ÁREAS OCUPADAS POR CEMITÉRIOS E SEUS IMPACTOS NA QUALIDADE DA ÁGUA DA CIDADE DE SANTA MARIA – RIO GRANDE DO SUL (BRASIL)

Areas Occupied by Cemeteries and Their Impacts on Water Quality in the City of Santa Maria – Rio Grande do Sul (Brazil)

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Resumo

Os cemitérios podem trazer graves consequências ambientais, particularmente sobre a qualidade das águas subterrâneas. Preocupando-se com as possíveis consequências que os cemitérios podem causar ao meio ambiente, o objetivo deste estudo foi analisar a vulnerabilidade das águas subterrâneas em áreas ocupadas por quatro cemitérios no município de Santa Maria – Rio Grande do Sul, Brasil. Poços de monitoramento foram instalados nos cemitérios Santa Rita de Cássia, Jardim da Saudade, Ecumênico Municipal e são José, onde os parâmetros cor aparente, turbidez, condutividade elétrica, alcalinidade total, demanda bioquímica de oxigênio, nitrato, fósforo, sódio, coliformes fecais e totais foram analisados de março a setembro de 2009. Com base nos

resultados das análises, conclui-se que a água subterrânea ao entorno dos cemitérios não possui padrões de potabilidade de água, não sendo aconselhável para o consumo. Parâmetros como coliformes e nitrato mostraram-se alterados em alguns cemitérios, indicando possível contaminação por necrochorume, a partir da decomposição de corpos humanos.
Palavras-Chave: contaminação; necrochorume; qualidade da água; coliformes.

Abstract

Cemeteries may bring along serious environmental consequences, particularly on the quality of groundwater. Concerned with the possible consequences that cemeteries may cause to the environment, the objective of this study was examine the vulnerability of groundwater in areas occupied by four cemeteries in the municipality of Santa Maria – Rio Grande do Sul, Brazil. Monitoring wells have been installed in Santa Rita de Cássia, Jardim da Saudade, Ecumenical Municipal and São José Cemeteries, where the parameters of apparent color, turbidity, electric conductivity, total alkalinity, biochemical oxygen demand, nitrate, phosphorus, sodium, total and fecal coliforms were analyzed from March to September of 2009. Based on the analyses results, it has been concluded that the groundwater surrounding the cemeteries has no drinking water standard, and therefore it is not advisable to use it for consumption. Parameters such as fecal coliforms, total coliforms and nitrate had values altered in some cemeteries, indicating possible contamination of groundwater by necrochorume from the decomposition of human bodies.
Keywords: Contamination; Necrochorume; Water quality; Coliforms

Introduction

Water, as well as other elements, plays a key role as a means of watering, hydration and nutrition, acting as the main factor in life support. The advance of industrialization, the population growth, the intensive use of land and the increased use of chemicals are endangering the environment ecological balance, contaminating surface water with heavy metals and pathogenic bacteria, intoxicating and killing living beings in the entire food chain.

Faced with these anthropic actions, water resources undergo major degradation and shortage, turning groundwater the main source of supply for the population in the future. However, these waters are available in large quantities only in few countries, with Brazil as one of the regions benefited by the largest reserves of groundwater in the world, the so-called Guarani aquifer (GUIMARÃES, 2007).

Once dead, the human body begins to change, becoming an ecosystem of populations consisting of arthropods, bacteria, pathogenic microorganisms that destroy organic matter, and so on, and they may bring risk to the environment and the public health. The human body then undergoes putrefaction, which is the destruction of the body tissues by the action of bacteria and enzymes, resulting in the gradual dissolution of the tissues in gases, liquids and salts. The gases which are then produced are hydrogen sulfide (H_2S), methane (CH_4), ammonia (NH_3), carbon dioxide (CO_2) and water (H_2O). The odor is caused by some of these gases and by a small amount of mercaptan – a substance containing hydrogen sulfide bond with saturated carbon. The decomposition may take from some months to several years, depending on the action of the environment (Macêdo, 2009).

