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ECOLOGY

Water quality for rural home supplying in the south of Brazil

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ABSTRACT. Underground and surface water as a result of human activity are increasingly polluted. Mainly due to improper disposal of waste, discharge of effluents, among other actions that compromise the environment. The water analysis is necessary to determine and evaluate the situation of water supply to the population. This study evaluated the supply situation of three rural communities located in the south of Brazil, where the water is carried out through the abstraction of groundwater. Pastures, fields and remnants of native vegetation characterize the region. The water quality used to supply was what motivated the accomplishment of this work. The wells are unprotected in the middle of the pastures near to black cesspits and crops that use frequently agrochemicals. The water quality was characterized over one year by physical-chemical, microbiological and toxicological characteristics. The results were compared to water potability standards in Brazil. In order to ensure sanitary conditions for this population, environmental education actions were carried out given the importance of access the information. It follows that the resources analyzed need disinfection to ensure better and safer water supply.

Keywords: environmental education; water treatment; water supply; groundwater; organisms tests.

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Introduction

The water is an essential life resource and indispensable to innumerous human activities. It has been considered an inexhaustible source due to its purification capacity and to be recyclable by its cycle (Vörösmarty et al., 2010; UN-Water, 2011). Therefore, with the population growth the water demand has increased. In this context, the aquatic environment resilience was overwhelmed by the impacts of industrial and agricultural increase, and the disorderly urbanization (Foley et al., 2005; Zhou et al., 2017).

One of the noblest water purposes is public supply, but worldwide there is a shortfall when it comes to sanitation (Shannon et al., 2008). According to the latest data by WHO and UNICEF (World Health Organization [WHO], 2015), until 2015, 663 million people did not have sources of drinking water yet. A factor to be concerned given the capacity of water to transmit diseases (Liu et al., 2017).

In Brazil around 20% of the population does not have access to treated water. It means that 41.56 million individuals are exposed to contaminated water risks. The situation is even more critical in the north where only 49% of the population has water supply. This deficit leads to several social and environmental problems, health diseases, and consequently financial problems to the country (Ministério do Desenvolvimento Regional, Secretaria Nacional de Saneamento [SNS], 2019). The lack of sanitation services is more significant in rural areas, where only 27.8% of the rural population has water supply networks. The other 72.2% uses alternatives sources supply (Conselho Nacional de Segurança Alimentar e Nutricional [CONSEA], 2017).

As a consequence of the lack in water supply systems, people needed to search for new water sources and these are not always in adequate conditions to consumption, for it may spread diseases or cause problems to the environment (Reichwaldt, Ho, Zhou, & Ghadouani, 2017).

The underground water is attractive as an exploration source, since it has superior quality when compared to surface water bodies due to their natural characteristics and the soil filtering process (Vasanthavigar et al., 2010). However, these fountains are susceptible to contamination, given that the soil does not have the capacity to retain all the compounds or microorganisms which can contaminate the water (Sojobi, 2016; Libutti & Monteleone, 2017).

It is estimated that 50% of the world population supply are via underground water (World Water Assessment Programme [WWAP], 2016). Therefore, water analysis is indispensable to determine and evaluate the water quality used to supply the population. It is crucial to ensure that the water present good quality, offering no health risks and in accordance with legal requirements (Zahedi, Azarnivand, & Chitsaz, 2017).

Based on above, the present study aims to analyze and relate the use and occupation of the soil, and the underground water quality from the rural area supply in communities of Parana, Brazil.

Material and methods

The study area characterization

The work was carried out in Francisco Beltrão – Paraná, south of Brazil. The city has 78,943 inhabitants and approximately 13% living in rural areas, which are distributed in 75 communities (Instituto Brasileiro de Geografia e Estatística [IBGE], 2014).

This work studied the supply water in three wells located in communities of Rio Pedreiro (26°00'40,4"S 53°09'24,6"W), Rio Pedreirinho (25°59'29,7"S 53°10'03,6"W) and Volta Alegre (26°00'47,3"S 53°10'26,8"W). They are located about 18 km from the urban border. The wells chosen are located close to each other, which facilitated to identify the use and occupation of the soil.

Sample collection

The water samples were collected in the well output, as recommended by the National Guide of Sample Collect and Preservation (Companhia Ambiental do Estado de São Paulo [CETESB] & Agência Nacional de Águas [ANA], 2012). From each well samples were collected in April, July and September 2015, with the purpose of to evaluate quality changes throughout the year.

