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Environmental quality of the Paraim River springs, far south of Piauí

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Abstract: The small flows of runoff give rise to water bodies which, through their multiple uses, contribute to satisfying the basic vital needs of animals, plants and ecosystems. Spring areas play an important role in maintaining the environmental quality of the basin. To this end, it is essential that these areas have an effective conservation policy. The aim of this study was to determine the environmental quality of the Paraim River's spring areas, emphasizing the physical-chemical and biological quality of the water and characterizing local environmental conditions through macroscopic assessment. Visits were made to seven of the Paraim River's perennial springs and the macroscopic assessment made it possible to identify the impacts observed in the springs and permanent preservation areas, access conditions, proximity to rural centers and types of use of the springs. The physical-chemical and microbiological parameters of the water were assessed and compared with Resolution 357/2005 of the National Environment Council (CONAMA) and the Water Quality Index (IQA). The macroscopic assessment of the springs showed that 57.1% of the springs were rated as "excellent" or "good" and only one spring was rated as "very bad". Determining the WQI of the springs resulted in values varying between 59 and 86 in the dry season and between 56 and 89 in the rainy season. This shows that all the springs evaluated had satisfactory WQIs ("good" or "excellent"). The assessment of water quality made it possible to observe the relationship between the quality parameters, as well as their influence on the macroscopic characteristics of the springs. In this way, the information obtained indicates that, despite the good quality of the water, the assessment of the environmental situation of the springs warns of the need for future strategies aimed at planning for land use and environmental management of micro-watersheds.

Key words: water quality; macroscopic evaluation; environmental quality; water resources

1 Introduction

In natural environments, various interactions take place that are essential for maintaining life and ecological balance. Small flows of runoff give rise to water bodies which, through their multiple uses, contribute to satisfying the basic vital needs of animals and plants. Areas of native vegetation must be significantly conserved to guarantee local environmental quality (SILVA et al., 2017).

Water resources are directly influenced by the quality of biomes and ecosystems (WWDR, 2018). Thus, the deterioration of forested areas, intensive land use and loss of biodiversity are adverse impacts that compromise the integrity of surface and underground water sources. Worldwide, water demand is determined by population growth, urbanization, food security and energy policies (UNESCO, 2015). This makes it possible to intensify exploitation activities in areas adjacent to surface springs, resulting in landscape change and causing negative environmental impacts that are reflected throughout the basin area.

The New Forestry Code establishes that the areas of springs and waterholes must have a permanent preservation area - APP, a protected area with the function of preserving water bodies, landscapes and biodiversity. *Federal Law No. 12.651 of 2012* determines that the APPs of springs must have a radius of 50 meters (BRASIL, 2012).

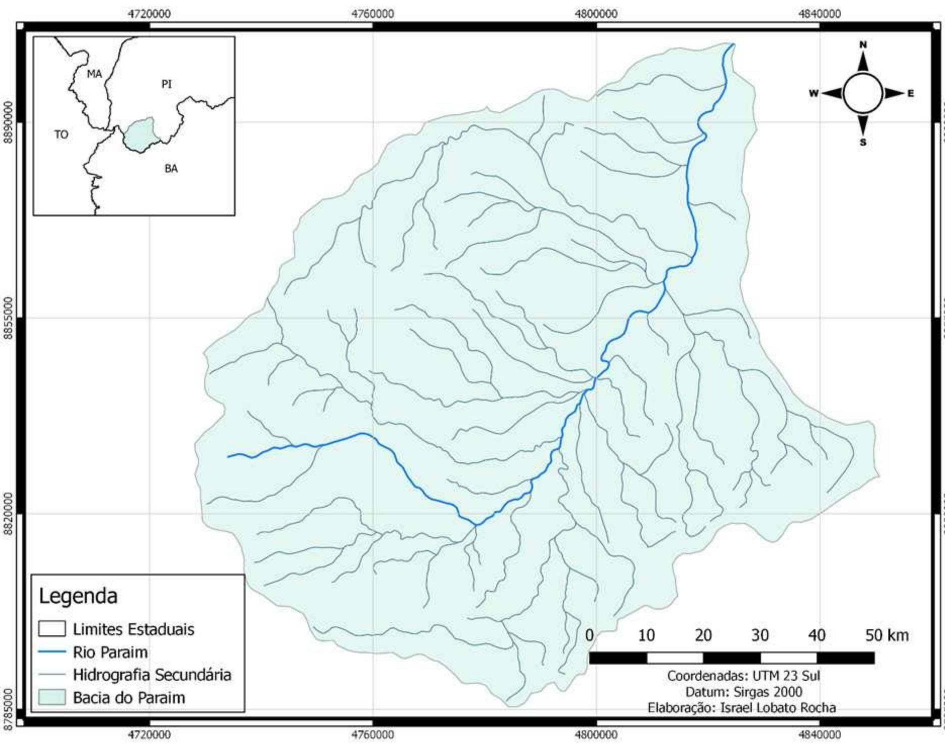
The loss of forest remnants in areas close to water sources intensifies erosion processes. The main means of transporting eroded sediment is water (MEDEIROS et al., 2009). Thus, the replacement of natural vegetation along the entire length of the basins culminates in the intensification of the siltation process in the bodies of water.