The putrefaction of the corpses is influenced by intrinsic and extrinsic factors. Intrinsic factors are those of the body, such as: age, physical constitution and causes of death. Extrinsic factors are relevant to the environment where the body has been deposited, such as: temperature, moisture, aeration, mineral composition of the soil and permeability. The contamination can reach groundwater through necrochorume (Romanó, 2009). The necrochorume is an aqueous solution, rich in minerals and degradable organic substances, with brown-grayish tone, strong-smelling and varying degrees of pathogenicity, and it is released by rotting corpses. Its constitution is 60% of water, 30% of minerals and 10% of organic substances; two of them, cadaverine and putrescine, which can also contain pathogenic microorganisms, are highly toxic.

In the wild environment, necrochorume decomposes and is reduced to simpler and harmless substances during a given time. Under certain geological conditions, the necrochorume reaches the groundwater virtually intact, with its chemical and microbiological loads causing contamination and pollution. The vectors thus introduced in the groundwater, thanks to its disposal, may be spread in the immediate and mediate surroundings of the cemeteries, reaching large distances, if hydrogeological conditions allow.

According to Pacheco (1986), organisms which are susceptible to transmit diseases by water are *Clostridium* (tetanus, gas gangrene, food toxic infection), *Mycobacterium* (tuberculosis), enterobacteria such as *Salmonella* (typhoid fever), *Shigella* (bacillary dysentery) and hepatitis A; the indicators of contamination most commonly used are coliform bacteria, especially the group of thermotolerant or fecal coliforms and streptococci. From these, the fecal coliform bacteria are frequently used in assessing the water quality. According to Martins et al. (1991), other indicators have been proposed for evaluating the quality of water; this is the case of pH of physical and chemical parameters, conductivity, oxidizability, among others, and some ions such as chlorides, sulfates, phosphates, sodium, potassium and calcium, to the extent that they may indicate a possible contamination.

Cemeteries may bring along serious environmental consequences, particularly on the adjacent groundwater quality. The infiltration and percolation of rainwater through the tombs and the soil will cause the migration of a number of inorganic and organic chemicals through the unsaturated zone, and some of these compounds may reach the saturated zone, therefore polluting the aquifer. Due to this reason, the monitoring of groundwater in the vicinity of cemeteries is of utmost importance in environmental studies.

The municipality of Santa Maria, in the central region of Rio Grande do Sul State – Brazil, has private and municipal cemeteries located in different areas of the city. Concerned with the possible consequences that cemeteries may cause to the environment, this work is aimed to analyzing the vulnerability of groundwater in areas occupied by cemeteries in the county.

Material and Methods

Localization of Study Area

The cemeteries selected for the survey were: the Santa Rita cemetery (figure 1.a), a Garden Park-type private cemetery founded in October 1970 on the RS 509 road, Km 4, number 2969. It has an area of 9.88

ha. It has currently more than 6,000 graves, receiving an average of 15 bodies per month; the Ecumenical Municipal Cemetery (figure 1.b), founded around 1804 and has an approximate area of 6.52 ha. It is located at 2 de Novembro Avenue, N. 54, Patronato District. About 180 bodies are buried monthly in the cemetery, which has over 25,000 graves; the São José Cemetery (figure 1.d) that belongs to the municipality of Santa Maria, it was founded in 1916 and has an approximate area of 0.46 ha. It is located at Passo dos Weber Street, unnumbered, Chácara das Flores District. About 10 bodies are buried monthly in the cemetery, which has over 1,500 graves and the Jardim da Saudade Cemetery (figure 1.c), also known as Caturrita, founded in 1940 and has an approximate area of 1.47 ha. It is located at José Barima Street, unnumbered, Caturrita District. About 20 bodies are buried monthly in the cemetery, which has over 5,000 graves. The table 1 shows the latitude and longitude of each sampling point.

