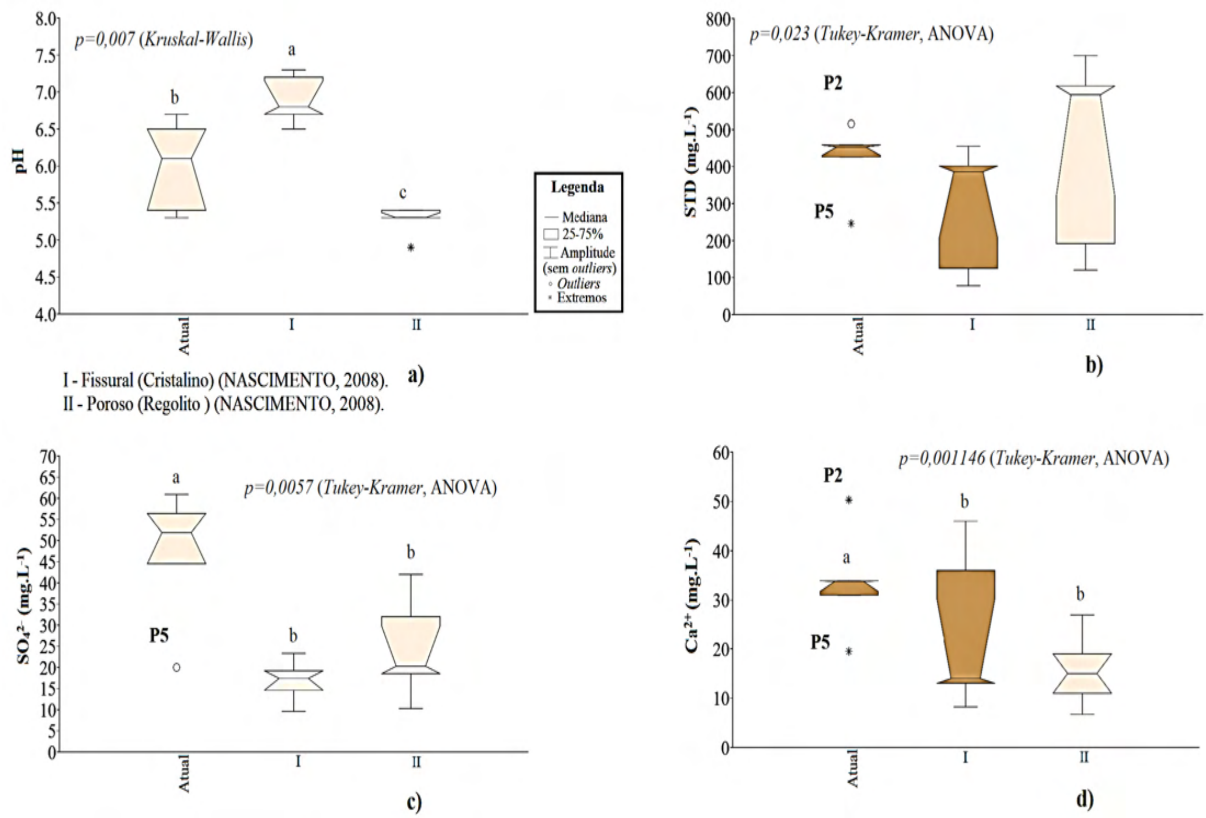

Figure 2 – Box-plot diagram for comparative analysis of the dispersion of hydrogeochemical variables from samples from the CCQL's area of influence and from Nascimento's hydrogeological investigation (2008).

Source: Own elaboration.

which confirms the correct choice of this methodological strategy for the assessment of environmental impacts. of CCQL's cemetery activities on water quality.

It is proposed that the calcium contents in the water samples in the CCQL's area of influence originate mainly from natural sources, from the chemical weathering of the minerals that constitute the rocks, which host the Alto Cristalino Aquifer System of Salvador, although the addition of quicklime in burials and the leaching of calcium from cadaveric decomposition products contribute to the enrichment of groundwater in calcium in the CCQL's area of influence (Figure 2 d). It is inferred that the Ca2+ contents reflect the influence of cemetery activities, climatic, geomorphological, pedogenetic aspects, vegetation cover and chemical weathering of minerals in the host rocks of the Alto Cristalino Aquifer System of Salvador.

