Water quality for consumption and bathing in springs with different soil cover in the Rio Grande watershed

Qualidade da água para consumo e balneabilidade em nascentes com diferentes coberturas de solo na microbacia do Rio Grande

Calidad del agua para consumo y balneabilidad en manantiales con diferente cobertura de suelo en la microcuenca del Río Grande

Received: 08/25/2022 | Reviewed: 09/06/2022 | Accept: 09/09/2022 | Published: 09/17/2022

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Abstract
Land use and occupation by agriculture and urbanization generate several impacts on the natural environment and water quality in a watershed is the main parameter capable of reflecting the consequences of anthropogenic activities that occur in this location. Protecting water resources and their tributaries is of utmost importance for the preservation of the nature and health of the population in relation to direct and indirect consumption of water. In this sense, objectified with this research was to analyze the water quality for consumption and bathing in springs (N1, N2, N3, N4, N5 and one outfall, Foz),) with different soil cover in the Rio Grande watershed. Water collections were performed monthly over a period of one year and physical, chemical and bacteriological parameters were evaluated. The data obtained were submit to statistical analysis and the results showed that the sources N1 and N2 had the lowest values in turbidity, color, biological oxygen demand (BOD) and pH, being the latter very close to neutrality. The spring N3 in relation to the others, presented lower values for temperature and dissolved oxygen. N1 indicated having the best water quality values for the physical and chemical parameters. All springs and outfall presented some type of bacteriological contamination and the risk to the population using these waters. Finally, the results show that the presence of vegetation around the water resources influences in the water quality of the springs.
Keywords: Coliforms; Contamination; Health; Water quality; Water resource.

Resumo
O uso e ocupação do solo pela agricultura e urbanização geram vários impactos no meio ambiente natural e a qualidade da água em uma bacia hidrográfica é o principal parâmetro capaz de refletir as consequências das atividades antrópicas que ocorrem nesse local. A proteção dos recursos hídricos e de seus afluentes é de extrema importância para a preservação da natureza e saúde da população em relação ao consumo direto e indireto da água. Nesse sentido, objetivou-se com esta pesquisa analisar a qualidade da água para consumo e balneabilidade em nascentes (N1, N2, N3, N4, N5 e um exutório, Foz), com diferentes coberturas do solo na microbacia do Rio Grande. As coletas de água foram realizadas mensalmente durante um período de um ano e os parâmetros físicos, químicos e bacteriológicos foram avaliados. Os dados obtidos foram submetidos à análise estatística e os resultados mostraram que as nascentes N1 e N2 apresentaram os menores valores de turbidez, cor, demanda biológica de oxigênio (DBO) e pH, sendo este último muito próximo da neutralidade. A nascente N3 em relação às demais apresentou menores valores de temperatura e oxigênio dissolvido. A N1 indicou ter os melhores valores de qualidade da água para os parâmetros físico-químicos. Todas as nascentes e Foz apresentaram algum tipo de contaminação bacteriológica e risco para a população que utiliza essas águas. Por fim, os resultados mostram que a presença de vegetação ao redor dos recursos hídricos influencia na qualidade da água das nascentes.
Palavras-chave: Coliformes; Contaminação; Saúde; Qualidade da água; Recursos hídricos.

Resumen
El uso y ocupación del suelo por la agricultura y la urbanización generan diversos impactos en el medio natural y la calidad del agua en una cuenca hidrográfica es el principal parámetro capaz de reflejar las consecuencias de las actividades humanas que se dan en ese lugar. La protección de los recursos hídricos y sus afluentes es de suma importancia para la preservación de la naturaleza y la salud de la población en relación al consumo directo e indirecto de agua. En ese sentido, el objetivo de esta investigación fue analizar la calidad del agua para consumo y balneabilidad en manantiales (N1, N2, N3, N4, N5 y una desembocadura, Foz) con diferentes coberturas de suelo en la microcuenca del Río Grande. Las colectas de agua se realizaron mensualmente por un período de un año y se evaluaron los parámetros físicos, químicos y bacteriológicos. Los datos obtenidos fueron sometidos a análisis estadístico y los resultados mostraron que los manantiales N1 y N2 presentaron los valores más bajos de turbidez, color, demanda biológica de oxígeno (DBO) y pH, siendo este último muy cercano a la neutralidad. El manantial N3 en relación a los demás presentó valores inferiores de temperatura y oxígeno disuelto. N1 indicó tener los mejores valores de calidad de agua para los parámetros fisicoquímicos. Todos los manantiales y Foz presentaron algún tipo de contaminación bacteriológica y riesgo para la población que utiliza estas aguas. Finalmente, los resultados muestran que la presencia de vegetación alrededor de los recursos hídricos influye en la calidad del agua de los manantiales.
Palabras clave: Coliformes; Contaminación; Salud; Calidad del agua; Recursos hídricos.

1. Introduction

The maintenance of all terrestrial life depends on one of the most abundant natural resources on the planet, water. Although present in great abundance on the planet, water suitable for human consumption and agriculture is distributed in different quantities and places. In addition, for the proper balance of ecosystems to occur, as well as the survival of living beings, it is necessary to observe not only the availability of water, but also the quality of this resource (Ana, 2011).

Water quality is relate to several parameters, which are characterized as physical, chemical and biological. The investigation of these parameters is a premise for the different uses for which it is intended, that is, whether this resource will be available for consumption, balneality and others (Merten & Minella, 2002; Abreu & Cunha, 2015).

