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Technical Article

Evaluation of soil contamination by heavy metals at public cemeteries in the municipality of Lages, southern Brazil

Avaliação da contaminação de solos por metais tóxicos em cemitérios públicos do município de Lages, Sul do Brasil

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ABSTRACT

The burial of bodies is a potentially polluting activity. Taking this into consideration, the aim of the present study was to verify the compliance of two cemeteries with environmental legislation and to quantify the concentrations of heavy metals in soils affected by burial activities. Physicochemical characterization of the soil was performed by analyzing control samples from areas near the cemeteries. Concentrations of cadmium, lead, chromium, nickel, zinc and copper were determined using high-resolution continuum source atomic absorption spectrometry. The two cemeteries had unsatisfactory properties for the retention of metal cations, with clay percentages ranging from 15.40 to 41.40% and sand percentages ranging from 28.75 to 66.85%. The control samples presented low cation exchange capacity (12.27 to 22.73 cmolc/dm^3) and high aluminum (Al^{3+}) saturation (66.74 to 90.16%). Although neither of the two cemeteries had concentrations above the limits established for the metals analyzed by Resolution No. 420/2009 of the National Environment Council, the contaminants may be leaching to groundwater due to inadequate soil characteristics.

Keywords: HR-CS AAS; cation exchange capacity; contaminants; necro-leachate; heavy metals.

RESUMO

O sepultamento de corpos é uma atividade potencialmente poluidora. Este trabalho teve como objetivo verificar a adequação das áreas de dois cemitérios públicos à legislação ambiental e à atividade cemiterial e quantificar a concentração de metais pesados nos solos que estão sob influência desses empreendimentos. Realizou-se a caracterização físico-química do solo, com a análise de amostras testemunha de solo de cada cemitério. Também foram determinadas as concentrações dos metais pesados: cádmio, chumbo, cromo, níquel, zinco e cobre, por meio de espectrometria de absorção atômica de alta resolução com fonte contínua. As áreas dos cemitérios apresentam condições insatisfatórias para a retenção de íons catiônicos metálicos, com percentuais de argila variando entre 15,40 e 41,40% e de areia entre 28,75 e 66,85%. Os solos testemunha apresentaram reduzida capacidade de troca de cátions entre 12,27 e 22,73 cmolc/dm^3) e elevada saturação por alumínio entre 66,74 e 90,16%. Apesar de nenhum dos cemitérios apresentar concentrações dos metais analisados acima dos limites de prevenção estabelecidos pela Resolução nº 420/2009 do Conselho Nacional do Meio Ambiente, em função das características dos solos, os contaminantes podem estar sendo lixiviados para os recursos hídricos subjacentes.

Palavras-chave: HR-CS AAS; capacidade de troca catiônica; contaminantes; necro-lixiviado; metais tóxicos.

INTRODUCTION

The environment depends on the integrated functioning of many components, including soil, which performs important ecological functions. In urban areas, humans have drastically modified soil characteristics, in addition to using this resource for storing undesirable materials. Many of these materials have contaminants that, when not assimilated by the soil, percolate through the unsaturated zone and reach the water table, becoming potential environmental pollutants (AHARONI *et al.*, 2020).

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Traditional burial is a practice in urban areas that generates byproducts, such as necro-leachate, which is a potential liquid pollutant that changes the physicochemical and biological characteristics of the bedrock (MAJGIER & RAHMONOV, 2012; CRUZ *et al.*, 2017). Necro-leachate has many components originating from the decomposition of bodies, coffins, adornments, and fabrics used to dress the bodies as well as products and substances introduced into the body throughout the individual's life (WILLIAMS *et al.*, 2009; FIEDLER *et al.*, 2012; JONKER & OLIVIER, 2012).

The first registered study on the environmental impact of cemeteries was developed in Europe in 1951 by Van Haaren (UÇISIK & RUSHBROOK, 1998). In Brazil, bacteriological contamination of the water table by microorganisms from decomposing bodies was detected in a study conducted in the state of São Paulo in 1991. Henceforth, several studies have addressed the impact of burial activities on the environment and public health (PACHECO, 2000).

According to Barros *et al.* (2008), most studies investigating the contamination of natural resources by inappropriate burial activities have emphasized nonmetallic pollutants, especially those of a microbiological origin in groundwater. However, more recent studies, such as those developed by Barros *et al.* (2008), Jonker and Olivier (2012), Fiedler *et al.* (2012), Amuno (2013), Floriani (2013), Silva (2016), and Rocha (2016), have quantified heavy metals in soils. The most frequently found heavy metals above legally established limits are chromium and lead (BARROS *et al.*, 2008); chromium, copper, zinc, rubidium, strontium, cesium, and lead (JONKER & OLIVIER, 2012); arsenic, chromium, and lead (AMUNO, 2013); and iron, chromium, copper, nickel, lead, and zinc (SILVA, 2019).