Physical, chemical and biological analysis

The analyses performed were: pH and electrical conductivity determined by potentiometric method; turbidity determined by the nephelometric method; total dissolved solids determined by gravimetric; total hardness determined by titration method; total iron and nitrate determined by spectrophotometry and thermotolerant coliforms determined by technique of filter membrane. The methodologies are described by American Public Health Association [APHA] (2012). The tests were carried out in triplicate. It was possible to compare with the data obtained with the ordinance 2,914 of 12 December 2011 from Brazilian Health Ministry.

Toxicological tests

The cytotoxicity and mutagenicity were evaluated using the root meristematic cells of *Allium cepa L.* (onion) test prepared by Feulgen reaction and stained with the Schiff reagent (Fiskesjö, 1985).

Onion bulbs were rooting in bottles with mineral water at room temperature, ventilated and protected from light. Before each treatment, two roots were collected and fixed in 3 mL of methanol solution and 1 mL of acetic acid, to serve as their own control bulb (Co 0h - control). Following, the bulbs roots were placed in water samples collected during 24 hours. After the treatment time, two roots of each onion were taken and fixed (Tr 24h - treatment time). The remaining roots were washed and the bulbs were placed in water for 24 hours to recover from any damage, being the remaining roots removed and fixed (Re 24h – recovery).

The slides were analyzed through a 'blind' test in a light microscopic with a 40 x objective determining the Mitotic Index (MI%). About 1,000 cells were analyzed per bulb, totaling 5.000 cells per group. The MI calculation was made by the reason of cells number divided by the total of cells analyzed, multiplied by 100. And to assess the mutagenic potential it was calculated the Mutagenic Index (MIG%), proportion of cells changed by the total of cells analyzed, multiplied by 100. Five bulbs were used in the control group and for each treatment group.

Statistical analyses were performed using the Kruskal-Wallis test with significance of 5%.

The acute toxicity test with *Artemia salina L.* was performed with a method proposed by Guerra (2001) with adjustments. Initially, *Artemia sp.* cysts were incubated in a synthetic sea salt solution (30 g L^{-1}), aerated, without light and at 25°C in BOD incubator to induce their outbreak for approximately 24 hours. After hatching, 10 nauplii were transferred to test tubes containing 2 mL of sample diluted in saline solution at concentrations: of

100, 50, 25, 12.5, 6.2 and 3.1%. The negative control group contained only 2 mL of saline solution and the positive control was performed with mineral water. Quadruplicates were made of each sample group and after 24 hours of incubation at 25°C in BOD incubator, protected from light, the count of dead nauplii was made. It considered dead those who stand motionless for 20 seconds of observation.

The mean (± standard deviation) of dead bodies to each sample was compared with the negative control through Dunnet test ($\alpha = 0.05$).

Use and occupation of the soil

The characterization of soil use and occupation in the study area was performed by in loco observations, verifying the surrounding areas of wells in a radius of 1 km, examining the cesspit existence, proximity to crops, preservation, conservation situation of the natural ecosystem in the location where the well is installed.

Results and discussion

Physical, chemical and biological analysis

The water data from the wells are present in Table 1. As can be observed some parameters showed a significant variation during the year ($p < 0.05$), mainly due to the effect of seasonality. Almost all of the parameters monitored are in agreement with what is established in the ordinance 2.914 of 12 December of 2011 from Brazilian Health Ministry (Ministério da Saúde [MS], 2011).

The data from physical, chemical and biological analysis prove that the water used in rural areas present satisfactory quality, being in accordance with the main legal requirements. Nevertheless, since the water can be a disease carrier it was recommended to the population to treat the water before drinking.

It is through contaminated water that diseases such as cholera and typhoid fever spread. In this sense the disinfection, according to Li and Mitch (2018), can be considered one of the greatest achievements of public health. It is worth to mention that the enteric diseases are still one of the main causes of death among children in developing countries and are related in the majority of the cases with contaminated water (World Health Organization [WHO], 2009).

Thereby, considering the results of the analysis, a way to make the water accessible to that population is installing a low-cost chlorinator to purify the water, since chlorination is one of the most efficient ways to reduce the risk of waterborne diseases. The EMBRAPA (Brazilian Agricultural Research Corporation) developed a handout with directions to make it viable this disinfection at low cost (Otenio et al., 2014).