Another important factor in the analysis of these water parameters is the observation of the natural and anthropogenic systems within the watershed, that is, the type of vegetation cover, the topographic, geological, geomorphological, pedological and thermal characteristics of this watershed. This arrangement plays an essential role in the hydrological behavior of the watershed, and it is very important to measure these processes (Garcez & Alvarez, 2002).

The watershed is considered as a physical system where inlet balances from the precipitated volume of water are made and the output is the volume of water discharged through the exutory (Foz), with evaporation, transpiration and water infiltration losses in soil (Tucci, 2007).

Human activities or anthropogenic factors in a watershed have a decisive factor in the preservation of its water resources, because the impact of these activities can be generated by actions such as urbanization and industrialization of agriculture (Porto & Porto, 2008), causing the reduction of riparian forest due to its occupation, reducing the quality of the soil and of this basin (Teles et al., 2022a). Moreover, water resources such as springs and reservoirs impacted by these factors lose their ability to keep quantitative and qualitative water parameters stable (Heller & Pádua, 2010).

It is essential to elaborate and carry out studies on the effect of land use and occupation on the quality of water resources (Collares et al., 2021), because by monitoring physical parameters (temperature, turbidity, color, odor), chemicals (pH, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, electrical conductivity), bacteriological (total coliforms, heterotrophic bacteria, thermo tolerant coliforms) and artificial agents such as pesticides, it is possible to evaluate the impact generated by anthropic activities (Teles et al., 2022b), contribute to the protection of the health of the dormant population this resource and the preservation of the natural environment.

In this sense, objectified with this research was to analyze the water quality for consumption and bathing in springs with different soil cover in the Rio Grande watershed.

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2. Methodology

The scientific methodology of field study used quantitative research, following the fundamentals described by Estrela (2018).

The research project was carried out in a watershed located in the municipality of Boa Esperança - MG, in the domain of dissected hills and low hills (Baptista et al., 2010), between latitudes 21°04´30” S and 21°06´54” S and longitudes 45°35´32” W and 45°31´30” W. It is a naturally area formed headland drained by a watercourse, upstream of a considered cross section, into which all runoff water converges.

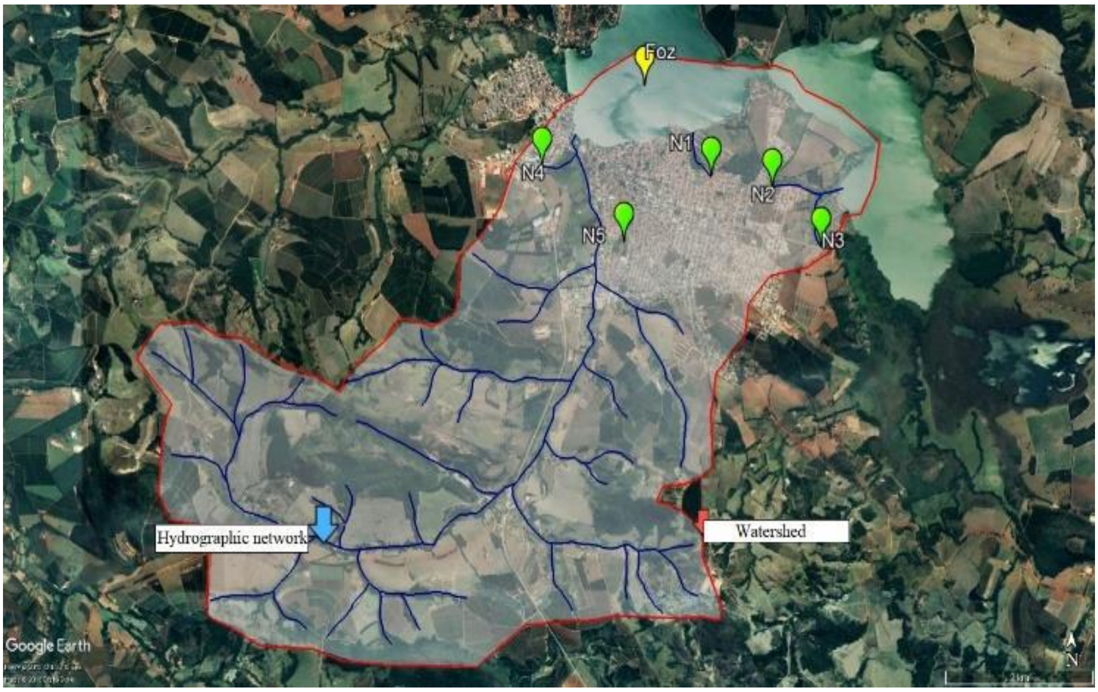
The area under study is part of the drainage network of the Rio Grande Basin and where it is born in the Serra da Mantiqueira, in the municipality of Bocaina de Minas (MG), at an approximate altitude of 1.980 meters. This microbasin presents conformation of some springs in the Municipality of Boa Esperança, and flows upstream into the Lago dos Encantos dam, and can be considered as the most important in the Municipality, as well as being flanked by the Serra da Boa Esperança State Park and the Rio Grande, much of it is surrounded by the urban area of Boa Esperança and by rural properties.

The local climate was classified according to the Köppen Climate Classification system as humid hot summer mesothermal (Cwa), with rainfall between 1.100 and 1.700 manuals and the warmest month average temperature is over 22°C and that of the coldest month below 18°C (Peel et al., 2007).

It presents the Cerrado as the predominant biome and the native vegetation is composed by the montane semideciduous seasonal forest. In the area there are forest fragments and the main productive crops are Coffee, pastures and olericultures (Ibge, 2012).