According to He *et al.* (2004), the availability and mobility of heavy metals are controlled by chemical and biochemical processes such as precipitation-dissolution, adsorption-desorption, complexation-dissociation, and oxidation-reduction. Moreover, these processes are affected by pH and biological processes as well as the environment and the chemical toxicity of the element (OLIVEIRA, 2012). In the case of cemeteries, where burials normally occur in deep layers of the soil (1.5 to 1.8 m), the amount and quality of clay are determinant factors of heavy-metal adsorption capacity (BARROS *et al.*, 2008).

Most studies quantifying metals in soils affected by cemeteries have not considered physicochemical characteristics, and no studies have analyzed the natural amount of metals in soils of the surrounding region. Resolution No. 335/2003 of the National Environment Council (*Conselho Nacional do Meio Ambiente* — CONAMA, 2003), which regards the environmental licensing of cemeteries as well as issues involving construction aspects and cemetery regulations, establishes minimal norms that must be observed regarding the depth of the grave and properties of the subsoil. This resolution also stipulates the distance from the grave to the maximum height of the water table, practices for the burial of bodies, the location of the burial area, practices that enable gas exchange, and criteria for horizontal cemeteries in areas of springs that supply water for human use (BRAZIL, 2003).

When the characteristics of the soil at burial sites are unsuitable for the retention and filtration of the necro-leachate, the liquid lixiviated through the unsaturated zone reaches the underlying aquifer. The conditions of the unsaturated zone determine attenuation processes and the eventual elimination of chemicals or the lixiviation of necro-leachate and the contamination of surface and groundwater bodies (OLIVEIRA *et al.*, 2013; IEPA, 2015). Unlike most organic contaminants, metals are not degraded or promptly detoxified by microorganisms, in such a way these elements pose a greater pollution problem over time (OLIVEIRA *et al.*, 2010).

The aim of the present study was to identify the adequacy of burial activities at two public urban cemeteries located in the municipality of Lages, southern Brazil, to quantify levels of heavy metals in the soil affected by these activities, and to compare the results to the limits established by the Brazilian environmental legislation.

METHODOLOGY

Study area

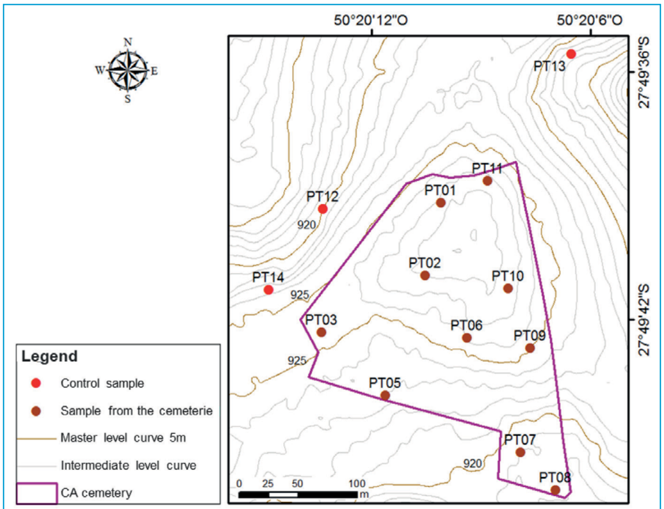
The municipality of Lages is located in the state of Santa Catarina, in southern Brazil, and has a population of 157,727 residents, 98.22% of whom live in urban areas and 1.78% live in rural areas (IBGE, 2010). The city has two public cemeteries in urban areas: Nossa Senhora da Penha (NCP) and Cruz das Almas (CA). The NCP cemetery is located between the following geographic coordinates: 50°17'29.6" to 50°17'34.7" W and 27°48'29.6" to 27°48'37.4" S. It has been operating for approximately 75 years, occupying an approximate area of 60,817 m². NCP is the largest public urban cemetery in the city, with an average of 44 burials per month. It has a slope of approximately 30 m between the highest and the lowest points. The surroundings are mostly occupied by residences and the cemetery is close to water bodies. The CA cemetery is located between the following geographic coordinates: 50°20'13.7" to 50°20'06.5" W and 27°49'36.8" to 27°49'46.5" S. It has been operating for 127 years and is the second largest public urban cemetery in Lages, covering an area of 38,824 m². It is located on a water divide and has an average of 13 burials per month. Residences and businesses, such as gas stations, funeral homes, and commercial buildings, compose the surrounding area. This study received authorization from the city of Lages, which is responsible for the surveyed cemeteries.