Nascimento (2008) investigated the hydrogeochemistry of the Alto Cristalino of Salvador, obtaining as the most representative hydrochemical types the sodium facies (65.6%), mixed (31.2%) and, secondarily, the calcium hydrochemical facies (3.1%). This author related the mixed facies to the influence of chemical weathering of the mineral phases present in the altered rock (regolith) and in the crystalline rocks. In this sense, he proposed that the ionic activity of Ca2+ in groundwater samples could originate mainly from the chemical weathering of the amphibole, clino, orthopyroxene, biotite and calcic plagioclase mineral phases of tonalitic granulites in the local geology; as well as charnoenderbites and associated mafic and ultramafic bodies.

It is also noted the presence of levels of the variables ammoniacal nitrogen and nitrate that exceed the maximum value allowed by Resolution no. 305/2005 of CONAMA (BRASIL, 2005), or that locally restrict the uses and conditions of potability, as provided in Ordinance number: 888/2021 (BRASIL, 2021) (Table 5). It is noteworthy

Sample Estimator	Ammoniacal Nitrogen ($N-NH_3^-$)		Nitrate ($N-NO_3^-$)	
	Actual	I	Actual	I
Minimum	0,02	0,10	0,05	0,50
Maximum	0,09	3,50	21,40	33,00
Average	0,035	1,11	14,25	10,58
median	0,04	0,22	16,80	5,75
Standard deviation	0,026	1,50	8,37	13,14
Standard Error	0,01	0,61	3,74	5,36
Coefficient of variation (%)	63,35	135,83	58,71	124,12
Shapiro-Wilker (p-value)	0,15[A]	0,01[B]	0,16[A]	0,10[A]
V.M.P.	**1,50**	**1,50**	**10,00**	**10,00**

I - Crystalline Aquifer (Fissural), data provided by Nascimento (2008).

[A]: Gaussian distribution; [B]: Non-Gaussian distribution; V.M.P.: maximum value allowed by Ordinance number: 888/2021 (BRASIL, 2021), or by CONAMA Resolution number: 357/05, or the value recommended by W.H.O (2006).

Table 5 - Statistical summary and comparison of the results of the analysis of the variables ammoniacal nitrogen and nitrate of the water samples of the CCQL and of the hydrogeological investigation of Nascimento (2008).

Source: Own elaboration.

that the highest levels of ammonia nitrogen at point P2, considered one of the points of internal comparison, under greater influence of CCQL, although it can be noted that the measurements of ammoniacal nitrogen are more expressive in the points of external comparison, revealing the influence of sanitation failures on water quality. However, the most expressive ionic activities of nitrate are recorded in water samples from the area of influence of the CCQL, a chemical species nitrogen that accumulates under oxidizing conditions.

From the analysis and interpretation of figure 3b, it can be seen that the dispersion of the average or median levels of nitrate in the water samples under the influence of the CCQL did not differ significantly from the results of this inorganic pollution indicator obtained in the groundwater samples of the external comparison points, related to the Fissural Aquifer (I). It is also noted that the analysis of the box-plot diagram indicated that there would be less dispersion of data in the samples collected in the present study, in the area of influence of the CCQL. Furthermore, the value of the average, or the median, of the ionic activity of nitrate reveals pollution of groundwater in the area of influence of CCQL's cemetery activities, or of the forms of land occupation and failures of public sanitation services in the surrounding area. of the CCQL.

Mendes and Oliveira (2004) emphasize that nitrate values greater than 5.0 mg.L-1 in groundwater indicate pollution and restriction of water use and risks to public and collective health. With this, attention must be paid to the environmental and health risks related to the uses of groundwater in the area of influence of the CCQL, or its surroundings, without its physical-chemical and microbiological quality being known, or adequate treatment being carried out. Thus, environmental monitoring, health surveillance, water and environmental management, environmental

