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Cemeteries heavy metals concentration analysis of soils and the contamination risk for the surrounding resident population

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ABSTRACT
This research aims to quantify and analyze the levels of soil contamination by heavy metals in three cemeteries located in the city of Carazinho-RS, Brazil. The decomposition of buried bodies in traditional cemeteries releases high amounts of heavy metals into the ground, which compromises population settlements near the cemeterial areas. In each of the three selected cemeteries (A, B and C), five sampling points were determined through the Triangular Irregular Network (TIN) method. The depths to collect the samples were 0-20cm and 20-40cm. Four sample sites outside the cemeteries (for the same depths), 100m away from each other were also defined in order to obtain a triangulation of up to 400m away from each analyzed cemetery. The results indicated that all cemeteries in question had significantly higher heavy metal values when compared to Brazilian tolerated limits, especially regarding to copper (Cu). Iron (Fe), manganese (Mn) and lead (Pb) concentration analysis also deserve attention due to the high values found. The results of this research warn for possible soil contamination hazards by heavy metals to residents who live near cemeteries, in a 400m radius.

***Keywords* :** Urban expansion, cemeteries, heavy metals, contamination.

I. INTRODUCTION

The study of the cemeteries in relation to their roles and meanings within the cities permeates urban analyzes that highlight the importance of developing research to discuss its configuration, morphology and urban, regional and environmental impacts [1, 2, 3].

Cemeteries consist of an important urban equipment, employed since the Old Age by society for the deposition of the dead [3]. However, few actions are taken to mitigate the environmental impacts generated by urban cemeteries. One of the main consequences of the implementation of these spaces in urban areas is soil contamination by heavy metals released from bodies in decomposition that may affect the surrounding population directly [1, 3, 4, 5, 6]. This contamination can occur more intensely in a 400m radius, namely in the vicinity of cemeterial areas [3, 5, 6].

This fact is directly linked to the urban land expansion, which does not consider areas near cemeteries as a risk for local people's health [5, 6]. Concerns regarding cemeteries location stood in the background; which did not happen, for example, in the Middle Ages, or even in Brazil during the colonization period, when these sites were considered unhealthy and were placed away from cities. [2].

The lack of information regarding the contamination risks caused by cemeteries made urban planning disregard these spaces in the cities expansion actions [2, 5, 6]. So it is quite common to find cemeteries integrated to cities, even in the most central areas [6, 7]. According the historiography of this theme [3.8], construction of most cemeteries did not take into account geological, hydrogeological and sanitation studies, which would be important data to prove high risk potential for soil and groundwater contamination. This aspect was confirmed by the absence of specific legislation in Brazil until 2010. Only since this year it is required environmental licensing for the implementation of cemeteries in Brazil [3].

In this context, the Brazilian National Environmental Council - CONAMA, through Resolution n.420 of 2009 began to emphasize the requirement of monitoring areas that exposed the population to contaminants [9]. Therefore, the resolution established Prevention Values for some of the heavy metals studied in this paper (Table 1) [9].

Table 1–List of guiding values for soil in mg/Kg dry weight.

Substances	Prevention Values (PV)
Lead (Pb)	72
Copper (Cu)	60
Chrome (Cr)	75
Iron (Fe)	*
Manganese (Mn)	*
Zinc (Zn)	300

* It does not have prevention values set by CONAMA. Source: Adapted from [9].

Despite the aforementioned CONAMA resolution of 2009 establishing prevention values of iron (Fe) and manganese (Mn) for soil contamination, the Brazilian Ministry of Health, through the Federal Ordinance n.2.914 of 2011, specified maximum allowable concentration values of the cited metals in the water for human consumption. In the case of iron (Fe), the maximum value is 0.3 mg/L and manganese (Mn) is 0.1 mg/L [10]. The concentration values of heavy metals present in drinking water were determined due to percolation of these materials in the soil reaching the water table, which directly affect the population using this water for consumption [3, 8, 10].

This situation causes great concern [3, 8, 9], since the groundwater reserves can be contaminated by nitrogen, phosphorus, heavy metals as well as bacteria, fungi and viruses [4].