To collect data on water quality in the drainage network, a watershed was selected and delimited according to the method proposed by Pfafstetter (1989), which is part of the drainage network of the Rio Grande Basin. This watershed is located within the urban area in the municipality of Boa Esperança, MG, and has been given the name of “Hope Microbasin”, to facilitate understanding of its framework (Figure 1).

Figure 1. Chart of the Drainage Network and Collection Points of the Esperança Microbasin Water Resource, Municipality of Boa Esperança, MG.



Source**:** Adaptaded from Google Earth (2019).

In the evaluation of the physicochemical parameters of the water of the drainage network, it was considered as data collection point five locations in the drainage networks in watersheds of 1st order of magnitude and one point in the mouth, shown in Figure 1. These places were selected because they are points where it is known that the population has access to enjoy these waters for their own consumption and for leisure (Bathing).

The sampled areas were characterized as follows: Spring 1 (N1), coordinates 21°05'28.43"S and 45°33'12.28"W, has growing trees by recovery project. Besides remnant of riparian vegetation in the water course. It presents initial process of erosion in the bed and exit of rainwater drainage system below the source. Spring 2 (N2), coordinates 21°05'36.86"S e 45°32'39.07"W, presents degraded areas due to soil exposure. There is erosion on the bank of the source. It is characterized as pasture area, with only one tree and presence of bamboo. The water source is 6 m from paved street, with house next door and rubble nearby. Spring 3 (N3), coordinates 21°05'57.81"S e 45°32'18.75"W, has typical downstream marsh vegetation and pasture area at its head. It is apparently an unpreserved diffuse spring. There is also a building construction nearby. Spring 4 (N4), coordinates 21°05'30.6"S e 45°34'24.3"W, is in pasture area with little gallery forest. At its head was found sorghum plantation 8 m from the source. Spring 5 (N5), coordinates 21°05'56.50"S e 45°33'52.60"W, with little riparian vegetation, has bamboo and is 5 m from paved street. There is an adjoining house with animal presence and is located within a permanent preservation area (PPA). And the exutório (Foz), coordinates 21º 5'86.95"S e 45º33'55.12"W, is in the lake of charms with no vegetation and asphalt 4 m from the water.

The selection of collection points was conceived in order to calculate the effect of urbanization and agriculture on the physicochemical parameters of water determining the quality conditions in the springs for direct consumption by the population.

It is justified to select the first order of magnitude courses by the type of land use / occupation around their sources, so that the water to be analyzed does not receive direct influence from other vegetation cover, eliminating the effects on nutrient movement. and the water quality of other land use / occupation. Drainage courses of 1st order of magnitude were selected according to the drainage channel classification, being considered 1st order drainage channels those without branches, according to Strahler (1957). This identification includes permanent watercourses, as recommended by Strahler (1957) and Lueder (1959).

Surface water samples from 1st order streams were collected using a "clean" container with a volumetric capacity of up to 2 liters, opened at the time of collection and then closed.

In this research were analyzed physical - (temperature, turbidity) and chemical (pH, dissolved oxygen, electrical conductivity, Biochemical Oxygen Demand - BOD, Chemical Oxygen Demand - COD and tests for Agrochemicals) parameters.

Water temperature was determined at the collection site by direct reading on a multi sensor, orion star a series PH / ISE meter. Turbidity was determined in the laboratory using the portable water analyzer, digital microprocessor, 2100P turbidimeter, with reading range from 0 to 1.000 NTU. Electrical conductivity was measured using an on-site conductivity meter with portable equipment, orion star a series PH / ISE meter, with direct reading.

According to Cetesb (2010), the influence of pH on natural aquatic ecosystems is directly due to its effects on the physiology of different species. The pH was determined on-site with the portable equipment, orion star a series PH / ISE meter, with direct reading. The determination of dissolved oxygen will be made using the dissolved oxygen meter, with digital indication and relative accuracy of +/- 0.03 mg / liter, Hach brand.

Odor and apparent color were determined following the methodology of Standard Methods for the Examination of Water and Wastewater (Apha, 1998).

The determination of the COD was based on the oxidation process of organic matter by a boiling mixture of chromic acid and sulfuric acid (potassium bichromate in acid medium). And the determination of BOD made using the incubation method and, finally, the fecal coliform count made from the gene chrome method. The methodology used for the analyzes was based on the Standard Methods for the Examination of Water and Wastewater (Apha, 1998).

Regarding the determination of bacteriological organisms, basic techniques for detecting the presence / absence of microorganisms were adopted. The method used to count total coliforms was the Most Probable Number (MPN), made official by Aoac (2016).

The analysis of tests of the potential pesticides that could be present (January 2019) in the water was performed according to the Consolidation Ordinance nº 5 / 2017 (Brasil, 2017). The samples were analyzed at the Environmental Bioethics Environmental Analysis Laboratory in Araxá, MG. It was not possible to assess the presence of pesticides for springs in all months of water collection.

The monitoring of rainfall in the watershed was carried out through the weather station of Fundação Prócafe (2019), which is located near the experimental area.

The results were submitted to multivariate statistical analysis in order to evaluate the various aspects related to the variability of the data obtained from the physicochemical parameters of water. Multivariate cluster analyzes were applied to understand the structure of the characteristics of the evaluated watersheds. Analysis of variance was employed using the 5% Tukey test.

3. Results and Discussion

Table 1 shows the microbiological and physicochemical characterization of the sources under study and comparisons with the normative standards.