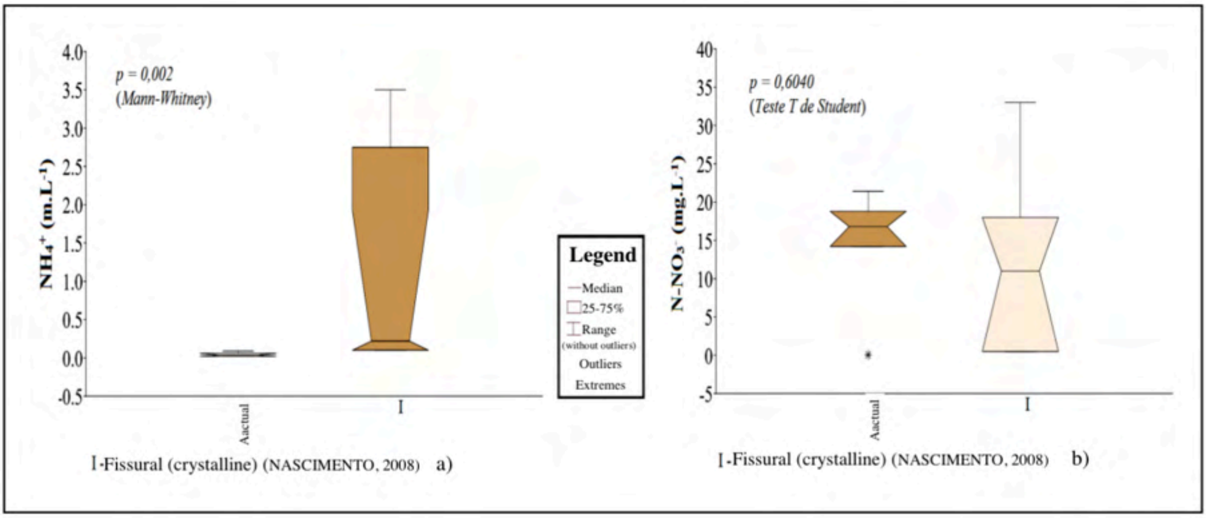

Figure 3 – Box-plot diagram for comparative analysis of the dispersion of the variables ammoniacal nitrogen and nitrate from the water samples from the CCQL and from the hydrogeological investigation by Nascimento (2008).

Source: Own elaboration.

risk management and interventions in environmental sanitation conditions are demanded.

MICROBIOLOGICAL ANALYSIS - WATER QUALITY AND HEALTH THREATS

The microbiological quantification of groundwater samples in the area of influence of CCQL's cemetery activities revealed the presence of local restrictions on water use, including potability, in relation to heterotrophic bacteria (20%), *E. faecalis* (20%) and thermotolerant coliforms (40%), that include *E. coli* (20%) (Tabela 6), based on the provisions of CONAMA Resolution number: 396/08 (BRASIL, 2008) and Ordinance number: 888/21 (BRASIL, 2021). The results of the microbiological quantification suggest that the uses of groundwater in the area of influence of the CCQL's cemetery activities must be restricted because they threaten public and collective health, and must be avoided as an alternative to access water in episodes of shortages, especially use for human consumption.

Figure 4 allows the integrated analysis of the hydrochemical and microbiological results of the water samples in the area of influence of the CCQL's cemetery activities, highlighting the local restrictions on potability in relation to the provisions of Conama Resolution no. 396/08 (BRASIL, 2008), Ordinance number: 888/21 (BRASIL, 2021) or W.H.O (2006). In this context, the use of water in the CCQL's area of influence must be based on the integration of the results of the analysis of the physical-chemical and microbiological quality of the water, in the assessment of environmental risks and the biosafety protocols applicable to the problem of cemeteries.

It is revealed that there are local restrictions on the use of these waters, including potability, regarding microbiological variables, in addition to the inorganic indicators of water pollution (N-NO3-), according to the results of analysis of groundwater samples from the area of influence of CCQL, which describe

Point	Location	UFC.100 $g^{-1}.mL^{-1}$	UFC.mL^{-1}	UFC.100 mL^{-1}			P/A 100mL
		Bacteria mesophilic aerobes	Bacteria heterotrophic	Coliforms thermotolerant	*E. coli*	*Enterococcus faecalis*	*Salmonella sp.*
P01	Fountain of Stones	$5,0 \times 10^1$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	Absence
P02	Mechanical Workshop I	$3,0 \times 10^2$	$2,7 \times 10^2$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	Presence
P03	Source	$1,0 \times 10^1$	$7,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	Absence
P04	Mechanical Workshop II	$3,4 \times 10^2$	$3,1 \times 10^2$	5,0	$2,0 \times 10^0$	$3,1 \times 10^1$	Absence
P05	Reseller	$1,8 \times 10^4$	$9,5 \times 10^3$	$1,0 \times 10^0$	$< 1,0 \times 10^0$	$< 1,0 \times 10^0$	Absence
V.M.P [A]		-	**500**	**< 1**	**< 1**	**< 1**	**Absence**

[A] Decree, number: 888/2021; CONAMA 396/08; W.H.O. (2006).