Toxicological processes can occur more frequently in tropical countries, such as Brazil, as hot and humid climates, favored by constant rainfall, culminate in higher water percolation in soil, favoring the proliferation of pathogenic bacteria [4]. Similarly, heavy metals in concentrations above tolerable limits may become a public health problem [6, 7, 8].

To identify contaminants and inform the public about the risks that may suffer, especially those who live in areas near the cemeteries, this study aimed to demonstrate contamination levels of heavy metals detected in the soil of the cemeteries located in the city of Carazinho (RS-Brazil). In this sense, the research is justified by the importance of qualitative research about the subsurface physical environment of cemeteries in the locality, to recognize any changes in heavy metals contaminants in environments with human density, as a result of chaotic urban development.

The results of this research could be used to improve legislation on the control and monitoring of polluting elements, likewise to contribute to the development of public policies that consider the expansion of cities near cemeterial areas.

II. METHODOLOGICAL PROCEDURES

This work was based on theoretical studies of impacts on the operation of cemeteries, particularly of heavy metals in the soil of these locations.

For the evaluation of soil contamination conditions, three cemeteries in the city of Carazinho/RS, Brazil were selected, entitled as A, B and C. In this experimental step, it was intended to relate the location of cemeteries to the environmental impacts that have been identified in the literature, as well as to verify compliance with laws, guidelines and parameters on the subject in this area.

The aforementioned city is located in the northwest middle region of the State of Rio Grande do Sul, between the geographical coordinates of latitude and longitude of 28º17' S and 52º47' W, and currently comprises a land area of 676 square kilometers [11].

The method of Triangular Irregular Network (TIN) was used to define the collection sites of soil samples, which requires at least three (3) locations to form triangles [12]. For this reason, five (5) sites on the perimeter of each of the selected cemeteries were chosen, and four (4) triangular locations set 100 meters apart from each other, in the near surroundings, within 400 meters outside the cemeteries. Therefore, a checkered geometric shape was used in relation to the size of the sampled areas.

The analyzed amount of heavy metals were interpolated with the land dimensions data, defined from the geographical coordinates and adjusted through the "Overlay Maps" command in Surfer 12 software.

All three evaluated cemeteries are considered horizontal and traditional, where the bodies are buried underground. The Municipal Cemetery (A), built in the late nineteenth century, has more than five thousand tombs. The Catholic/Evangelical Cemetery "*Jardim da Paz*" (B), established in 1966, has about a thousand buried corpses and the Cemetery Martin Lutero (C), installed in 1982, has about one thousand four hundred tombs.

In the soil analysis of Carazinho/RS cemeteries, the heavy metals considered for contamination parameters were: copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), lead (Pb) and chromium (Cr). Thus, the Separation Method (MRC) was applied on three samples and three repetitions were made. In this category it was included all certified reference materials used in chromatographic analysis such as liquid chromatography (HPLC), ion chromatography (IC) and gas chromatography (GC) with several types of detectors. They are mainly produced for chromatographs calibration developed for soil environmental analysis, comprising three replications in each of the three analyzed cemeteries. Possible bacteria and viruses present in the samples were not considered in this study.

In order to obtain soil samples to analyze quantitative levels of heavy metals in the cemeteries in question, two soil samples at each point were collected, with the depths of 0-20cm and 20-40cm in five (5) different sites inside the cemetery and other four (4) soil samples 0-20cm and 20-40cm deep spaced 100m apart up to a radius of 400 meters from each sampled cemetery (A, B and C). The total values of each sample locations were represented in variation graphs with average results of the different depths analyzed.

III. RESULTS AND DISCUSSION

The soil heavy metals analysis results of the three analyzed cemeteries are shown in Tables 2, 3 and 4. The amounts of heavy metals found in cemeteries A, B and C, respectively, were compared with the Brazilian parameters established by the Brazilian National Environmental Council (CONAMA), in accordance with Resolution No. 420 of 2009 (Tables 2, 3 and 4).

Table 2 - Heavy metal concentrations sampled in the Municipal Cemetery (A) in mg/Kg.