Table 1. Physical and chemical parameters of the wells in the communities under study obtained in the months of April (Apr.), July (Jul.) and September (Sep.) 2015.

Evaluation Points	pH				Electrical conductivity ($\mu S\ cm^{-1}$)				Turbidity (NTU)				Total dissolved solids ($mg\ L^{-1}$)			
	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}
Rio Pedreiro	6.71^{b}	7.66^{ab}	7.71^{a}	7.36	149.45^{ab}	138.63^{b}	154.23^{a}	147.44	0^{a}	0^{a}	0.29^{a}	0.09	0.23^{a}	0.16^{a}	0.44^{a}	0.27
Rio Pedreirinho	6.77^{b}	6.73^{a}	7.59^{ab}	7.03	106.65^{a}	89.98^{b}	103.43^{ab}	100.02	0^{a}	0^{a}	8.25^{a}	2.75	0.29^{a}	0.05^{a}	0.39^{a}	0.24
Volta Alegre	7.25^{b}	7.49^{a}	7.36^{ab}	7.36	155.40^{ab}	145.67^{b}	164.30^{a}	155.12	0^{b}	0.29^{ab}	14.14^{a}	4.81	0.41^{a}	0.13^{a}	0.57^{a}	0.37
Ordinance 2.914 Maximum	6.0 - 9.0								1 uT				1.0 $mg\ L^{-1}$			
Evaluation Points	Total Hardness ($mgCaCO_3\ L^{-1}$)				Total Iron ($mg\ L^{-1}$)				Nitrate ($mg\ L^{-1}$)				Thermotolerant coliforms (CFU)			
	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}	Apr.	Jul.	Sep.	M^{1}
Rio Pedreiro	77.90^{a}	80.30^{a}	80.23^{a}	79.48	0.05^{a}	0.04^{a}	0.03^{a}	0.04	0.10	0.24	0.07	0.13	11	0	6	-
Rio Pedreirinho	46.57^{a}	43.97^{a}	43.90^{a}	44.81	0.30^{a}	0.28^{a}	0.28^{a}	0.28	0.20	0.19	0.09	0.16	37	23	1100	-
Volta Alegre	82.90^{a}	84.97^{a}	84.90^{a}	84.25	0.08^{a}	0.07^{a}	0.07^{a}	0.07	0.10	0.25	0.12	0.15	190	0	0	-
Ordinance 2.914 Maximum	500 $mgCaCO_3\ L^{-1}$				0.30 $mg\ L^{-1}$				10 $mg\ L^{-1}$				Absent			

*Equal letters mean statistically equal averages by the Kruskal-Wallis test with 5% of significance. M^{1}: annual average to the parameters under study, except thermal tolerant coliforms, which do not show an annual average since they originate from a counting.

Toxicological tests

The water mitotic indices data (Figure 1) from Rio Pedreiro, Rio Pedreirinho and Volta Alegre wells (Tr-24h) are statistically similar in the negative control (Co-), bulb control (Co- 0h) and recovery time (Re-24h) for April, July and September. Therefore, no mitotic cell divisions or reduction in the onion cells occurred, and no cytotoxic characteristics were shown.