Table 6 - Microbiological analyzes of groundwater samples and sources around the CCQL.

Source: Own elaboration.

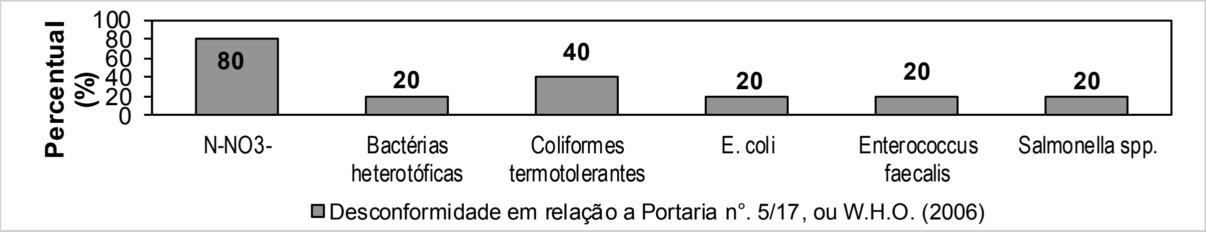

Figure 4 - Percentages of water samples that showed potability restriction in relation to hydrochemical and microbiological variables in the area of the Cemetery Complex: Quinta dos Lázaros.

Source: Own elaboration.

precarious hygienic-sanitary conditions (Figure 4). In the context of cemeteries pollution, Martins et al. (1991) and Neckel et al. (2017) point out that from a public health perspective, hygienic-sanitary aspects must be investigated with the help of microbiological indicators of pollution of fecal origin, as well as pathogens.

It is noteworthy that the presence of enterobacteria from the thermotolerant coliform group, which includes *Esclerichia coli*, indicated restriction of water use, and even of potability, in a total of 40% of the samples, despite the low values quantified in this study (Table 6). The quantification of bacteria: *Enterococcus faecalis* indicated the local loss of water quality, corroborating the results of the quantification of thermotolerant coliforms. It is noteworthy that bacteria: *E. faecalis* are also excreted in human feces, being found in smaller amounts than when compared to bacteria of the coliform group, such as: *E. coli.*

In this sense, the presence of salmonella, *Salmonella ssp*. (*Enterobacteriaceae*) in the water samples and the highest values of the NH3- variable at the internal comparison point P2 (Mechanical Workshop I) indicate a situation of local contamination of groundwater by products of CCQL cemetery activities, mainly necrochorume; as well as indicate that the sample point P02 is located closer to the polluting source. It is noteworthy, therefore, that the decomposition of organic compounds that constitute necrochorume produces a diversity of diamines, with high toxicity, such as putrescine (C4H12N2) and cadaverine (C5H14N2), whose degradation by the microbial metabolism of organic compounds produces NH3 -. It is also possible to quantify in the liquid produced by cadaveric putrefaction, or necrochorume, high virus load, heterotrophic, proteolytic and lipolytic bacteria; as well as pathogens.

It is understood that pollution and microbiological contamination of groundwater in the area of influence of CCQL's cemetery activities is not dissociated from pollution and microbiological contamination of soils, on the contrary, research on pedological attributes and the role in natural attenuation of pollution and contamination of surface and groundwater. In this clipping, the finding of alteration in the quality of the soil and water when indicated by the assessment of environmental impacts of the activities of the cemeteries points to a situation of flagrant disagreement with the provisions of CONAMA Resolutions no. 357/05, no. 368/06, number:402/08 and to which the technical standards (NBR) proposed by the Brazilian Association of Technical Standards

(ABNT) guide, pointing to NBR 10.157/87, NBR 15.495-1/07 and NBR 15.495- 2/08.