Sampling

For the CA cemetery, control soil samples were collected from adjacent areas unaffected by human activities to represent the levels of metals normally found in soils outside the study area. A total of ten soil samples were collected from the cemetery itself. The sampling criterion was the direction of the hydrostatic flow, which normally follows the surface topography. The sampling points inside and outside the CA cemetery are shown in Figure 1. For the NCP cemetery, 13 samples were collected from within the cemetery, in addition to collecting three control samples, two samples from a swamp area between the cemetery and a water body (not identified) located south-southwest to the cemetery, and three samples of alluvial soil, which were collected from the eastern bank of the creek (Figure 2). Samples were collected at depths between 160 and 180 cm, utilizing Dutch and screw augers, following Technical Norm No. 15,492 (ABNT, 2007). In cases where the bedrock was located at less than 160 cm from the ground, samples were collected as close to the bedrock as possible. All samples were dried in an oven at 65°C for at least 24 hours, ground, and sieved with a 0.212 mm/µm stainless-steel sieve (65 mesh).

Physicochemical characterization

Physicochemical analyses of the control soil samples were conducted (three duplicate samples from NCP and three from CA). The analyses were performed at the Soil Analysis Laboratory of the Santa Catarina Agricultural-Livestock Research and Extension Company (*Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina* – EPAGRI) in the city of Chapecó, Brazil, which is accredited by the Official Network of Soil Analysis Laboratories (*Rede Oficial de Laboratórios de Análise de Solo e de Tecido Vegetal nos Estados do Rio Grande do Sul e de Santa Catarina* – ROLAS). The physical analysis of the soils consisted of the quantification of particle size following the methods described by Embrapa (1997) and Klein (2008). The chemical analysis was performed for the determination of organic matter (OM), potential of hydrogen in water (pH H_2O), available phosphorus (P; Mehlich), exchangeable potassium (K; Mehlich), and exchangeable aluminum (Al), calcium (Ca), and magnesium (Mg) using methods described by Tedesco *et al.* (1995) (standards of the Brazilian Soil Science Society). Potential acidity (H + Al), cation exchange capacity (CEC), Al (M-value), and saturation percentage of the CEC at pH 7.0 (bases, K, Ca, Mg) were obtained from mathematical calculations. The physicochemical characterization was only performed in the control samples of both cemeteries, as the physicochemical characteristics of the samples from within the cemeteries have been altered, making the analysis of the environmental adequacy of these soils for the burial activity unfeasible.

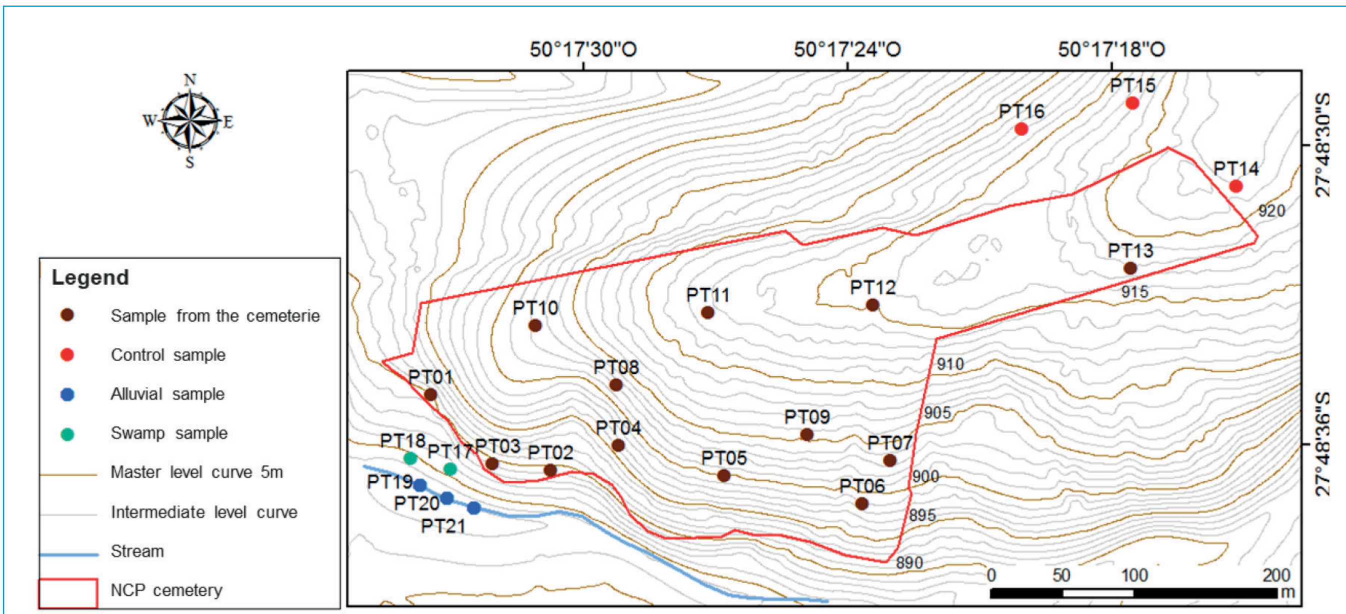


Source: elaborated for the authors.