Collection Points (Depths (m))	Cu	Zn	Fe	Mn	Pb	Cr
A1 (0-20 cm)	75	63	2058.64	213	106	2
A1 (20-40 cm)	134	138	2149.67	302	42	40
A2 (0-20 cm)	117	128	2161.97	334	85	37
A2 (20-40 cm)	118	97	2163.68	371	54	36
A3 (0-20 cm)	183	200	2151.42	302	127	40
A3 (20-40 cm)	178	328	2154.92	307	105	29
A4 (0-20 cm)	120	120	2146.17	254	79	29
A4 (20-40 cm)	106	96	2149.67	220	53	34
A5 (0-20 cm)	102	11	2147.92	288	43	27
A5 (20-40 cm)	122	135	2140.92	305	49	35
AF1 (0-20 cm)	106	105	2149.67	397	11	31
AF1 (20-40 cm)	127	131	2149.67	306	32	26
AF2 (0-20 cm)	90	75	2002.56	211	9	5
AF2 (20-40 cm)	92	80	2002.57	226	12	15
AF3 (0-20 cm)	60	67	1923.36	190	6	6
AF3 (20-40 cm)	68	69	1924.37	196	8	10
AF4 (0-20 cm)	40	58	1820.25	170	4	3
AF4 (20-40 cm)	46	62	1830.42	174	5	8
Maximum values	60	300	-	-	72	75

Table 3 - Heavy metal concentrations sampled in the Cemetery "*Jardim da Paz*" (B) in mg/Kg.

Collection Points (Depths (m))	Cu	Zn	Fe	Mn	Pb	Cr
B1 (0-20 cm)	119	108	2135.67	335	18	33
B1 (20-40 cm)	121	121	2149.67	424	12	40
B2 (0-20 cm)	108	117	2161.93	381	<LD	40
B2 (20-40 cm)	118	129	2154.92	346	<LD	32
B3 (0-20 cm)	113	162	2151.42	316	<LD	36
B3 (20-40 cm)	120	174	2160.18	408	61	41
B4 (0-20 cm)	110	262	2140.92	321	36	33
B4 (20-40 cm)	127	125	2146.17	343	49	33
B5 (0-20 cm)	117	109	2137.42	358	58	44
B5 (20-40 cm)	133	126	2154.92	383	66	43
BF1 (0-20 cm)	144	120	2153.17	497	21	35
BF1 (20-40 cm)	130	101	2160.18	298	21	26
BF2 (0-20 cm)	115	109	2120.51	422	19	31
BF2 (20-40 cm)	118	116	2122.11	190	16	27
BF3 (0-20 cm)	99	102	2109.82	375	12	26
BF3 (20-40 cm)	105	97	2110.60	172	10	23
BF4 (0-20 cm)	88	95	2099.52	280	11	25
BF4 (20-40 cm)	92	90	2098.42	164	10	19
Maximum values	60	300	-	-	72	75

*<LD: Below detection level.

Table 4 - Heavy metal concentrations sampled in the Cemetery Martin Lutero (C) in mg/Kg.

Collection Points (Depths (m))	Cu	Zn	Fe	Mn	Pb	Cr
C1 (0-20 cm)	103	136	2147.92	225	40	17
C1 (20-40 cm)	98	112	2149.67	225	32	21
C2 (0-20 cm)	99	119	2142.67	283	52	29
C2 (20-40 cm)	89	89	2140.92	283	41	24
C3 (0-20 cm)	95	83	2142.67	252	47	22
C3 (20-40 cm)	99	104	2133.92	247	64	20
C4 (0-20 cm)	86	99	2153.17	291	32	30
C4 (20-40 cm)	82	81	2153.17	298	7	33
C5 (0-20 cm)	96	72	2139.17	274	8	31
C5 (20-40 cm)	96	77	2147.92	318	10	26
CF1 (0-20 cm)	121	89	2142.67	636.9	< LD	33
CF1 (20-40 cm)	139	127	2165.43	554	< LD	25
CF2 (0-20 cm)	93	78	2124.89	225	6	15
CF2 (20-40 cm)	93	82	2124.89	225	7	16
CF3 (0-20 cm)	80	72	2090.88	190	5	12
CF3 (20-40 cm)	89	79	2095.69	205	4	15
CF4 (0-20 cm)	78	69	2064.11	188	4	11
CF4 (20-40 cm)	82	75	2075.18	188	4	10
Maximum values	60	300	-	-	72	75

*<LD: Below detection level.