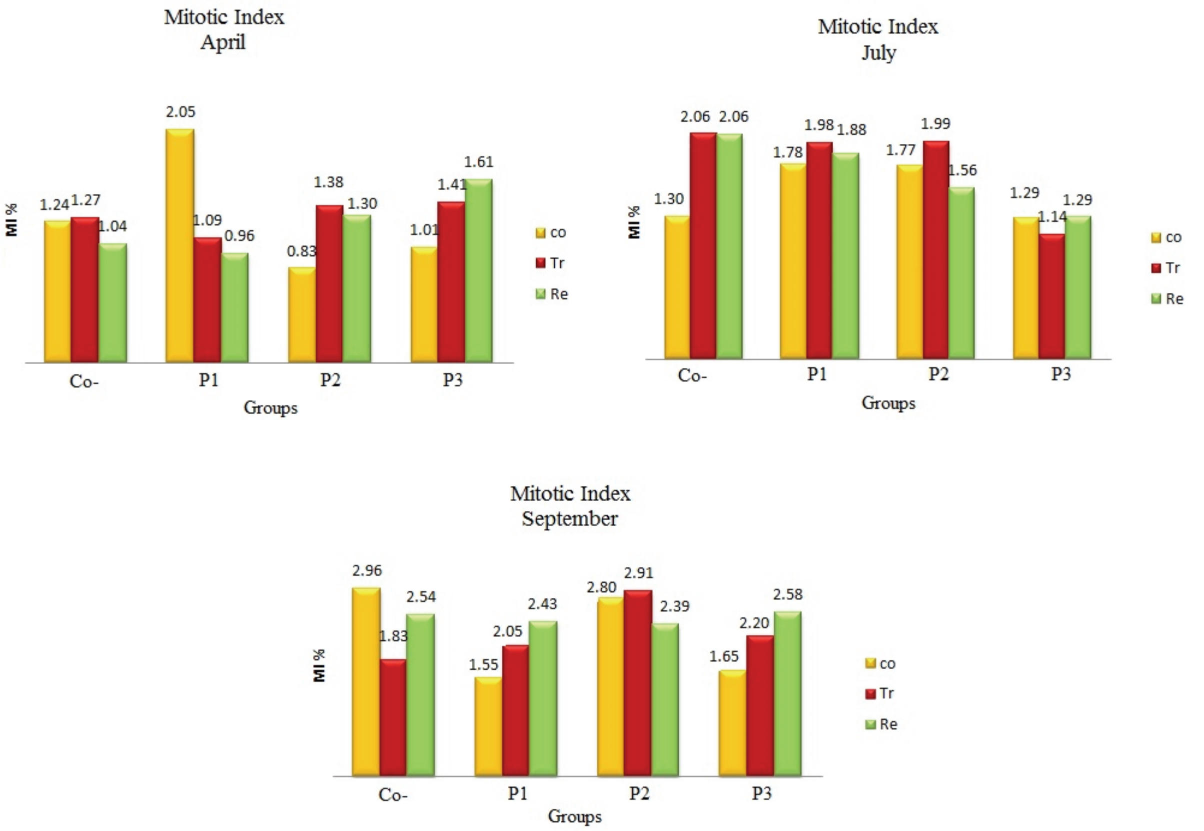

Figure 1. Mitotic Index Percentage (MI) along the three months collecting water from wells. Co-: negative control. P1: Rio Pedreiro well. P2: Rio Pedreirinho well and P3: Volta Alegre well. Sampling times: Control (C0) = 0h. Treatment (Tr) = 24h. Recovery (Re) = 24h. Kruskal-Wallis Statistical test with 5% of significance.

Düsman et al. (2011), Ferreira, Frueh, Düsman, Heck, and Vicentini (2012) and Circunvis, Heck, and Vicentini (2012) used the similar test as this study to analyze of water samples from rivers and streams and found no cytotoxicity in water as well. The negative effect of cytotoxicity corroborates with the results obtained in physical and chemical analysis, because of all the parameters are complied with the legislation. According to Silva, Erdtmann, and Henriques (2003) low pH values may promote a toxic effect in the water. That could increase the metal ions dissolution and concentration in the water, which was not observed in this study.

In addition, Cabrera and Rodriguez (1999) showed that precipitation rate has influence on toxic compounds due to greater dilution in rainy period, thus reducing the toxic power. Therefore, Francisco Beltrão is a town with high precipitation rate that may have influenced in the absence of cytotoxicity in the water samples from wells.

From the mutagenicity index (Figure 2), it was found that the values of MIGs were statistically similar to MIs negative control (Co-), control of the bulb itself (C0-0h) and recovery time (Re-24h) of each onion. Moreover, the variance throughout the year was not statistically significant.

The Chromosomal changes observed (Figure 3) were mainly colchicine, disorganized metaphases, multipolar anaphases and with loss of chromosomes. These results are similar to those observed by Costa, Domingues, Düsman, Almeida, and Vicentini (2015) who analyzed the water of Rio do Peixe (São Paulo), and by Maschio (2009) who examined the water from Municipal Dam of São José do Rio Preto (SP). In spite of the alterations observed, those studies did not evidence cytotoxic characteristics in samples, which corroborates with the present study.