Table 1. Water quality parameters in the Esperança watershed. Period: September 2018 to August 2019.

Parameters		Collection Points - Springs (N) and FOZ					
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Temperature (ºC)	Average	23,2 ab	22,8 ab	21,0 b	22,0 ab	21,9 ab	23,8 a
	Maximum	25,0	24,0	24,0	24,0	24,0	28,0
	Minimum	22,0	21,0	16,0	18,0	18,0	19,0
	DP	1,0	1,2	2,8	2,3	2,2	3,4
	CV (%)	4,4	5,2	13,2	10,3	10,0	14,1
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Turbidity (UNT)	Average	0,3 b	1,1 b	24,6 a	4,2 b	5,1 b	6,9 b
	Maximum	0,7	3,8	99,8	25,2	18,9	12,8
	Minimum	0,1	0,5	1,4	0,6	0,7	3,1
	DP	0,2	0,9	30,0	6,8	5,1	3,6
	CV (%)	56,2	82,9	121,9	162,8	99,9	52,9
		* Maximum limit of 40 nephelometric turbidity units (UNT)					
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Dissolved oxygen (mg L^{-1})	Average	3,1 c	4,4 b	2,3 c	4,8 b	3,2 c	6,9 a
	Maximum	5,1	5,3	3,0	6,4	5,4	8,2
	Minimum	2,4	3,3	1,5	2,5	2,0	4,8
	DP	0,8	0,6	0,5	1,3	1,0	1,0
	CV (%)	26,9	13,3	21,0	26,8	32,5	15,1
		*Limit ≥ 6 mg O_2 L^{-1}					
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Hydrogen potential (pH)	Average	5,1 d	5,5 c	5,8 bc	5,8 bc	5,9 b	6,6 a
	Maximum	5,4	6,1	6,2	6,6	6,1	7,2
	Minimum	4,4	5,2	5,4	4,3	5,4	6,2
	DP	0,3	0,3	0,3	0,6	0,2	0,3
	CV (%)	5,0	4,6	4,9	9,5	3,3	3,9
		*Adequate pH range: 6,0 a 9,0					
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Color (Pt-Co)	Average	2,3 d	2,1 d	44,0 a	9,5 c	15,6 bc	40,4 ab
	Maximum	10,2	5,5	127,0	62,1	65,1	83,7
	Minimum	0,0	0,0	2,1	0,9	2,2	9,5
	DP	3,1	1,9	41,5	17,1	18,7	27,3
	CV (%)	132,8	89,6	94,4	180,5	120,1	67,6
		*Limit ≤ 75 mg Pt Co L^{-1}					
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Electric condutivity (µs.cm-1)	Average	63,4 b	75,1 b	131,1 ab	178,0 a	140,6 ab	32,1 c
	Maximum	198,9	281,4	216,2	446,1	209,3	142,7
	Minimum	10,4	16,2	30,6	84,9	39,9	47,6
	DP	62,3	77,0	55,3	98,3	45,5	32,1
	CV (%)	98,1	102,6	42,2	55,2	32,3	37,2
		N1	**N2**	**N3**	**N4**	**N5**	**FOZ**
Biochemical Demand of Oxygen - BOD (mg L^{-1})	Average	3,5 c	4,3 bc	7,5 a	4,7 bc	5,3 b	4,2 bc
	Maximum	5,0	6,0	12,4	5,4	8,1	5,0
	Minimum	0,2	3,0	5,0	3,0	4,0	3,0
	DP	1,4	0,8	2,7	0,7	1,6	0,5
	CV (%)	39,1	16,9	34,8	13,3	29,0	12,1
		*Limit ≤ 3 mg O_2 L^{-1}					

*Conama Resolution No. 357 (2005). Numbers followed by distinct letters differ according to the Tukey Test at 5% probability. Source**:** Authors (2019).

In this study, the average temperatures ranged from 21.0ºC to 23.8ºC, with an amplitude of 2.8ºC. The highest temperature values during the period of analysis of the experiment occurred for FOZ, being 23.8ºC the average and 28.0ºC the maximum recorded. The spring N3 presented the lowest average and minimum values throughout the period (21.0 and 16.0ºC, respectively). This difference in temperature between the springs and FOZ, probably occurred due to the presence of vegetation around these water resources and the water shading caused by the plants present in these places, and the highest values found in environments without plant shading were in FOZ, N1 and N2.

In the water resources whose presence of shading was observed, the temperature values indicated smaller amplitudes throughout the experiment, highlighting the spring N3 (swamp region with vegetation covering the spring). In N4 (gallery forest vegetation) and N5 (little riparian vegetation, but in an early stage of regeneration), which is in an environment with intermediate shading, the temperature value also presented lower values when compared to springs without any vegetation type. in your surroundings.

Donadio et al. (2005) assessing the impacts on water quality in springs, found lower temperatures in springs with remaining natural vegetation than in springs without natural protection. Arcova and Cicco (1999) in a study conducted in the region of Cunha, São Paulo, found greater warming in waters that do not have riparian forests, as well as Sugimoto et al. (1997) which discuss the importance and influence of riparian forests on water temperature within the water resource, as they provide the necessary coverage for water temperature control and maintenance of chemical, physical and biological reactions in these natural systems.

In this sense, the preservation of riparian forests is of paramount importance for the springs to be able to maintain an ideal temperature for aquatic ecosystems, given that the water temperature in the springs does not directly imply health problems for humans, but may influence in other factors and parameters considered essential for the maintenance of life.