It must be noted that the Complex of cemiteries: Quinta dos Lázaros and other municipal cemeteries in Salvador, such as the Cemitério de Ilha de Maré and the Cemitério do Campo Santo, demand management of environmental risks, which include monitoring soil pollution and water by products of cadaveric putrefaction, such as necrochorume and diamines. Leite (2009) obtained values for the quantification of thermotolerant coliforms above 200 CFU.100 ml-1 in groundwater samples in the area under the influence of the Cemitério da Ilha de Maré, in Santana, Salvador, Bahia, but could not prove the relationship between cemetery activities and the quantification of coliforms, because the loss of the microbiological quality of the water also covered the points outside the area under the influence of the cemetery.

Machado and De Almeida (2008) explained the influence of sanitary sewage failures and forms of land use and occupation on water from sources and wells on Ilha de Maré. These authors obtained local restrictions on use and potability for the variables ammoniacal nitrogen, nitrate and thermotolerant coliforms in water samples collected in Santana, Botelho and Praia Grande, on Ilha de Maré, Salvador. In this context, it would be up to monitor the impacts of sanitary sewage and the activities of the cemetery.

Santos, Moraes and Nascimento (2015) observed the absence of *Esclerichia coli* in the water samples in the area under the influence of Campo Santo Cemetery, Salvador, Bahia, but the presence of bacteria: *Clostridium perfringens*, sulphite reducing agents, indicated the loss in water quality. The presence of thermotolerant coliforms, such as E. coli, in a water sample reveals a precarious hygienic-sanitary situation and a recent fecal contamination of human origin, or other endothermic ones, which demands restriction of water use (DAWSON; SARTORY, 2000; MORAES; JORDÃO, 2002; LEÃO et al., 2018). However, Martins et al. (1991) indicated that the use of thermotolerant coliforms as indicators of enteric pathogens present in water is limited because these bacteria have a shorter survival time in soil and groundwater than certain pathogens.

As a result, there is a demand for environmental monitoring and assessment of the environmental impacts resulting from the products of CCQL's cemetery activities on water, soils and the health of the population that resides or uses natural waters in the CCQL's area of influence. Therefore, it is emphasized that the application of microbiological indicators in the assessment of water quality under the influence of cemeteries covers thermotolerant coliforms, *Pseudomonas aeruginosa* and *Enterococcus faecalis* (MARTINS *et al*.; 1991; DE ALMEIDA *et al*., 2006; KIM; KIM, 2012; ZYCHOWSKI; BRYNDAL, 2014; SANTOS *et al*., 2015; NECKEL *et al*., 2017; MASSAS *et al*., 2018; TURAJO *et al*., 2019). These authors point out that the species of the genus Clostridium, especially the species Clostridium perfringes, represent the best microbial indicators for the assessment of water pollution by necrochorume.

SPATIAL ANALYSIS, GEOENVIRONMENTAL AND WATER QUALITY ASSESSMENT

The spatial analysis integrated the results of the investigation of the chemical and microbiological quality of the water, the occupation of the soil, the climatic and geoenvironmental attributes and the displacement of the superficial flow of the Complex of Cemeteries: Quinta dos Lázaros (Figure 5). In this geoenvironmental context, the water sample from the collection point P2 (Mechanical Workshop I), which constitutes