After the sampling results, comparisons with soil toxicity parameters were made. Therefore, alarming data was found regarding the heavy metals contamination high levels in cemeterial soils in Carazinho/RS - Brazil, when compared to tolerated prevention values set by CONAMA [9].

The concentration values of copper (Cu), for example, extrapolated acceptable CONAMA prevention values in all samples, reaching 183.00 mg/Kg in Cemetery A, 144.00 mg/Kg in Cemetery B and 139.00 mg/Kg in Cemetery C. Such high values pose serious human health risks, especially if these heavy metals contaminate the water table.

Similarly, the concentration values of lead (Pb), highly polluting and harmful to human health, exceeded toxicity prevention limits established in several sites of the Cemetery A, reaching maximum measurements of 127 mg/Kg. The maximum prevention value set by CONAMA is 72 mg/Kg. By comparing the values sampled outside the perimeter of Cemetery A, concentrations of lead (Pb) in the cemetery reached about 4 times the tolerable standards, exceeding by 181.42% acceptable lead levels. High concentrations like these may cause direct contamination for the population living near this urban equipment. According to [3, 7, 8, 9, 10], for its high toxicity, lead when absorbed by the human body may lead to death, directly affecting brain functions, blood, digestive system, kidneys and stimulating the emergence of cancer cells.

The collected samples of this element in cemeteries B and C were within acceptable limits established by CONAMA, although in some samples of Cemetery B (61 and 66 mg/Kg) these values are already close to the prevention value. In this case, if the burial practices continue as business as usual, the Pb concentrations may also extrapolate the prevention limits in the coming years.

The amounts of zinc (Zn) in the analyzed samples remained below prevention parameters except for one sample of Cemetery A (A3: 328 mg/Kg). Despite this single sample that extrapolated the prevention limits, currently measured values do not present significant risks to the environment and/or human health as they are within the limits set by CONAMA. Likewise, measurements of the existence of chromium (Cr) remained below prevention parameters.

Due to insufficient legislation and control parameters on the acceptable amount of the elements iron (Fe) and manganese (Mn) and the lack of research related to soil pollution concentration limits, it is not possible to establish a comparison of their maximum allowable concentrations in the ground.

Despite this fact, soil samples presented high concentrations of iron and manganese, reaching an average concentration of 297.82 mg/Kg of manganese in the three cemeteries. The maximum concentration value found was 636.90 mg/Kg in Cemetery C. On the other hand, concentrations of iron in soil samples exceeded 2000 mg/Kg in all studied cemeteries, demonstrating an average of 2137.88 mg/Kg per collection site, noticeably high levels to normal soil patterns.

Through a systemic projection, the variation of contaminants is represented by Figure 1 (Cemetery A), Figure 2 (Cemetery B) and Figure 3 (Cemetery C), in which it was possible to show the variations inside and outside the perimeter of each cemetery, as determined by Triangular Irregular Network (TIN) method [12].

Heavy metals such as Cu, Zn, Fe, Mn, Pb and Cr, represented by Figures 1, 2 and 3 vary with greater intensity and concentration in the internal boundaries of the cemeteries A, B and C. These monitoring locations are hence specified: Cemetery A (A1, A2, A3, A4, A5); B (B1, B2, B3, B4, B5) and C (C1, C2, C3, C4, C5) and presented a higher proportion of contamination by heavy metals comparing to the conducted analysis outside cemeterial areas in the three studied cemeteries (A, B and C).

The investigation carried out in the vicinity of cemeteries observed the spacing of 100 meters between the collection sites, up to a limit of 400 meters from the cemetery boundaries (4 monitoring locations assessed), in each of the three cemeteries. When comparing the results of the internal monitoring locations with the external samples in Cemeteries A (AF1, AF2, AF3, AF4), B (BF1, BF2, BF3, BF4) and C (CF1, CF2, CF3, CF4) a reduction of contaminants (Cu, Zn, Fe, Mn, Pb, Cr) is observed as the monitoring sites move away from the cemeteries analyzed.