According to the Ordinance 2.914 / 2011 of the Ministry of Health (Brasil, 2011), the natural turbidity of water ranges from 3 to 500 UNT. The highest turbidity value (Table 1) was found in N3, which also had the highest Biochemical Oxygen Demand (BOD) values. However, BOD variation may be related to the amount of organic matter present in water or the amount of solids, as it has significant relationship with both parameters.

The lower results for the springs (N1, N2, N4, N5, N6 and FOZ) can be indicated by the forage grasses present around these springs, where they protect the body of water from negative processes to the spring, such as runoff and erosion. Another factor that can influence the amount of BOD is the amount of dry matter mass coming from the trees (leaves, fruits, branches, etc.). It is important to highlight that N1 presented more expressive values regarding the turbidity parameter, with an average of 0.3 UNT. This result may indicate the direct influence of the existing protection offered by fencing at this location, given that N1 is the only source with this management, being this process performed to avoid trampling cattle and other animals around the water eye, which decreases the presence of animals and consequent contamination from soil erosion and fecal loading.

In studies by Donadio et al. (2005) and Rodrigues et al. (2009), the authors found in springs in the middle of the woods, turbidity between 2.0 to 0.4 UNT and 4.5 UNT, respectively, values well below that found in N3 (99.8 UNT). A probable explanation for this expressive difference can be elucidated by the observation of the very low flow rate at the site, as the water accumulates naturally, forming a flooded bed and serving as a resource for animals, which may have caused movement and soil erosion and increment of organic matter in this spring.

Primavesi et al. (2002) also observed similar results when studying springs with riparian forest 50 m away from its source, similar to the values found in some of the springs (N4, N5 and FOZ), presenting turbidity of 6.9 UNT.

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Another important aspect refers to the study by Rodrigues et al. (2009) in which a 42 UNT turbidity was found in springs emerging within the production system (citrus and sugarcane), without protection by riparian forest. In dammed springs with riparian forest protection, turbidity values were close and 6.0 UNT.

In this sense, it is evident that Turbidity and BOD correlated with each other and this is due to the fact that Turbidity varies upwardly with the amount of organic matter in the water, being evident its greater influence on turbidity value.

Regarding dissolved oxygen (DO), the minimum value for the preservation of aquatic life, established by Conama Resolution 357/05 (2) is 5.0 mg O_2 L^{-1}. The dissolved oxygen values found in the springs were low, especially in the spring N3 (2.3 mg O_2 L^{-1}). Another factor that may explain the average of 2.3 and minimum of 1.5 of N3 is the lack of water runoff, due to the little unevenness of the terrain, which hinders a permanent runoff of water. The lack of flow in the water flow together with a higher load of organic material provides greater intensity in eutrophication processes and a drop in dissolved oxygen concentration in water.

On the other hand, FOZ recorded discrepant DO values in relation to the springs, being the only one in the present study to present an average higher than 5.0 mg O_2 L^{-1}. This fact may be related to the large extent and volume of water in this water resource, since the average obtained was 6.9 mg O2 L^{-1}, due to its larger area and volume of water. These aspects contributed directly to the processes of self-purification and dilution or deposition of waste in water. The springs, on the other hand, received a greater load of waste in a smaller volume of water, thus impairing the natural physicochemical processes that occur in the water.

According to (Table 1) the pH values are within the range considered normal for natural environments, from 4.0 to 9.0, according to Von Sperling (2007). However, it is observed based on the results found a slightly acidic pH for the springs, with the main mean range between 5.0 to 6.0. However, the most common is to observe values between 6.0 and 8.5 (Chapman & Kimstack, 1992). For the destination of water to the population, the values must be between 6.0 and 9.5 according to the Ordinance 2.914 / 2011 of the Ministry of Health (Brasil, 2011).

According to Cunha et al. (2011), low pH values may be related to the soil characteristics of the region and the physicochemical characteristics of the water of a specific region, as well as the disposal of organic and industrial waste in the water. Primavesi et al. (2002) and Donadio et al. (2005), in studies of springs located under the predominance of Red Latosol, the water samples presented more acidic pH values (between 5.4 and 6.4). The results found in the table 1 indicate that it is necessary to perform a pH control before its consumption by the population.

The color of the water samples for N1 and N2 springs presented lower and very close average values between them (2.3 and 2.1) during the whole period evaluated, while N3 and FOZ presented higher indices (40.0 and 40.4), with means close to the allowed limit (75 mg Pt Co L^{-1}). The color increase in the springs (N3 and FOZ) may be related to the erosive effect on the soil, since its destructuring due to improper management, especially in the pasture (N3) has sufficient potential to contribute to this increase. As well as the discharge of domestic effluents (FOZ) that contributes to the increase of the color parameter values.

The higher values of N3 and FOZ in color show that suspended sediments and the carrying of material to water interfered with water coloration, according to the same situation observed by Arcova and Cicco (1999).

The parameter electrical conductivity, the results show that the spring N4 obtained the highest average (178.0), while the FOZ the lowest (31.0) (Table 1). The high values of electrical conductivity in spring N4 indicate that the water of this spring presented higher charge of ions in solution. This can be explained by the presence of animals and agriculture (sorghum planting) around this spring and the organic waste possibly dumped in the water. FOZ presented low values, showing that during this monitoring period the site did not suffer anthropic and natural actions, so as not to have their values elevated.