Figure 1 – Location of soil sampling points at the Cruz das Almas cemetery.

Determination of heavy metals

Acid digestion and the determination of heavy metals were performed at the Routine Water and Waste Analysis Laboratory of the Department of Environmental and Sanitary Engineering of Universidade do Estado de Santa Catarina following the methods described by the United States Environmental Protection Agency (USEPA, 1996). Levels of cadmium (Cd), lead (Pb), copper (Cu), chromium (Cr), nickel (Ni), and zinc (Zn) were determined in the samples from the NCP cemetery, CA cemetery, and control samples for both cemeteries. The minimum detection limits were 0.0004 mg/kg for Cd; 0.005 mg/kg for Pb; 0.001 mg/kg for Cu; 0.005 mg/kg for Cr; 0.012 mg/kg for Ni; and 0.001 mg/kg for Zn. The digestion of the samples followed the USEPA 3050B method (USEPA, 1996), using reagents with Merck analytical standards. Digestion of the samples was performed with nitric acid (HNO_3), hydrochloric acid (HCl), and hydrogen peroxide (H_2O_2). Metals were determined using



Source: elaborated for the authors.

Figure 2 – Location of soil sampling points at the Nossa Senhora da Penha cemetery.

the direct air-acetylene flame method through high-resolution continuum source atomic absorption spectrometry (HR-CS AAS), using the Analytik Jena contrAA 700 spectrometer. The equipment was calibrated with stock solutions prepared for each metal of interest based on the calibration curves created from reference stock solutions. Descriptive statistics were performed to determine the behavior of the data. Geographical spatialization of the data was conducted using the kriging method with the aid of the ArcGIS 10.1 software. Concentrations of metals detected in the samples were compared with the Prevention and Intervention Values established by CONAMA (2009) Resolution No. 420/2009.

RESULTS AND DISCUSSION

Physicochemical characterization

The depth of the soils ranged from 50 to 180 cm in the NCP cemetery and from 95 to 180 cm in the CA cemetery. The shallow depth at some sampling points is due to the closeness to the bedrock, with graves built directly over it at these spots. The depth of the saturated zone and the type of geological material are determinant factors for the filtering of liquids resulting from body decomposition (SILVA & MALAGUTTI FILHO, 2008), as this zone serves as a filter and adsorbent (UÇISIK & RUSHBROOK, 1998). However, there are no reference values for these characteristics. CONAMA (2006) Resolution No. 368/2006 only establishes that the lowest level of the graves must be at least 150 cm above the highest level of the water table measured at the end of the rainy season (BRAZIL, 2006).

The physicochemical characteristics of the control soils from both cemeteries are presented in Table 1. Both of them had similar mean percentages of clay and sand. The soils from the CA cemetery had a predominance of sand (47.32%), followed by clay (29.40%), whereas the soils from the NCP cemetery were predominantly clay (38.07%), followed by sand (34.13%). The soils had a suitable texture for the burial activity, which, according to Silva (1995, *apud* SILVA & MALAGUTTI FILHO, 2008), ranges from 20 to 40% of clay to favor aerobic decomposition and the drainage of the necro-leachate. Soils composed of a mixture of clay and sand of low porosity and a small to fine grain texture maximize the retention of degradation products (UÇISIK & RUSHBROOK, 1998) due to the larger specific surface area and, consequently, higher CEC. According to the Potash and Phosphate Institute (1998), the CEC depends on the amount and type of clay and organic matter. Higher CEC values are commonly found in weathered soils.

Soils from the NCP cemetery had CEC values ranging from 12.55 to 22.73 cmolc/dm³ and those from the CA cemetery had values ranging from 12.27 to 16.73 cmolc/dm³, suggesting that the predominant clay minerals in both cemeteries are kaolinite, which has a CEC between 5 and 15 cmolc/dm³, and illite, which has a CEC between 10 and 50 cmolc/dm³ (RONQUIM, 2010). According to Becegato *et al.* (2006), clay soils that have 2:1 clay minerals (montmorillonite) have a higher CEC compared with soils with a sandy/clay texture. Moreover, high amounts of sand result in less water retention and proneness to the lixiviation of cations (BECEGATO *et al.*, 2006). A low CEC indicates that the soil has little capacity for retaining cations, resulting in greater loss through lixiviation (RONQUIM, 2010).