These three analyzed cemeteries are increasingly being incorporated to the urban built mass due to urban expansion [13]. One of the solutions to reduce the heavy metal contamination generated by the decomposition of corpses in cemeteries would be to consider these spaces in city planning, and analyze the social and environmental impacts of such equipment [14].

In this context, vertical cemeteries are proposed as a future alternative to cities, in order to mitigate environmental impacts and allow the treatment of effluents and gas resulting from the decomposition process. In addition, soil would not be exposed to contamination by decomposition fluids of corpses and coffins.

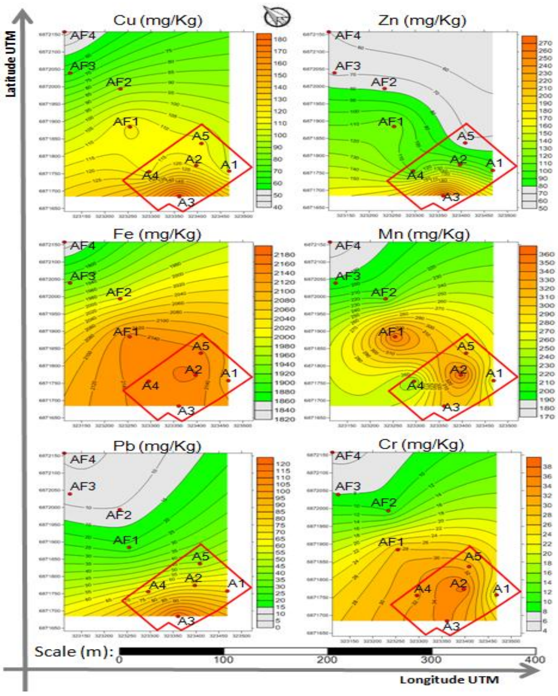

Figure 1 : Cemetery "A" perimeter representation in relation to the environment with the existing levels of heavy metal in the soil.

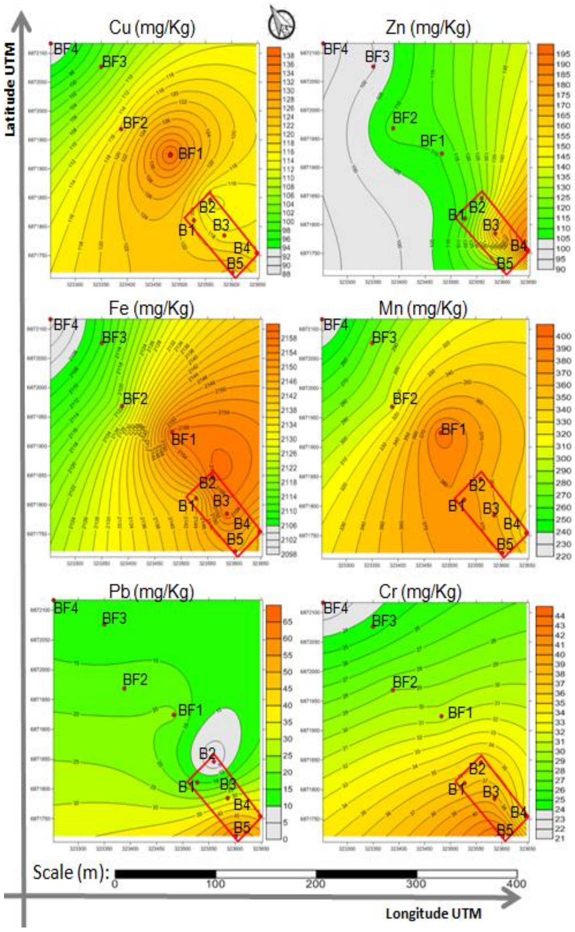

Figure 2 : Cemetery "B" perimeter representation in relation to the environment with the existing levels of heavy metal in the soil.

Previous studies conducted in the state of Rio Grande do Sul - Brazil, in which the city of Carazinho is established, present evidences that environmental contamination by cemeteries began around 1000 BC, with the utilization of structures for indigenous burial ceremonials, being aggravated later with the arrival of immigrants after the discovery in the year 1500 AD [15]. Evidently, over the centuries, there was an increase in population and burials, worsening this scenario, in which the urban population expanded horizontally to inhabit the surrounding areas of cemeteries [16].