Thus, spring areas play an important role in maintaining the environmental quality of the basin. To this end, it is essential that these regions have an effective policy for conserving local ecosystems, maintaining the vegetation surrounding the areas where groundwater flows (waterholes), controlling land use - avoiding practices that damage environmental resources - and recovering degraded areas. In this way, the aim of this study was to determine the environmental quality of the Paraim River's spring areas, emphasizing the physicochemical and biological quality of the water and characterizing local environmental conditions through macroscopic assessment.

2 Materials and methods

2.1 Study area

The Paraim river basin has a total area of approximately 8,634 square kilometers and the main river is 204.42 kilometers long (Map 1). It is located in the Parnaíba hydrographic region (MMA, 2006) and its main tributaries are the Corrente, Palmeiras, Riachão, Fundo and Curimatá rivers (ANA, 2019). It rises at the base of the escarpments of the Chapada das Mangabeiras (NASCIMENTO et al., 2018) at an average altitude of 595 meters. The climate of the region under study, according to IBGE (2002), is tropical semi-humid with a five-month dry season. It has average minimum temperatures of 20°C and maximum temperatures of 34°C and accumulated annual rainfall of 980 mm (INMET, 2018).



Map 1. Geographical location of the Paraim river basin. Source: ANA (2015)

The relief of the study area is made up of the Chapadas das Mangabeiras, which have irregular and sinuous profiles, forming well-defined escarpments in the upper part, constituting walls with verticalized profiles and mostly devoid of soil or vegetation cover (ICMBIO, 2018). The highest point of the Chapada can reach an altitude of 880 meters (BRASIL, 2006).

2.2 Methodological procedures

2.2.1 Identification of springs

On-site visits were made to seven perennial springs on the Paraim River (Table 1). The sample points (springs) were identified through knowledge of the local population, the use of maps, satellite images and cartographic charts. Spatial data (coordinates) was obtained in the field using a GPS (Global Positioning System) receiver and thematic maps of the study area were then drawn up using the GIS (geographic information system) Quantum GIS (QGIS) version 2.0 Dufour. For their development, the IBGE municipal maps were used, as well as shapefiles of the water bodies made available by the ANA and altimetric data from the SRTM (Space Shuttle Radar Topographic Mission) for the detailed extraction of the drainage of the basin under study.

Table 1. Distribution of sampling points (springs) and their coordinates

Point	Name of spring	Geographical coordinates
Spring 1	Nascente da Tapera	10°53'09"S / 45°34'62"O
Spring 2	Nascente da Prata	10°53'01"S / 45°35'82"O
Spring 3	Nascente da Gia	10°50'10"S / 45°38'01"O
Spring 4	Nascente Cabeceira	10°49'95"S / 45°38'03"O
Spring 5	Nascente Grotas	10°50'24"S / 45°38'03"O
Spring 6	Nascente Areais	10°50'25"S / 45°38'05"O
Spring 7	Nascente das Pedras	10°50'34"S / 45°38'38"O

2.2.2 Macroscopic assessment of the springs

After mapping the sampling points, a macroscopic assessment of the springs was carried out. According to methodologies adapted from Gomes et al. (2005), Felippe et al. (2012), Gomes (2015) and Leal et al. (2017), macroscopic assessment is a qualitative survey aimed at identifying environmental impacts on watercourse springs. During the expedition to the springs, the following qualitative variables were observed: impacts observed on the springs, impacts on permanent preservation areas, access conditions, proximity to rural and/or urban areas, types of uses of the springs, information on the area of insertion, etc.