According to Costa et al. (2015) these types of chromosomal alterations are due to changes in the formation process of spindle fibers, which prevent equatorial plate organizing and chromosomes to be separated correctly during anaphase. That indicates the presence of eugenic substances (Oliveira, Voltolini, & Barbério, 2011), influenced by toxic compounds that had contact with organisms such as heavy metals and agrochemical compounds (Maschio, 2009; Peron, Canesin, & Cardoso, 2009).

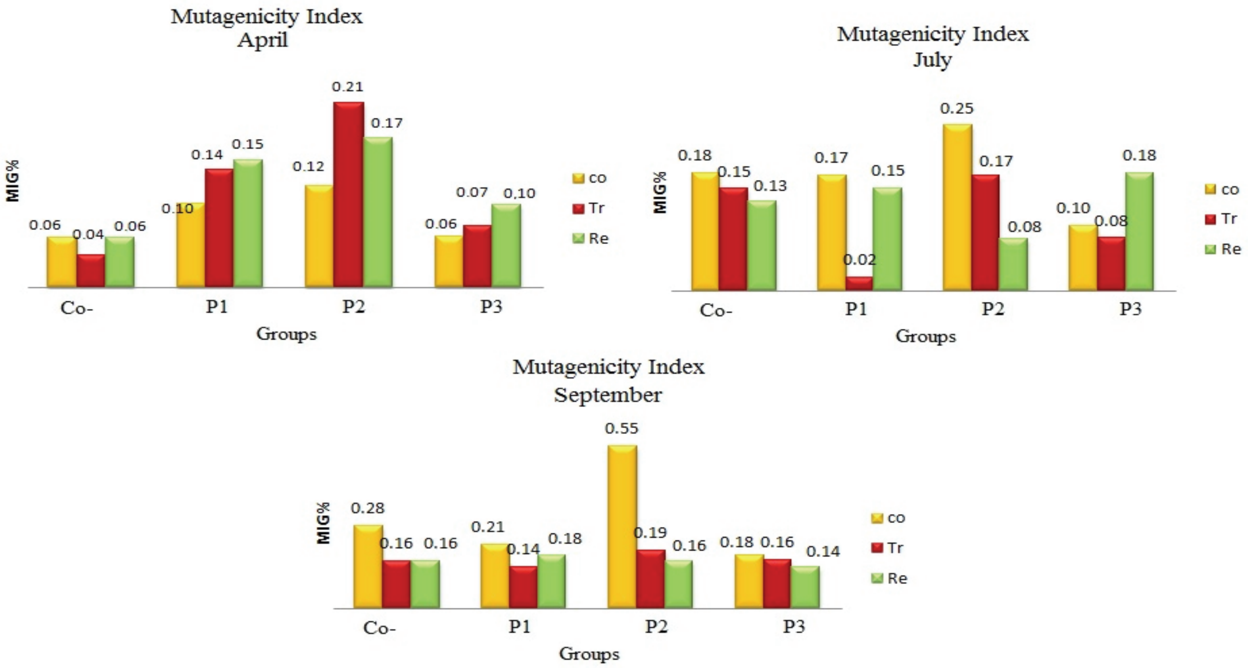

Figure 2. Percentage of Mutagenic Indexes (MIG) of three months of collecting water from wells. Co-: negative control. P1: Rio Pedreiro well. P2: Rio Pedreirinho well and P3: Volta Alegre well. Sampling times: Control (C0) = 0h. Treatment (Tr) = 24h. Recovery (Re) = 24h. Statistical test of Kruskal Wallis. with a 5% level of significance.