Another important characteristic to consider is the fact that the metal-adsorption of soils depends on the aluminum (Al^{3+}) concentration, as this metal affects the CEC. Al^{3+} was high in the control soils for both cemeteries, with values ranging from 66.74% (NCP16) to 90.16% (NCP15). The exception was CA13, for which 0.0% of Al^{3+} was found. The presence of this element in the CEC indicates that the metal is adsorbed by negative charges (PPI, 1998; ZAMBROSI *et al.*, 2007), preventing other cations, such as Cr, Cd, Pb and Cu, to be adsorbed by negative charges.

The amount of organic matter in the study areas ranged from 14 g/dm³ (NCP14) to 27 g/dm³ (NCP15 and CA12). Soils with more than 60 g/dm³ normally indicate an accumulation of organic matter due to poor drainage conditions or high acidity (CÓ JR., 2011). The pH was between 4.0 and 5.0 for all soils, except for that collected from CA13 (pH 6.10). The NCP and CA cemeteries had a mean pH of 4.2 and 4.8, respectively. The pH value exerts a strong influence on the dynamics of metal cations, which are more mobile under conditions of low pH (RIEUWERTS *et al.*, 2006).

According to He *et al.* (2005), the availability and mobility of heavy metals are controlled by chemical and biochemical processes such as precipitation-dissolution, adsorption-desorption, complexation-dissociation, and oxidation-reduction. However, these processes are affected by pH and biological processes as well as the environment itself and the chemical toxicity of the element (OLIVEIRA, 2012). Although clay was within

Table 1 – Physicochemical characteristics if the control soil samples at the Nossa Senhora da Penha cemetery and at the Cruz das Almas cemetery, in mean.

Point	Clay	Sand	Silt	pH-H_2O (1:1)	CEC pH7.0 (cmolc/dm³)	Saturation Al^{3+} at the CEC (%)	Al/ bum of bases
	------------(%)----------						
NCP14	41.40	33.40	25.20	4.05	12.55	86.83	4.60 / 6.55
NCP 15	40.40	28.75	30.85	4.20	22.73	90.16	4.40 / 4.57
NCP 16	32.40	40.25	27.35	4.35	16.20	66.74	2.40 / 7.39
Mean	38.07	34.13	27.80	4.20	17.16	81.24	3.80 / 6.24
CA12	41.40	30.70	27.90	4.10	16.73	75.81	3.90 / 7.51
CA13	15.40	66.85	17.75	6.10	12.27	0.00	0.00 / 83.70
CA14	31.40	44.40	24.20	4.25	13.73	87.64	3.7 / 5.45
Mean	29.40	47.32	23.28	4.82	14.24	54.48	2.53 / 32.22

CEC: cation exchange capacity; NPC: Nossa Senhora da Penha; CA: Cruz das Almas. Source: elaborated for the authors.

the recommended amount for both criteria (SILVA, 1995, *apud* SILVA & MALAGUTTI FILHO, 2008), chemical characteristics such as the CEC, Al^{3+} saturation in CEC, and pH, indicate that soils from both cemeteries are prone to the lixiviation of cations and possible contaminants, which places groundwater at risk.

Heavy metals in soil

In the control samples, the concentrations of heavy metals were lower than the minimum detection limits of the spectrometer or lower than the mean values obtained in the samples from the cemeteries, except for Cr in the NCP cemetery and Pb in the CA cemetery (Table 2). For NCP, the mean concentration of Cr was higher in the control samples compared with the mean concentration in the samples obtained from the cemetery. However, Cr levels were higher at NCP04 and NCP13 than the levels in the control samples.

Considerable variability was found in the levels of Cu, Cr, Pb, Zn, and Ni at both cemeteries, ranging from 55.83% to 104.40% in NCP and 29.44% to 144.50% in CA (Table 2). This variability may be attributed to the geology of the area, which is influenced by the Lages Dome, the sedimentary extracts of which were mixed by the Botucatu-Pirambóia, Teresina and Rio do Rastro formations. This combination affected the mineralogical and textural compositions of the soils (BECEGATO *et al*., 2019) and, consequently, their metal-retaining capacity. Higher concentrations of Cu, Ni, Zn, and Cd were detected at lower topographic heights, which may be associated with lixiviation of heavy metals and their accumulation, as the terrain topography normally follows the direction of the hydrostatic flow. In the case of the CA cemetery, the variability may also be due to the age of the burials, which are more recent in the southern and southwestern portions of the cemetery.

Table 2 – Statistical results of the cemetery and control soil samples of the studied cemeteries.