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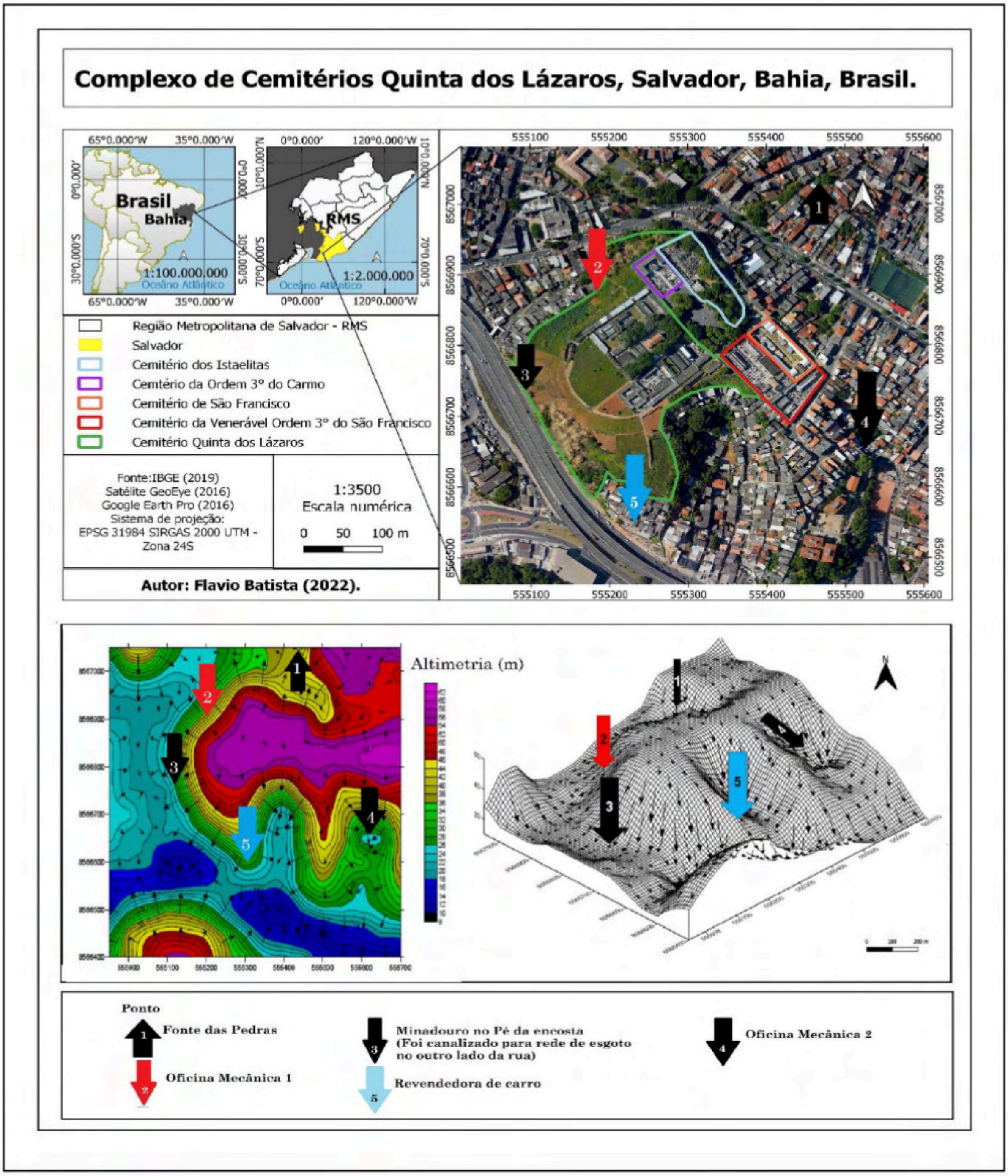

Figure 5 - Collection points around the Complex of cemiteries: Quinta dos Lázaros, and 3D surface flow.

Source: Own elaboration.

the internal comparison points, showed the highest ionic activities of ammoniacal nitrogen (N-NH3-), even in an oxidizing environment, of calcium, of DT and STD, as well as the lowest levels of dissolved oxygen, configuring the loss of quality. It is proposed that the contribution of organic matter associated with necrochorume pollution contributes to the depletion of DO levels and the likely increase in the biochemical oxygen demand.

The sample point P2 is located southwest of the Complex of cemiteries: Quinta dos Lázaros, situated at the back of a mechanical workshop which borders the CCQL (Figure 5). It is also possible to observe higher relative levels of ammoniacal nitrogen at point P2 than at other sample points in the CCQL's area of influence, which suggested that this sampling point must be in the vicinity of the source and characterizes a recent pollution of cadavers, a hypothesis that was supported by the presence of the pathogen Salmonella ssp.

In the southwest portion of the Complex of cemiteries: Quinta dos Lázaros (Figure 5), the pits are distributed on the top and on the topographic slope, close to the groundwater catchment area where the mechanic shop is located (P2). This workshop is located in the lower part of the model and is surrounded by the CCQL, configuring an area that receives pollutants that move along with the flow of surface water (runoff) and the displacement of groundwater in one of the preferential lines of flow, which passes through the Cemeteries of the Israelites and that of the Ordem Terceira do Carmo. Pollutants leached from the soil and regolith from the burial area reach the groundwater and are transported to receiving areas (point P2).