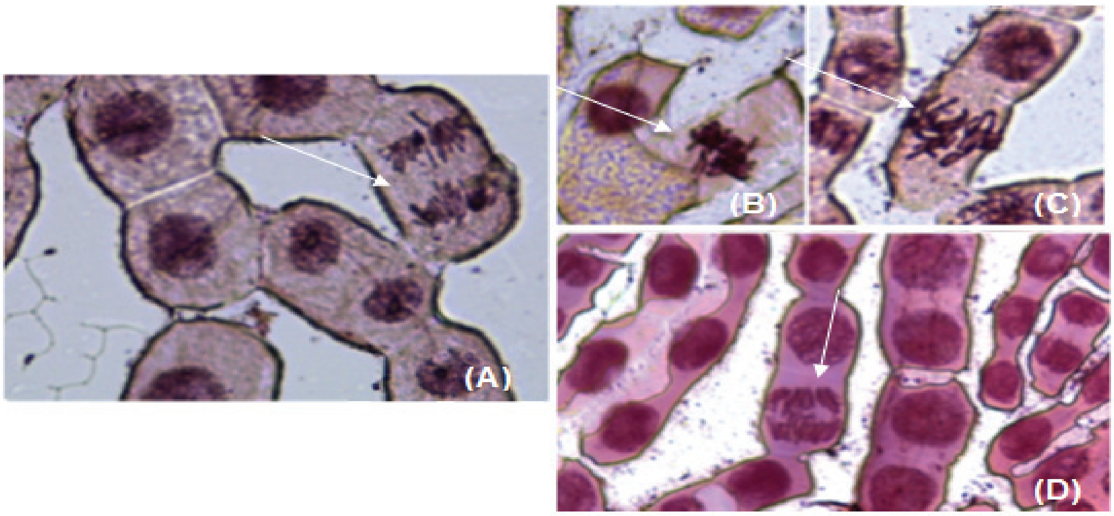

Figure 3. Chromosomal changes found in treatments with the water from the wells under study in root cells of *Allium cepa L.* (microphotographs obtained with the 40 x objective). A) Multipolar Anaphase; B) Metaphase with loose chromosome; C) Metaphase-colchicine; D) Anaphase multipolar.

The samples toxicity assessed by bioassay using the *Artemia sp*. brine shrimp as bioindicator organism (Figure 4), show that the dead organism's number in each concentration of water from each well has not presented a statistical variation compared to the negative control in each month. the samples showed no acute toxic action. Mendes et al. (2011) evaluating the water quality of the Marombas river (SC/Brazil) using *Artemia sp*. as a bioindicator, did not find any significant organisms' mortality as well.

According Figueiredo, Oliveira, Diniz, Mendonça, and Okuyama (2013) tests using *Artemia sp*. as indicator organism are useful, cheap and easy to perform and can be used for preliminary analysis of toxicity. Simple methodologies to perform are important to have rapid and inexpensive evaluation of resources such as these. The region under study presents agricultural characteristics with intensive agrochemicals use, which can compromise the water quality causing risks to human health.