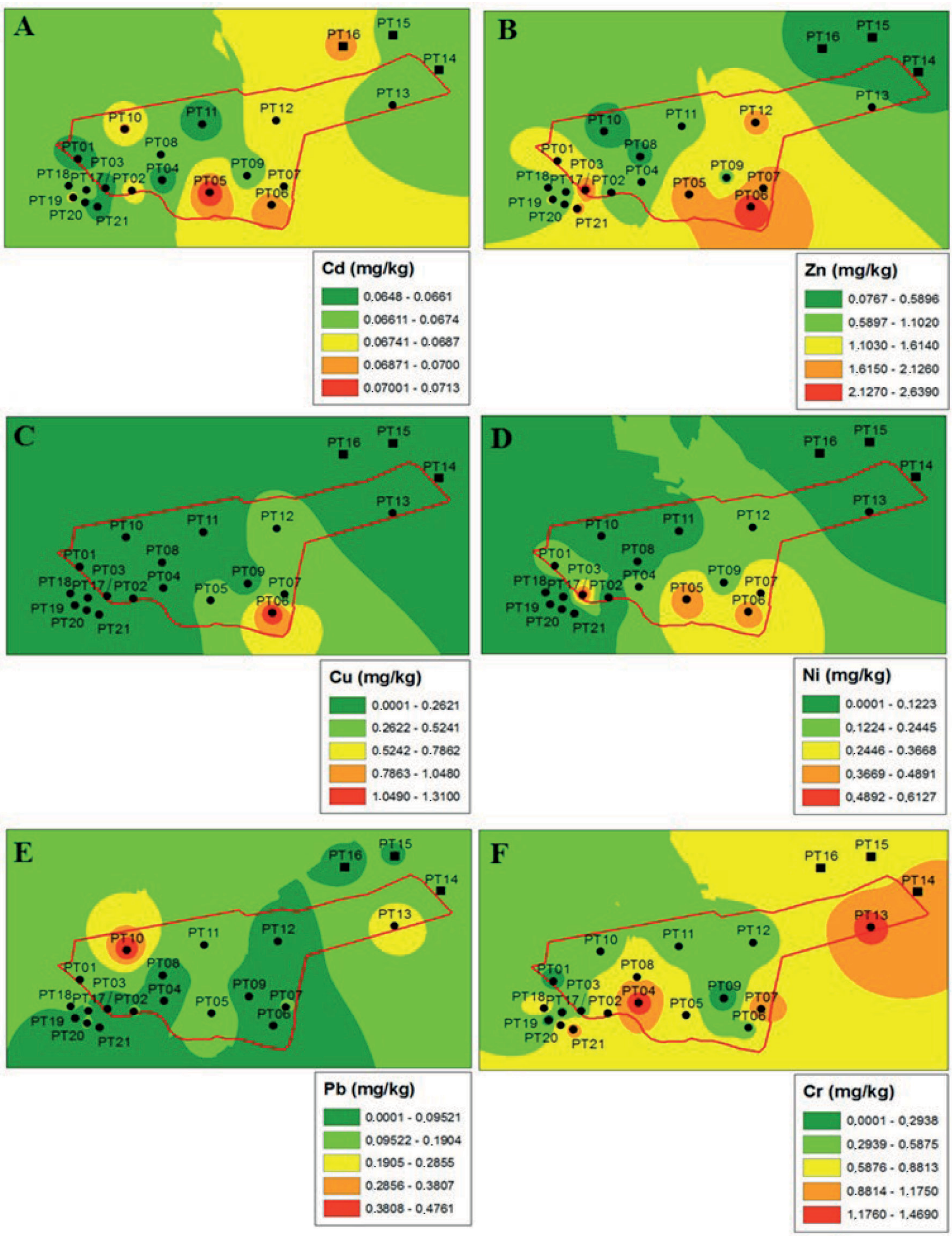
NOSSA SENHORA DA PENHA CEMETERY							
Sample	Statistical parameters	Cu	Cr	Pb	Ni	Zn	Cd
		---mg/kg---					
Cemetery	Score*	3	10	8	6	10	10
	Mean	0.40	0.73	0.15	0.30	1.20	0.07
	Minimum	0.09	0.11	0.03	0.02	0.08	0.06
	Maximum	1.31	1.47	0.48	0.61	2.64	0.07
	Standard deviation	0.42	0.41	0.11	0.18	0.76	0.01
	Coefficient of variation (%)	104.4	55.83	78.88	62.47	63.68	2.77
Control (n = 3)	Mean	< DL	0.77	0.12	< DL	0.27	0.07
CRUZ DA ALMAS CEMETERY							
Sample	Statistical parameters	Cu	Cr	Pb	Ni	Zn	Cd
		---mg/kg---					
Cemetery	Score*	7	16	14	9	18	18
	Mean	0.64	1.02	0.09	0.24	1.03	0.07
	Minimum	0.43	0.09	0.01	0.01	0.14	0.06
	Maximum	0.79	4.89	0.18	0.92	2.01	0.07
	Standard deviation	0.19	1.38	0.07	0.35	0.69	0.01
	Coefficient of variation (%)	29.44	136.01	69.56	144.50	67.39	3.48
Control (n = 3)	Mean	< DL	0.06	0.29	0.01	0.86	0.07