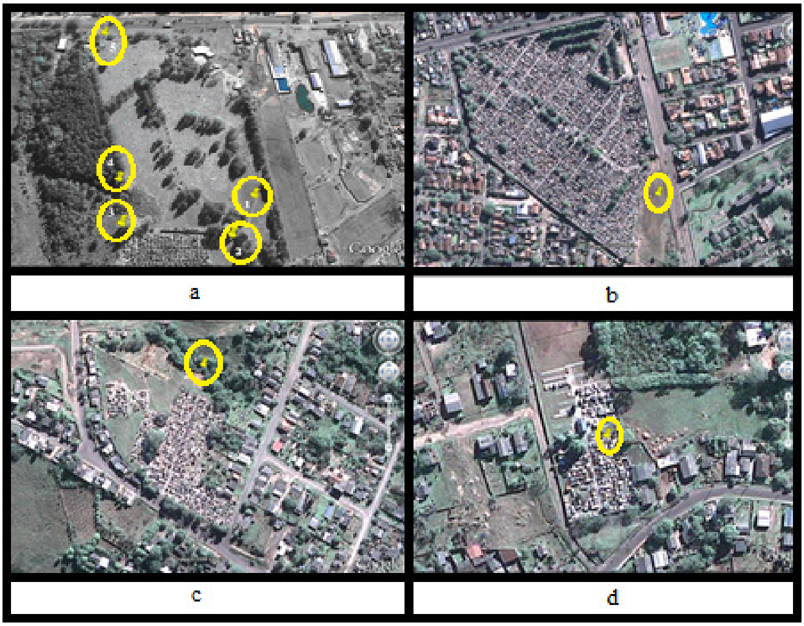

Figure 1 – Sampling points: (a) Santa Rita Cemetery; (b) Ecumenical Municipal Cemetery; (c) Jardim da Saudade Cemetery and (d) São José Cemetery.

Table 1 – Latitude and Longitude of sampling points.

Cemetery	Point	Latitude	Longitude
	1	29°41'50.215" S	53°45'28.028" W
	2	29°41'51.125" S	53°45'29.209" W
Santa Rita	3	29°41'51.490" S	53°45'34.970" W
	4	29°41'49.410" S	53°45'34.973" W
	5	29°41'40.239" S	53°45'36.039" W
Ecumenical Municipal	1	29°41'47.263" S	53°49'22.920" W
Jardim da Saudade	1	29°40'05.279" S	53°50'29.549" W
São José	1	29°39'56.215" S	53°49'15.843" W

Description of the water sampling method

Water samples were obtained from the points of figure 1 and table 1. The water samples analyzed were obtained from wells purged 24 hours prior to sampling. Water samples were taken from monitoring wells equipped with a sampler endowed with a non-return valve, previously sterilized with 70% of alcohol solution. The samples were packed in plastic bottles of 2L, properly labeled and identified according to the number of registered wells. The collection of samples for coliform determination was performed with sterile disposable bottles of 50 mL. These cemeteries were monitored from March 2009 to September 2009, total of seven samples of each point.

Water quality by physicochemical analysis

The water quality analysis was done taken the water parameters like temperature, dissolved oxygen and pH, the apparent color, electric conductivity, total alkalinity, sodium, nitrate and phosphorus. Biological parameters like total and fecal coliforms were quantified too. Each water samples were sent to the Laboratory of Environmental Engineering of the Franciscan University Center – UNIFRA.

After determining the parameters above, a comparative analysis of the results was performed, comparing the values obtained with the values established by Ordinance No. 518 of the Ministry of Health, which establishes procedures and responsibilities relating to control and surveillance of water quality for human consumption and their pattern of drinking, and the No. 396/2008 CONAMA resolution, which provides the classification and environmental guidelines for groundwater analysis. The samples were also compared between all cemiteries.

Analyses were performed with the instruments and the methodologies described in Table 2. At the site were evaluated the air temperature, water temperature and dissolved oxygen.

Table 2 – Equipment and methodology used for analysis.