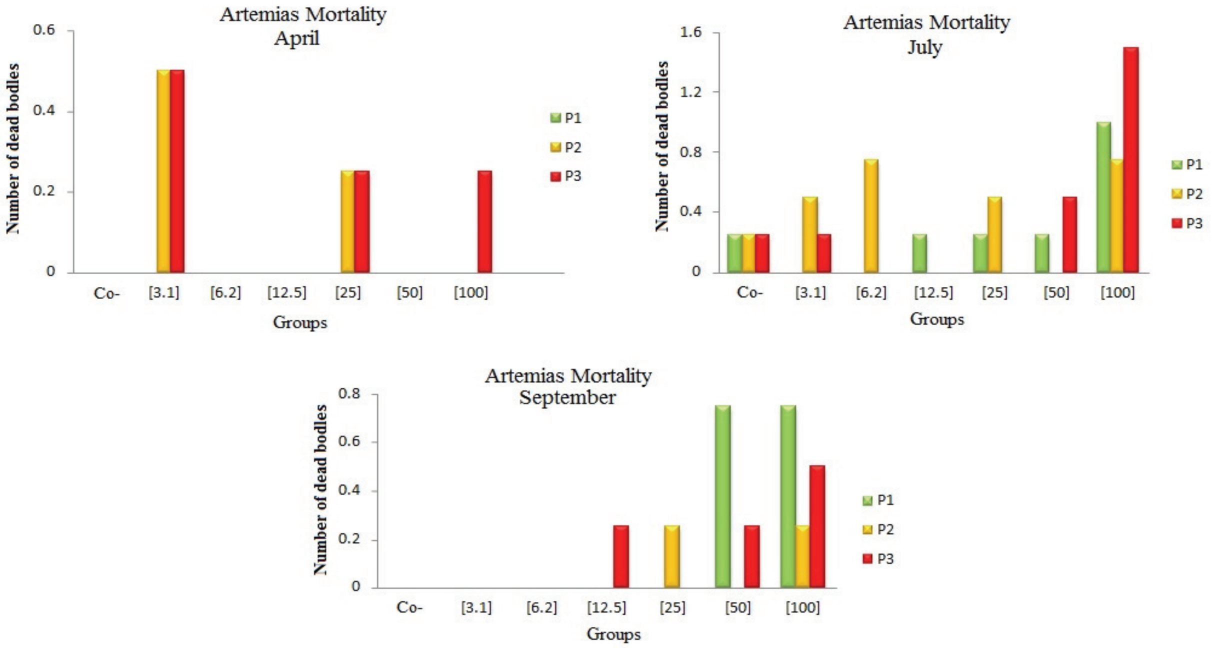

Figure 4. Average number of dead organisms of the negative control (Co-) and of different concentrations of water from the wells tested in three months. P1: Rio Pedreiro well; P2: Rio Pedreirinho well; P3: Volta Grande well. Statistical test by Dunnet with 5% of significance.

Use and occupation of the soil in the communities

In loco observations identified that all residences inside the study area had black pits as domestic effluent disposal system, which is a potential contaminant to groundwater. As highlighted by Silva, Dourado, Krusche, and Gomes (2009) this is a reality of most Brazilian municipalities. In Table 2 is presented the result of use and occupation of the soil around the wells (Table 2).

Table 2. Use and occupation of the soil around the wells within a radius of 1 km.

	Native vegetation	Reforestation	Pastures	Tillage
Rio Pedreiro	37.9%	16.88%	13.37%	31.85%
Rio Pedreirinho	18.78%	37.58%	21.34%	22.3%
Volta Alegre	36.30%	17.55%	9.53%	36.62%

*100% corresponds to 1 km^2

The three locations under study are occupied by dairy farming and agriculture predominating soy and corn. In general, farmers do not use management and conservation practices to the soil, although laminar erosion was observed in the arable areas and pastures.

In field observations it was possible to observe the conservation and preservation in the surroundings area of wells, and three of them are located in the middle of pastures sharing space with animals. In the face of the fact that the three wells are not fenced, the animals have contact with the local which can justify the presence of thermal tolerant coliforms (Figure 5).

Figure 5. Pictures of the place and surroundings of wells in the communities of Volta Alegre (A). Rio Pedreiro (B) and Rio Ribeirinho (C).

According to Freitas, Eckert, and Caye (2001), the wells must have a delimited area around them whenever possible with a 10 m radius defined as a protection perimeter to assure protection against surface pollution. Thus, considering the current situation of wells conservation, it is suggested to use an effective isolation in the wells in order to avoid animals contact. The well top should be done with concrete protection slab, measuring approximately 1 meter wide by 1 meter long and 0.30 m high, with cement on the surface of the edges. However, this was not observed in the wells under study that did not have any kind of protection.

Relation of use and occupation of the soil with water quality

The Pearson correlation test made possible to verify that physical. chemical and biological parameters of the wells water did not have a significant correlation with the use and occupation classes of soil. According to Nordborg, Sasu-Boakye, Cederberg, and Berndes (2017) the use and occupation of the soil has a strong correlation with the characteristics of underground water.

From the main analysis of components (Figure 6), it can be noticed that Well 3 (Volta Alegre community) has a greater influence of plantation areas and has the greatest average values for total dissolved solids and turbidity. On the other hand, it has less area with pastures.

For Well 2 (Rio Pedreirinho Community), there was a positive relation for the total iron, nitrate and reforestation parameters, opposed to conductivity, hardness and pH parameters, native vegetation class and to the Well 1 (Rio Pedreiro community).

Thus, it is clear that the parameters positively associated to Well 2 are opposed to Well 1. Well 1, in turn, presented a positive relationship with the conductivity, hardness and pH parameters and the native vegetation.