To leach and transport of pollutants from soils, under the influence of products of cadaveric decomposition in the area of influence of the CCQL, to waters, vary depending on the demand for inhumation and can be enhanced in the wettest four months (April to July), which coincides with the filling of the vacancies available for burial in the CCQL. The environmental impacts of cemeteries on water quality must be monitored in the Metropolitan Region of Salvador, and metropolis, Salvador, considering the influence of rainfall in the two least rainy quarters and in the wettest quarter.

From this point of view, the loss of chemical and microbiological quality of groundwater in the area of influence of CCQL's cemetery activities, especially the samples from point P2, demonstrates non-compliance with environmental legislation and specific legislation for the management of cemeteries. Thus, in the universe of environmental risk management and biosafety, it is noteworthy that CONAMA Resolution number: 368/06 (BRASIL, 2006) recommends that cemeteries must be kept away from water bodies, avoiding altering their quality or restrict its use. It also provides that cemeteries have an efficient drainage system on their perimeter and interior that can prevent soil erosion, flooding and earth movement.

Pollution of soils, surface and underground waters and ecosystems resulting from cemetery activities pose risks to public and collective health and must not be tolerated. It must be noted that cemeteries must have a project that includes measures to mitigate impacts and environmental control, including after correcting deviations from current legislation, assuming that necrochorume originates from cadaveric decomposition in the first year after death, as recommended by CONAMA Resolution, number: 368/06 (BRASIL, 2006). Leite (2009) points out that the corpse must remain buried until the complete decomposition of organic matter, at least for three years, as provided by the legislation applicable to cemeteries.

The presence of nitrate levels is verified in the water samples in the CCQL's area of influence and in the samples from the external comparison points, in the area around the CCQL, which are in disagreement with the provisions of environmental legislation and Ordinance 888/21 (BRAZIL, 2021). It is noteworthy that the presence of high levels of nitrate in the water may indicate pollution resulting from sanitation failures, as well as that the ingestion of these waters can cause harm to human health (YANG et al., 1998; SANTOS, 2017; BATISTA et al.., 2021). Silva and Araújo (2003), Mendes and Oliveira (2004), Magnoni et al. (2007), Gonçalves et al. (2018), Hirata et al. (2020) and Gonçalves et al. (2021) point out that the presence of high levels of nitrate in aquatic ecosystems indicates its pollution by a source, which restricts water uses, representing, in particular, a threat to the health of the low-income population.

In this clipping, it is proposed that part of the nitrate pollution of water samples, even those collected at the foot of the CCQL area (point P2), can be attributed to sanitation failures, although the CCQL area is inserted in the context of the Program Bahia Azul, the most robust program to improve sanitary conditions in Bahia, since the 1970s. This way, it is understood that the impacts of pollution resulting from sanitation failures, mainly from sanitary sewage problems, on water quality in the area of influence of the CCQL explain a demand for improving living and health conditions and for overcoming asymmetries in access to sanitation in the city of Salvador, in the Metropolitan Region of Salvador, in Bahia, in the Northeast of Brazil, in the country and in America Latin.

This way, the results of the integration of the data of the present research, allowed by the spatial analysis, suggest that the loss of water quality in the area of influence of the CCQL can be related to environmental pollution associated with the activities of the cemeteries, as well as not to be neglected. the negative environmental impacts of sanitation failures. With this, it is emphasized that the consumption of water collected from springs on the influence of microbiological contamination by necrochorume and other pollutants in the surroundings of the CCQL has socio-environmental and epidemiological relevance for the population that uses this water. Access to springs and distribution water in the public supply, without care with quality and treatment, stands out among the transmission routes of pathogens, and the potability condition must be evaluated on an ongoing basis (SCALIZE et al., 2014).

In this sense, the set formed by negative environmental impacts and threats to public health associated with underground pollution in the CCQL's area of influence must be monitored annually, in accordance with NBR 15495-1 (ABNT, 2007) and 15495-2 (ABNT, 2007). It is also required the implementation of monitoring and sampling wells, whose annual sampling must be arried out in cemeteries in operation for more than five years. While for recent cemeteries, whose period of operation is between one and five years, environmental monitoring and a biannual sampling plan are applied, with points arranged upstream and downstream of the area of influence.