	Equipment: make and model	Methodology for:
Physical Parameters		
Apparent Color	Colorímetro/Aqua-Tester/611-A	Macêdo, 2003
Air Temperature	Hygroterm/0,1°C/7429	***
Electrical Conductivity	Condutivímetro/Analion/C 708	Macêdo, 2003
Chemical Parameters		
pH	pH-metro/Analion/PM 608	Macêdo, 2003
Total Alkalinity	***	Macêdo, 2003
Dissolved Oxygen	Oxímetro/Digimed/DM-4	Macêdo, 2003
Sodium	Fotômetro de Chama/Analyser/910M	Macêdo, 2003
Phosphorus	Fotômetro de Chama/Analyser/910M	Macêdo, 2003
Nitrate	***	Macêdo, 2003
Biological Parameters		
Total Coliforms	***	Alexander, 1982
Fecal Coliforms	***	Alexander, 1982

Results And Discussion

The water level did not change significantly during the period of monitoring; however, it has been noted that it is influenced by rainfall, being shallower during the rainy season and deeper in times of drought. According to No. 335/2003 CONAMA Resolution, it is recommended that the bottom area of the graves must maintain a minimum distance of five feet from the maximum water level (groundwater). The water level of all cemetery wells is shallow during the rainy season, reaching the ground surface in the winter. In these regions, bodies should not be buried, because if they are below the water level, they will be saponified. No. 335/2003 CONAMA Resolution also recommends that if the site does not maintain this distance, the burial should be made above the natural terrain.

Physicochemical quality of water samples analyzed

Table 3 shows the physico-chemical parameters analyzed during the research in the four cemeteries in the city of Santa Maria.

Table 3 - Variation of parameters measured in the four cemeteries in the city of Santa Maria - RS, Brazil.

		Cemiteries			
Parameters	**Unit**	**Santa Rita**	**Ecumênico Municipal**	**Jardim da saudade**	**São José**
Temperature	°C	20,2 – 27,9			
Dissolved Oxygen	mg/L	8,45 – 9,90	11,67 – 12,18	0,82 – 2,12	1,08 – 1,97
pH		5,12 – 6,73	6,56 – 7,56	7,69 – 8,30	7,69 – 8,30
Apparent Color	uH	5,0 – 104,4	0,8 – 1,4	49,3 – 73,6	32,1 – 37,5
Total Dissolved Solids	mg/L	39,0 – 104,0	73,0 – 82,0	97,0 – 114,0	69,0 – 90,0

Electrical Condutivity	µS/cm	34,05 – 239,6	623,0 – 779,3	79,54 – 88,02	60,75 – 111,4
Total Alkalinity	mg/L of $CaCO_3$	5,0 – 65,0	135,0 – 160,0	21,0 – 33,0	29,0 – 41,0
Phosphorus	mg/L	0,002 – 0,021	0,001 – 0,002	0,028 – 0,054	0,001 – 0,003
Nitrate	mg/L	5.94 – 18,37	1,97 – 2,63	2,73 – 4,38	3,14 – 5,69
Sodium	mg/L	2,0 – 8,0	34,0 – 42,0	5,0 – 7,0	14,0 – 18,0

Apparent Color

The color of the water is due primarily to the decomposition processes occurring in the environment. For this reason, surface waters are more likely to have color than groundwater. In addition, color may exist due to the presence of certain metal ions such as iron and manganese, plankton, macrophytes and industrial waste, as well as microorganisms distributed in the environment (MACEDO, 2004).

In places with high organic matter decomposition, it is likely that the apparent color rates are influenced along with other parameters, particularly pH and turbidity (Macedo, 2004). Groundwater has color values less than 5 ppm, although abnormally wich can reach 100 ppm; it is worth highlighting that 1 ppm equals 1 color Hazen unit µH (FEITOSA; MANOEL FILHO, 1997).

Ordinance No. 518 provides that the maximum allowable value of the apparent color is 15 µH. From the tested wells, nearly all of them were above the established maximum (table 3), causing a negative aspect in the appearance of the water. According to Souza et al. (2004), higher values may be related to a large amount of dissolved substances, among them iron and manganese, or by the decomposition of organic matter.