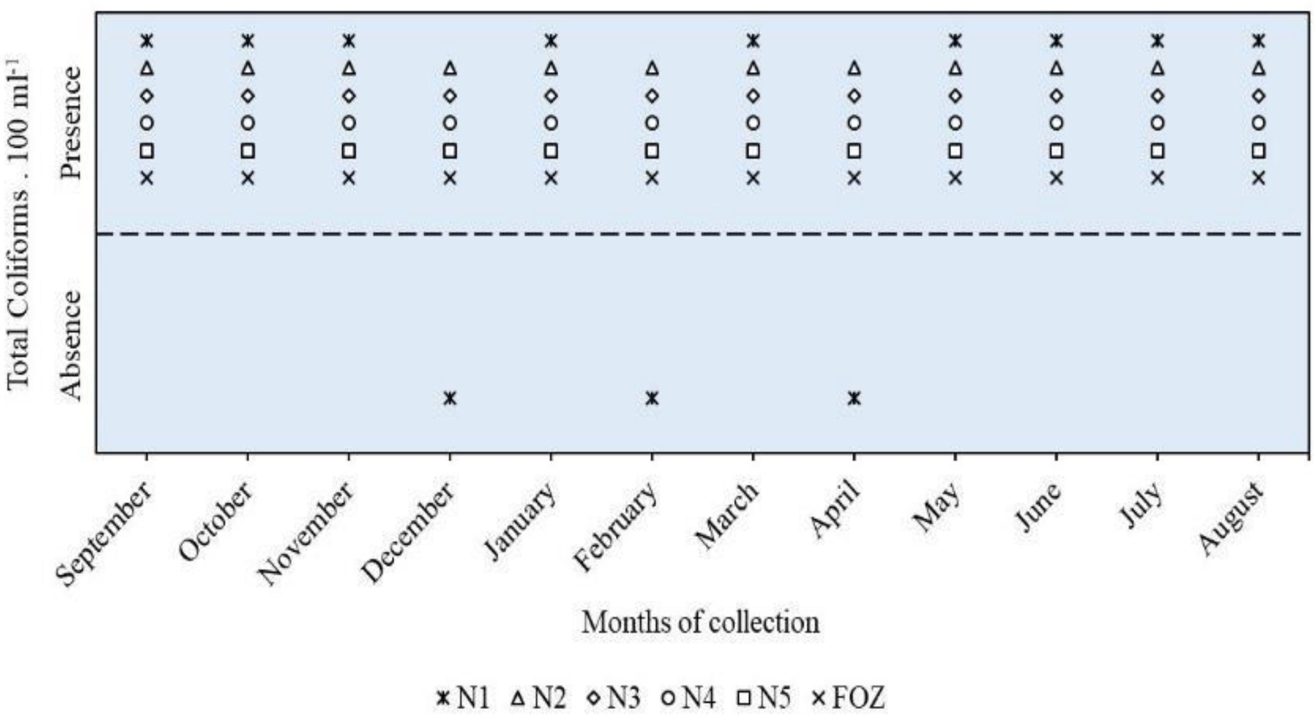
In this study, the highest BOD average was from spring N3 (7.5), where exactly we have the lowest OD (2.3, Table 1), indicating that the lower the dissolved oxygen of the spring, the higher the organic matter content. Another factor that contributes to the results obtained in the BOD parameter of N3 is turbidity, which had the highest mean among springs (24.6). Thus, with low DO and high turbidity we obtained the worst BOD results in N3.

In the four months evaluated in 2018 the sum of the rainfall indices was 806.6 mm and in eight months of 2019 the sum was 726.8 mm, that is, in four months of 2018 we had more precipitation than eight months in 2019. From February 2019 the BOD of spring N3 begins to match the other springs, which remains until August 2019, when the BOD of N3 grows again. Rain can, through leaching, carry organic matter from the margins to the water body, resulting in increased BOD (Hernani et al., 1999).

Regarding Chemical Oxygen Demand (COD), the study presented the most significant records for N3, in October (55 mg O_2 L^{-1}), November (77 mg O_2 L^{-1}) and December (189 mg O_2 L^{-1}) of 2018 and March (36 mg O_2 L^{-1}), May (28 mg O_2 L^{-1}) and August (650 mg O_2 L^{-1}). One of the most likely factors for the values found is the presence of a water club located near this spring, where chemicals could be improperly flowing to this water resource.

The waters from all springs evaluated in the present study showed total coliform contamination in at least one of the months analyzed (Figure 2).

Figure 2. Total Coliforms in 100 ml of sample, present and absent during the data collection period, September 2018 to August 2019.



Source: Authors (2019).

Springs N2, N3, N4, N5 and FOZ were contaminated with these microorganisms in 100% of the analyzes, while N1 spring presented total coliforms in 75% of the evaluations.

The absence of total coliforms presented by N1 during three months (December, February and April) can be elucidated by the preservation of the spring, even though in a precarious situation it presents the best conditions, with growing