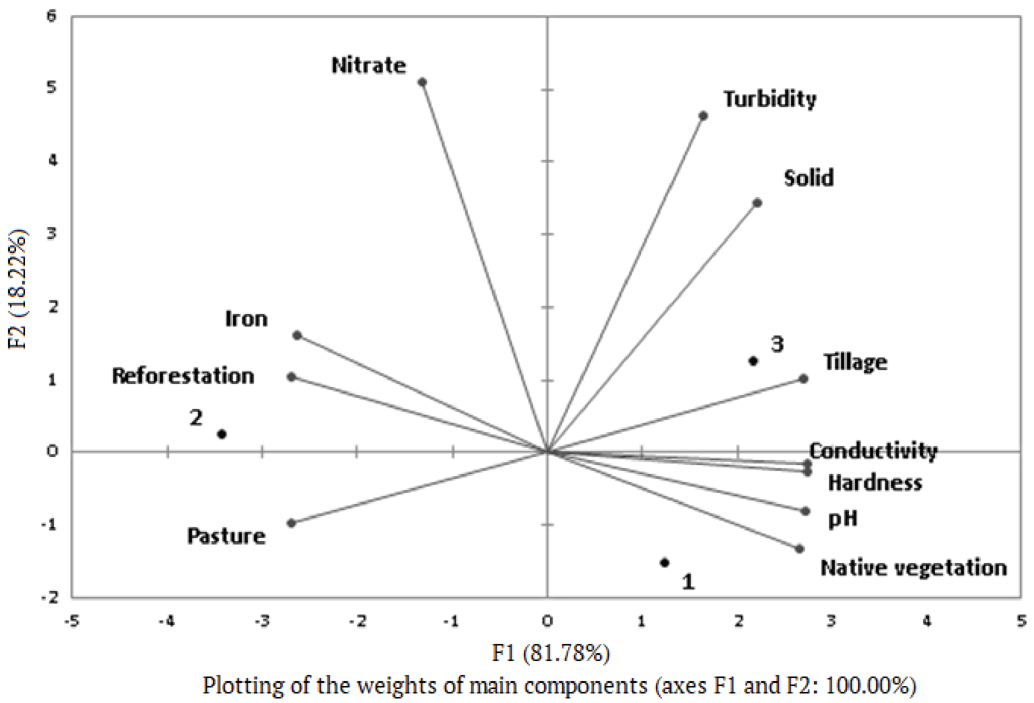

Figure 6. Graphical representation of the analysis of main components. 1: Rio Pedreiro well; 2: Rio Pedreirinho well; 3: Volta Alegre well.

In comparison with literature data, Araújo Neto, Andrade, Palácio, Sales, and Maia (2017) studied the influence of the use and occupation of the soil on the water quality in the valley of Rio Trussu in Ceará State (Brazil), and found that over the last ten years the region under study has undergone major changes due to anthropogenic activity that directly affected the characteristics of the groundwater quality. They highlighted the importance of studies that relate the local characteristics with the quality of the water.

Environmental education for water sustainable use

Based on the information obtained regarding the hydro sanitary conditions of the water supply, an educational action was carried out aiming awareness to the well's users. It was presented information about the quality of the water that comes from the community wells of these neighborhoods, as well as a brief action of environmental education regarding water quality for supply.

About 30 people were present and showed interest in the subject, asking some questions about the characteristics that they usually observe in the water. For example, questioning the reason of turbidity in the water on rainy days (Figure 7).

When it was exposed the sanitary condition of the water used, the majority was worried about the quality of the water. In the presentation of water chlorination as a treatment many residents seemed to understand the importance of water treatment. However, some of them did not agree with the disinfection process of the water supply. For them, the disinfection would cause alterations of the organoleptic standards causing the search for new sources to supply their needs.

In view of the situation, a petition has been proposed so that the municipal government can assist this installation, since the municipal public authority is responsible for the community wells.

In Brazil the access to benefits generated by sanitation is still a challenge to be achieved (Ministério das Cidades, 2009), since its endorsement requires the involvement of several public segments what makes the process difficult. The sanitation services are related to having a life quality and the natural environment protection, especially the water resources. In this sense, it is essential to develop educational actions that enable the understanding and stimulate people to take part in the process (Novotný, Hasman, & Lepič, 2018).

To make the obtained information available to the communities involved, is the main purpose of the present study. In this context, the environmental education regarding sanitation has the competence to stimulate the individuals to the expected transformations. This was manifested in the petition demanding the water disinfection which was undersigned by the residents.

Therefore, it is essential to stimulate a close look at the reality in which one lives, in order to transform it. It is essential that the population acknowledge different aspects related to sanitation.

Conclusion

The rural regions of south Brazil still present a high sanitation deficit requiring that the resources quality used in public supply must be evaluated periodically. The microbiological quality of water is still one of the most worrisome factors in these regions. However, the disinfection of this water can be easily adopted reducing the risk to contaminate the resource. Environmental education is extremely important. For the population start changing their habits it is necessary that they know the reality in which they live and the ways to improve their life quality.

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