This geo-environmental and groundwater quality diagnosis in the CCQL's area of influence configured a socio-environmental framework that generally requires environmental management, improvement of hygienic-sanitary conditions, monitoring of nitrate and other pollutants, such as necrochorume, cadaverina, putrescine, and pathogens, based on the recommendations of CONAMA Resolutions number: 357/05, number: 368/06, number: 402/08, or establish the standards NBR 10.157/87, NBR 15.495-1/07, NBR 15.495-2/08) and CETESB L1040/99, provided that the environmental impacts associated with the CCQL are considered in the legislation and that the health of the population surrounding the CCQL and respect for human dignity is ensured.

CONCLUSIONS

The analysis of chemical indicators, mainly ammoniacal nitrogen and nitrate, and microbiological indicators suggested that the products of cadaveric decomposition, such as necrochorume, in the area of influence of the Complex of cemiteries: Quinta dos Lázaros represent risk factors for contamination of groundwater and human health. This environmental commitment represents a flagrant non-compliance with legislation and an epidemiological emergency that are associated with the largest complex of cemeteries in Bahia.

It can be observed from the adoption of internal comparison points a greater loss of water quality in the sampling point P2, located in the pollutant receiving area resulting from the leaching of soils and regolith exposed to the products of cadaveric putrefaction of the burials of the Israelite Cemeteries and the Ordem Terceira do Carmo, compromise water quality and restrict its use. It was found, from the adoption of external comparison points, in the surroundings of the CCQL, that the loss of groundwater quality and pollution can result from cemetery activities and that the influence of sanitation failures must not be neglected.

It must be noted that the results of this research have public utility for the Salvadoran society, since it associated information based on the legislation relevant to cemeteries, water quality and the environment, in order to assess the quality of groundwater in the area of influence of the CCQL. However, further research is recommended, with special attention to the demands for cemetery activities during the COVID-19 Pandemic, since many lives were taken as a result of the health crisis, a syndemic, and that the study of the influence of cemeteries on Environmental quality has been neglected.

With this, the results of the present research revealed that the emergence of the socio-environmental, political and public and collective health issue of cemeteries requires more efforts from civil society and public managers in the assessment of impacts, in the protection of soil, water and biota, monitoring the activities of public cemeteries, monitoring compliance with legislation and managing environmental and biosafety risks.

In this context, the monitoring and annual sampling of soils and waters must be carried out, in accordance with the provisions of the technical standards NBR 15495-1/07 and NBR 15495-2/08, whose water monitoring wells must be located at upstream and downstream of the area where the cemetery is located, taking into account the preferred directions of groundwater flow. Thus, it is noted that monitoring the impacts of CCQL cemetery activities can contribute to the prevention of damage to ecosystems, loss of quality and restrictions on water use, outbreaks, endemics, epidemics, pandemics and health promotion.

This way, groundwater pollution resulting from CCQL cemetery activities demands environmental management, corrective measures to the issue and compliance with legislation in order to guarantee the population's health and water quality. This universe of actions offers greater protection and care for the soils, waters, biota and ecosystems and respect and dignity to those who are gone and to their living ones. In this sense, the following measures are recommended to remedy the problems revealed:

In the areas of Carneira: repair the sheep, graves and ossuaries, including those that are not in use, adapting them to the legislation and compliance with the drainage system, gas aeration and extravasation of cadaveric decomposition products (necrochorum);

(ii) **In the areas of the pits (soil)**: waterproof the bottom of the pits with concrete to prevent the percolation of cadaveric decomposition products; Observe its distance from the other graves and its legal framework; create terracing to reduce soil erosion; plant grasses in the burial area to protect the surface layer of the soil, preventing the splash resulting from the impact of raindrops on the soil. This would allow the retention of rainwater that carries pollutants and pathogens to the aquifer and trap the contaminants by adsorption and absorption, through its rhizosphere.

(iii) **Tree planting**: planting a taproot tree to remove microorganisms from the soil and part of the organic load from necrochorume; contribute to the reduction of the water table, the biodegradation and the attenuation of necrochorume by the soils.

(iii) **Monitoring**: build underground water monitoring wells in compliance with legislation; carry out geophysical studies for physical characterization of soils and quantify hydraulic conductivity by infiltration tests and granulometric analysis. Other aspects can be considered depending on the local geoenvironmental attributes.

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