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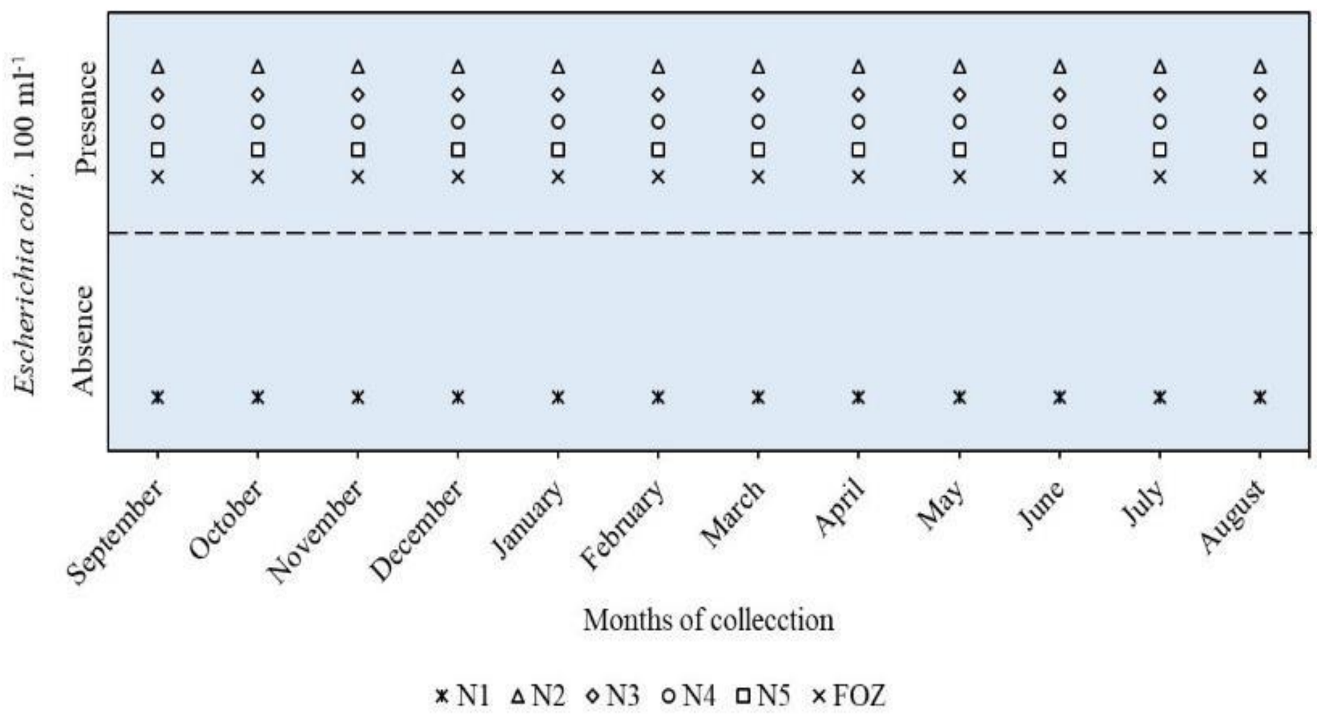
trees by recovery project, remaining ciliary vegetation in the water course. In this sense, Kravitz et al. (1999) demonstrated that protected water sources with a closed water collection system showed better microbiological quality than unprotected sources.

An important fact is that the presence of total coliforms in spring water is considered tolerable when *Escherichia coli* or thermotolerant coliforms are not detected. However, it is essential to eliminate any type of microbiological contamination, investigating the source of its occurrence to solve the problem, because the use of contaminated water can bring numerous problems to the health of the population, such as cholera, febretiphoid, hepatitis A and acute diarrheal diseases (Brasil, 2006).

Escherichia coli is included in both total and thermotolerant coliforms. Its natural habitat is the intestinal tract of warm-blooded animals, although it can also be introduced into food from non-fecal sources (Silva, 2010). The sample results for Escherichia coli are demonstrated in Figure 3.

Figure 3. Escherichia coli in 100 ml of sample, present and absent during the data collection period, September 2018 to August 2019.



Source**:** Authors (2019).

In the sample results, only in the spring N1 no colonies of this microorganism were detected. The waters of the other springs presented colonies of this microorganism in all months of sampling, which is a direct indicator of contamination by faeces, humans or animals

Thus, according to the legislation, all spring waters except N1 are unsuitable for human consumption according to these microbiological results, for Escherichia coli.

Heterotrophic bacteria also called parasites are those that get their food from living things, i.e, together with fungi, attack corpses of animals, plants and other types of organic matter disposed in water (Silva, 2010). The sample results for heterotrophic bacteria are shown in Figure 4.

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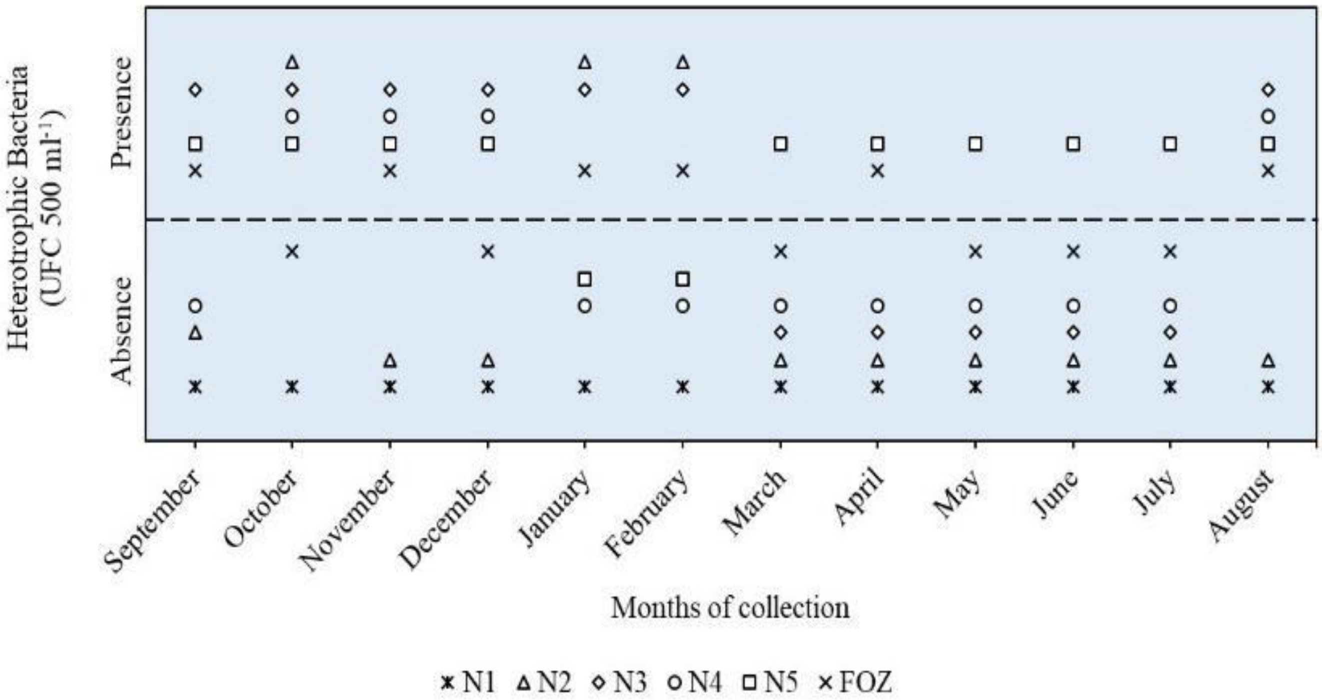
Figure 4. Heterotrophic Bacteria in 500 ml sample, present and absent during the data collection period, September 2018 to August 2019.