Temperature

The temperature influences biological processes, chemical and biochemical reactions that occur in water and in other processes, such as the solubility of dissolved gases and minerals. The temperature affects the microbial growth, so that each microorganism has an optimal range of temperature (MACÊDO, 2006).

In shallow aquifers, the temperature is slightly higher than the surface. Temperature values observed for water samples collected from all wells remained in the range between 20.2 to 27.9 °C (table 3).

pH

The values established by Ministry of Health Ordinance No 518, show variations of pH between 6 and 9.5 as a condition of potability. Therefore, the water from all wells monitored in the studied cemeteries has a pH value within the established, except the Santa Rita Cemetery, which values were below the limits (table 3); these results should not be related to the presence of decomposing bodies but to natural soil acidification (ALMEIDA; MACÊDO, 2005).

Similar results were found by Migliorini et al. (2006), where values of groundwater in the cemeteries of Cuiaba – Mato Grosso varied between 3.51 and 7.98. In most ponds, the pH may be influenced by changes in temperature, biological activity and release of effluents (Franca et al., 2006).

Dissolved Oxygen (OD)

Dissolved oxygen is one of the most important available parameters in the control of water pollution. It is essential to verify the maintenance of aerobic conditions in a watercourse receiving polluting material. As there is no reference about this parameter in Ordinance No. 518 and the CONAMA Resolution 357 for Class II freshwater was then taken into account, defining a minimum value of Oxygen Demand (OD) at 5 mg/L; only Santa Rita de Cássia Cemetery and the Ecumenical Cemetery are above this value (table 3). For the other cemeteries, the amount of oxygen is extremely low, indicating an advanced stage of pollution.

Electrical Conductivity

Analyzing the results of electrical conductivity parameter in Table 3, similar results were presented by Migliorini et al. (2006) in the analysis of groundwater in the cemeteries of Cuiabá – Mato Grosso, presenting values between 13 and 350 μS/cm. There are no direct references to that parameter in Ministry of Health Ordinance No. 518 and CONAMA Ordinance No. 396 with respect to the consumption of used water.

However, according to Chapman and Kimstach (1998), the electrical conductivity in fresh water varies 10-1000 μS/cm.

Although the values found in the water of all monitoring wells in the city of Santa Maria are considered normal, it has been noticed that the values of the Ecumenical Municipal Cemetery are extremely high compared to other cemeteries; this is due to the amount of dissolved ions in the water, which are electrically charged particles. Another factor that probably increased the electrical conductivity of the water in monitoring wells is the fact that the water, when pumped, causes a hydraulic gradient around it.

According to Matos (2001), the presence of necrochorume causes an increase in minerals, increasing the conductivity of the water, leading to an increase of ions such as chloride.

Sodium

The results of table 3 are quite below the recommended maximum value for human consumption (MAV) of Ordinance No. 518, which is 200 mg/L. According to World Health Organization (WHO, 1996), the maximum recommended value for sodium in drinking water is 200 mg/L. In groundwater, the sodium content varies between 0.1 and 100 mg/L, and there is a gradual enrichment of this alkali metal from the zones of recharge (FEITOSA; MANOEL FILHO, 1997).

Migliorini et al. (2006) found values with low sodium concentrations in groundwater from Cuiabá – Mato Grosso, usually between 0.2 and 5.0 mg/L, which values are also quite below the maximum allowed by Ministry of Health Ordinance No. 518/2004 and CONAMA Ordinance No. 396.

Total Alkalinity

With respect to the total alkalinity (table 3), both Ministry of Health Ordinance No. 518 and CONAMA Resolution No. 396, make no reference to the maximum allowed total alkalinity. The alkalinity of groundwater usually lies between 100 and 300 mg/L Calcium carbonate ($CaCO_3$), where only exceptional cases may reach 300 mg/L $CaCO_3$ (Franca et al., 2006), demonstrating that the findings are in full or even low acceptable range.