Currently, when assessed, most cemeterial sites are in their third layer of dead deposition [3]. Naturally, number of deaths will increase in coming years as a result of population growth; which possibly will become a problem for public administration [3, 17, 18].

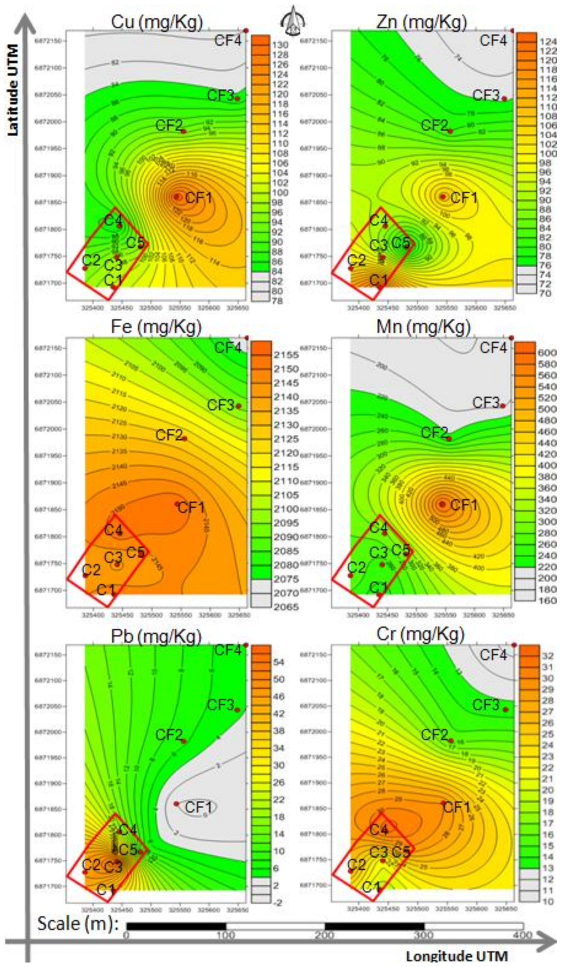

Figure 3 : Cemetery "C" perimeter representation in relation to the environment with the existing levels of heavy metal in the soil.

IV. CONCLUSION

Although it is recognized as an ancient practice, several studies indicate the harmful impacts to the environment and human health from the burial processes and the consequent decomposition of human bodies that occur within the cemeteries.

Previously installed in areas far from urban centers, cemeteries began to be a part of the dense areas of cities, mainly due to intense urbanization and the lack and/or inefficiency of legislation and related supervision. Today, cemeteries are commonly found fully integrated to the cities.

Regarding the distance from the analyzed cemeteries to the inhabitants' housing, it was observed that Cemeteries A and B are located within 200 meters from the residences. At Cemetery C, the situation is more critical, since there is no distance between the cemetery and the houses. It is important to remind that the establishment of most Brazilian cemeteries did not take into account geological, hydrogeological and/or sanitation, and in this context, these facilities pose a high risk potential for soil and groundwater contamination in several cities of the country [3, 8], as in the case of the cemeteries studied (A, B and C) in the city of Carazinho-RS.

Iron (Fe) and manganese (Mn) concentration analysis also deserve attention due to the high values found, although the legislation does not propose maximum safe levels for human and environmental health. In the other hand, the measured amounts of zinc (Zn) and chromium (Cr) are below the tolerated levels by CONAMA [9].

Thanks to the analysis of these three cemeteries, it is possible to confirm the high concentration of heavy metals contaminants in the cemeteries soils studied (A, B and C). This contamination can reach a radius of up to 400m from each cemetery.

Therefore, it is believed that this study is the first that examines the environmental impacts of cemeteries in the region, taking into account the risks of increased housing expansions near cemeteries. Furthermore, encourages other researchers to conduct similar studies in other cities of Rio Grande do Sul, Brazil and other countries, in order to perform comparisons among the results obtained.

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