Source**:** Authors (2019).

The N1 source was the only one that showed 100% absence for the results of heterotrophic bacteria. N2 was present in 25% of the analyzes, N3 in 50%, N4 in 33.3%, N5 in 8.3% and FOZ in 50%. Therefore, as discussed earlier, the risk of consuming these bacteria-containing waters is high and bacteria-bearing waters are unfit for consumption.

Table 2 presents data from the performance of a test for the presence of phytosanitary products in the spring water under study. These samples were taken in January 2019, which assessed the entire Consolidation Ordinance No. 5/2017 (Brasil, 2017), Annex XX of the Ministry of Health.

Table 2. Test for the presence of pesticides products in water. January 2019.

Pesticides	Consolidation Ordinance nº5 / 2017, annex XX of the Ministry of Health.	N1	N2	N3	N4	N5	FOZ
		Results					
	($\mu g\ L^{-1}$)						
Alaclor	20,0	0,10	0,10	0,10	0,10	0,10	0,10
Aldrin + Dieldrin	0,0	0,001	0,001	0,001	0,001	0,001	0,001
Atrazina	2,0	0,10	0,10	0,10	0,10	0,10	0,10
Clordano Gama	0,2	0,01	0,01	0,01	0,01	0,01	0,01
DDT + DDD + DDE	1,0	0,001	0,001	0,001	0,001	0,001	0,001
Endosulfan	20,0	0,01	0,01	0,01	0,01	0,01	0,01
Endrin	0,6	0,001	0,001	0,001	0,001	0,001	0,001
Lindano (gama HCH)	2,0	0,01	0,01	0,01	0,01	0,01	0,01
Metamidofós	12,0	5,0	5,0	5,0	5,0	5,0	5,0
Metolacloro	10,0	0,10	0,10	0,10	0,10	0,10	0,10
Molinato	6,0	1,0	1,0	1,0	1,0	1,0	1,0
Pendimentalina	20,0	0,10	0,10	0,10	0,10	0,10	0,10
Permetrina	20,0	0,60	0,60	0,60	0,60	0,60	0,60
Profenofós	60,0	30,0	30,0	30,0	30,0	30,0	30,0
Simazina	2,0	0,50	0,50	0,50	0,50	0,50	0,50
Tebuconazol	180,0	30,0	30,0	30,0	30,0	30,0	30,0
Terbufós	1,2	0,50	0,50	0,50	0,50	0,50	0,50
Trifluralina	20,0	0,10	0,10	0,10	0,10	0,10	0,10

Samples collected according to the Standard Methods for the Examination of Water and Wastewater, Methods 1060, EPA 8270D:2007 (Apha,2012). Consolidation Ordinance nº 5 / 2017, annex XX of the Ministry of Health (Brasil, 2017). Source**:** Authors (2019).

In these analyzes, 18 phytosanitary products were tested, resulting in values for the springs and FOZs, lower than those allowed by the Ordinance. One of the factors that may explain the lower limit for springs is that in the analyzed period (January 2019) no springs had plantations near the springs, which explains the non-use of pesticides near them. However, it is important to note that at some point (September to November 2018), N4 had sorghum plantation next to it and N5 corn plantation. It was proved that the plantations cultivated during this period did not influence the water contamination by phytosanitary.

4. Conclusion

The presence of vegetation in primary or secondary state of regeneration around the springs contributes to the reduction of human-induced anthropogenic impacts on water quality. Among the water resources evaluated, the source most affected by water quality was N3, with pasture and no area of riparian forest in its surroundings. The spring N1 presented the best water quality for the physical and chemical parameters, because it has an exit protection that captures the direct water from the outcrop. All the springs and the Foz were contaminated with some kind of colony of bacteria harmful to human and animal welfare, being considered unfit for consumption and bathing. No pesticide contamination was found in the water during January 2019.

It is important to highlight how the springs were revitalized at the end of the study, with the planting of native trees and fences, future research should be considered to measure the impact of these measures in improving the quality of water in the springs.

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