*The number of samples is not the same for each metal due to some samples having a concentration lower than the minimum detection limit of the device; < DL: concentration below the device's minimum detection limit; Cd: cadmium; Pb: lead; Cu: copper; Cr: chromium; Ni: nickel; Zn: zinc. Source: elaborated for the authors.

Comparing the total amounts of Cu, Cr, Pb, Ni, Zn, and Cd in the soil samples from the NCP and CA cemeteries with the Prevention and Intervention Values stipulated by the environmental legislation (CONAMA Resolution No. 420/2009), all concentrations at both cemeteries were below the established limits. The Prevention Value is the concentration limit of a given substance that enables the soil to fulfill its main functions, whereas the Intervention Value is the concentration of a substance above which there are potential risks to human health (BRAZIL, 2009). Nevertheless, due to the broad pedological variability in Brazil, the Intervention and Prevention Values may not reflect the actual situation of some places suited to the existing types of pedology.

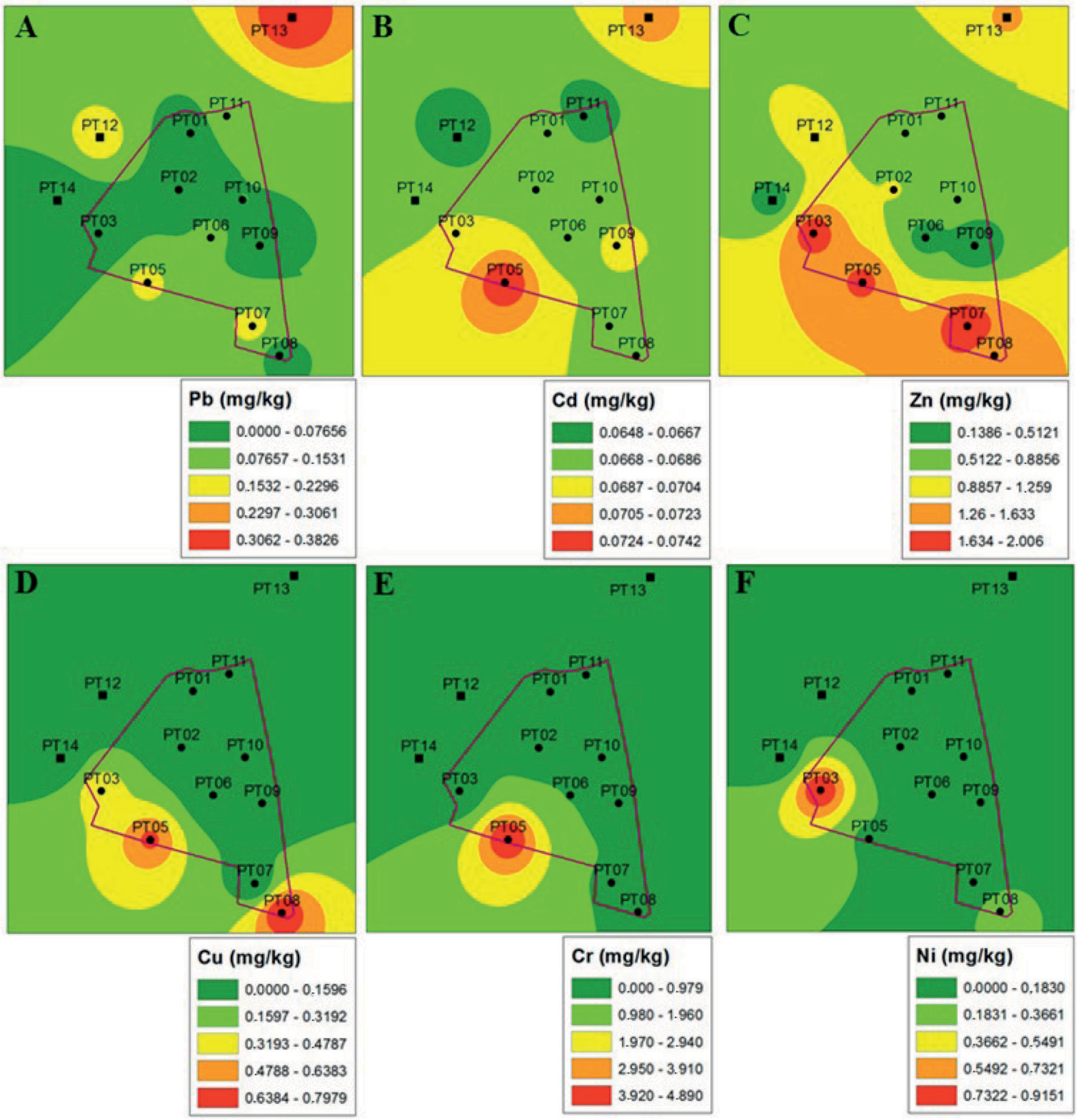
Rocha (2016) also evaluated heavy metals in cemetery soils and found values below the Prevention Values proposed by CONAMA Resolution No. 420/2009 (BRAZIL, 2009). In a pioneering study on soil contamination due to cemetery activities, Spongberg and Becks (2000) found values similar to those found in the present study: Cu = 0.27 mg/kg; Zn = 2.64 mg/kg; Pb = 0.41mg/kg; and Cr = 0.16 mg/kg. As the soils from the NCP and CA cemeteries have clay content suitable for the burial activity and have peculiarities in their topography, the behavior of metals in the area consists in a relevant information.