According to Zimbres (2009), the total alkalinity with regards to groundwater, is mainly due to the occurrence of carbonate and bicarbonate and, secondarily, of hydroxide oils, silicates, borates, phosphates and ammonia. The total alkalinity is the sum of the alkalinity produced by all these ions in a water sample, since in almost all, the pH was less than 8.2, indicating that this is due to HCO_3-(hydrogen carbonate) ions.

Phosphorus

Ministry of Health Ordinance No. 518 and CONAMA Ordinance No. 396, do not refer to the maximum allowable value (MAV) of phosphorus in groundwater. In high concentrations, phosphorus and nitrogen may contribute to the proliferation of algae and they may undesirably accelerate, under certain conditions, the process of eutrophication (Thomann; Mueller, 1987). The amount of total phosphorus found in sampling points was low (table 3), making this parameter unable to cause eutrophication.

Nitrate

Nitrate usually has the most common contaminant occurrence in large urban centers, mainly due to contamination from domestic activities through septic tanks, sewage, garbage, cemetery, nitrogen fertilizers and animal waste. The presence of nitrogen compounds in different oxidation states indicates contamination of aquifer and possible inadequate sanitary conditions. Nitrite and nitrate cause two adverse health effects, which are the induction of methemoglobinemia, especially in children, and the potential formation of carcinogenic nitrosamides and nitrosamines (Lewis et al., 1986).

Ministry of Health Ordinance No. 518 and CONAMA Ordinance No. 396, establishes a MAV of 10 mg/L for groundwater intended for human consumption; the least CONAMA Ordinance No. 396 also mentioned a MAV of 90 mg/L for waters intended for watering livestock, for this substance. All cemeteries were below the limit (table 3), except Santa Rita de Cássia Cemetery, which presented, in altimetric points, values which are higher than the maximum standard for drinking water required for consumption, and that may even cause health hazard.

Analyzing the groundwater of Alto Cristalino de Salvador, Bahia, Nascimento; Barbosa (2005) found that the nitrate value changed in 53% of the studied points, where values ranged between 1.3 and 41.0

mg/L, which demonstrates that there is water contamination by nitrate in different parts of Brazil, due to different factors.

The high levels of nitrate concentration can cause serious health consequences. In the human body, the nitrate converts to nitrite by combining with hemoglobin to form methemoglobin, preventing the transport of oxygen in the blood (Silva; Araujo, 2003).

Total and fecal coliforms: biological parameters analyzed as water quality indicators

Analyses performed on water samples from monitoring wells presented high levels of fecal and total coliforms (table 4). Ministry of Health Ordinance No. 518 establishes that, in order to drinking water be considered drinkable, there should be an absence of total and fecal coliforms in 100 mL of water. The same reference is found in CONAMA Ordinance No. 396 where, for groundwater intended for human consumption, this parameter must be totally absent in samples with 100 mL of water as for watering livestock, the PMV is 0.8 MPN/100 mL.

The determination of coliform concentration assumes importance as an indicator parameter of the possibility of the existence of pathogenic microorganisms which transmit diseases (Migliorini, 1994). Although they not pathogenic, they are called indicator organisms of fecal contamination, and may indicate if the water presents contamination by human or animal feces, as well as their potential for disease transmission.

Table 4 - Values of total and fecal coliforms in four cemeteries in the city of Santa Maria - RS, Brazil.

Parameters	Unit	Santa Rita	Ecumenico	Jardim da Saudade	São José
Total Coliforms	MPN/100mL	803,2	750,0	1700,0	4700,0
Fecal Coliforms	MPN/100mL	900,1	750,0	1700,0	4300,0

Conclusion

The above listed values are extremely high and may cause problems for neighboring communities that use groundwater; they may actually have their health endangered by the pollutant load which may be carried by water flow.

Finally, based on the results obtained, we conclude that the groundwater surrounding the cemeteries has no drinking water standard and therefore it is not advisable to use it for human consumption. Parameters such as fecal coliforms, total coliforms and nitrate had their values changed in some cemeteries, with high values when compared with the law, indicating a possible contamination of groundwater by necrochorume from the decomposition of human bodies.

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