The spatialization of the concentration of metals in the NCP cemetery is demonstrated in Figure 3. In Figures 3a and 3b, the resemblance between the spatialization of the concentrations of Cd and Zn may be due to the fact that Cd is rarely found in its pure form in nature, and its presence in the environment is directly related to zinc ore (ADRIANO 1986, *apud* MELLIS, 2006). Nascimento *et al*. (2010) state that Cd, Zn, and Ni pose higher risks of contaminating groundwater due to their greater mobility through soil compared with Pb, Cr, and Cu. Regarding concentrations of Cu and Ni in the NCP cemetery, the points with higher levels of both metals were located at lower topographic altitudes. Cr concentrations were higher than Pb concentrations, even at lower topographic altitudes. However, in Figure 3f it is verified that the control sampling points also had high Cr concentrations, which may be related to the geology of the area. Regarding the spatialization of the metals studied in the CA cemetery (Figures 4b and 4c), control sampling point CA13 (Figures 4a, 4b, and 4c) had slightly high amounts of Cd and Zn, and the highest Pb concentration may be related to another contamination source or from the cemetery itself. This behavior may be due to the fact that the texture of the soils is mainly composed of sand from the Botucatu-Pirambóia formation, which is more porous, thereby facilitating the percolation of contaminants. Cd and Zn concentrations had a similar spatial distribution, with higher concentrations in sites at lower topographic altitudes (Figures 4b and 4c). Cu, Cr, and Ni levels exhibited a similar behavior (Figures 4d, 4e, and 4f), with low concentrations at the control sampling points and high levels at a lower topographic altitude, demonstrating the possibility of lixiviation and the accumulation of contaminants in the area. Burial age is another possible



PT: sample point. Source: elaborated for the authors.

Figure 3 – Spatialization of the concentration of metals Cd (A), Zn (B), Cu (C), Ni (D), Pb (E) and Cr (F) in the soil of Nossa Senhora da Penha cemetery.



PT: sample point. Source: elaborated for the authors.

Figure 4 – Spatialization of the concentration of metals Pb (A), Cd (B), Zn (C), Cu (D), Cr (E) e Ni (F) in the soil of Cruz das Almas cemetery.

factor of influence, considering that the areas at lower altitudes correspond to more recent burials.

CONCLUSIONS

The studied cemeteries were in compliance with the legislation that guides their activities. Soils in the areas of both cemeteries had physical characteristics suitable for the burial activity. However, the analysis of the chemical characteristics demonstrated that the soils do not have the potential to adsorb metallic cations, which poses a risk of groundwater contamination.

Concentrations of metals were below the Prevention and Intervention Values for soils established by CONAMA (2009) Resolution No. 420/2009. Nevertheless, the spatialization of the metal concentrations in the investigated areas indicates higher concentrations of all elements at lower topographic altitudes. There is need for soil quality regulations regarding chemical substances at limits that are suitable for the different pedologies of the country.

AUTHORS' CONTRIBUTIONS

Baum, C. A.: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. Becegato, V. A.: Conceptualization, Investigation, Methodology, Resources, Writing – review & editing. Lavnitcki, L.: Data curation, Investigation, Methodology. Vilela, P. B.: Data curation, Investigation, Methodology. Duminelli, E. C.: Investigation, Methodology. Becegato, V. R.: Investigation, Methodology, Writing – review & editing. Robazza, W. da S.: Writing – review & editing. Paulino, A. T.: Resources, Methodology, Writing – review & editing.

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