For the macroscopic assessment of the springs, 14 qualitative parameters were used, which were classified as bad (1 point), average (2 points) and good (3 points), according to the rating each received (Table 2). In this way, the evaluation result ranges from 14 points (if all the parameters are considered bad) to 42 points (if all the parameters are considered good).

Subsequently, with the sum of the evaluation points, the springs were classified according to the degree of preservation in relation to the environmental impacts observed in the areas and classified according to class: A, B, C, D and E (GOMES et al., 2005; FELIPPE et al., 2012; GOMES, 2015; LEAL et al., 2017). This results in the Macroscopic Quality Index of Springs - IQMN (Table 3).

Table 2. Classification of springs according to qualification

Parameters	Qualification

	Bad (1)	Medium (2)	Good (3)
Water color	Dark	Clear	Transparent
Odor of the water	Strong smell	Weak smell	No smell
Waste around	Many	Few	Absence
Floating materials	Many	Few	Absence
Foams	Many	Few	No foam
Oils	Many	Few	Absence
Sewage in the spring	Visible	Evidence	No sewage
Vegetation	Absence	Altered	Preserved
Use by animals	Presence	Only marks	Not detected
Use by humans	Presence	Only marks	Not detected
Access	Easy access	Light reasonable	Difficult to access
Proximity (urban)	Less than 50 m	Between 50 and 100 m	More than 100 m
Erosion on the banks	Accentuated	Moderate	No erosion
Insertion area	Missing information	Private property	Unit. Conservation

Sources: Adapted from Gomes et al. (2005); Felippe et al. (2012); Gomes (2015) and Leal et al. (2017)

Table 3. Classification of springs according to degree of preservation

Class	Degree of preservation	Final score
A	Great	40 - 42
B	Good	37 - 39
C	Acceptable	34 - 36
D	Bad	31 - 33
E	Terrible	Below 30

Sources: Adapted from Gomes et al. (2005); Felippe et al. (2012); Gomes (2015) and Leal et al. (2017)

2.2.3 Water quality assessment

For the survey of the water quality of the main springs, the sampling points were the perennial springs of the main river (Paraim River). Water samples were taken from the springs during the dry season (May 2018) and the rainy season (December 2018). Seasonal variability was observed according to rainfall information provided by the National Meteorological Institute (INMET), at the automatic station located on the Campus of the Federal Institute of Piauí, in the city of Corrente (PI), code A374, with data for the year 2018 (INMET, 2018).

The samples were collected, packaged and preserved in accordance with the *National Guide for the Collection and Preservation of Water Samples* (CETESB et al., 2011). The physicochemical and microbiological parameters that make up the WQI (Water Quality Index) analyzed were: dissolved oxygen (DO), thermotolerant coliforms (TC), hydrogenionic potential (pH), temperature, turbidity, phosphorus, total nitrogen, total waste and biochemical oxygen demand (BOD). The samples were sent to the Water and Soil laboratory of the Federal Institute of Piauí - Campus Corrente and analyzed according to the Standard Methods reference method (Table 4) of the American Public Health Association (APHA, 2012).

Table 4. Information on laboratory analysis methodologies, equipment used and units of measurement for analyses of physico-chemical and microbiological parameters

Parameters	Method/Equipment*	Unit of measurement
Dissolved oxygen	Oximeter (Lutron) - DO-5519	mg/L
Temperature	Digital thermometer - TE07	°C
C. thermotolerant	Chromogen medium in DIP on paper - Colipaper	NPM/100 mL
pH	pH meter (Lutron) - PH 221	UpH
BOD	Volumetric method (Alfakit)	mg/L
Total nitrogen	Photocolorimeter (Alfakit)	mg/L
Total phosphorus	Photocolorimeter (Alfakit)	mg/L
Turbidity	Microprocessor turbidimeter (Alfakit)	UNT
Total waste	Gravimetric method	mg/L

*In accordance with Standard Methods 21 ed. (2012) and ABNT NBR 12614 (1992)

2.2.4 Water quality index - WQI

The Water Quality Index (WQI) was formulated by the National Sanitation Foundation in 1970 in the United States. Since 1975, the index has been used by Companhia Ambiental do Estado de São Paulo - CETESB (ANA, 2018). The WQI is made up of nine parameters and their respective weights. These weights were set according to the overall conformation of water quality (ANA, 2017). According to the condition of each of the parameters, the methodology established quality variation curves. Once the calculation has been carried out, the WQI of the sampled springs can be determined, according to the variation in quality (Table 5).

Table 5. WQI classification according to quality level

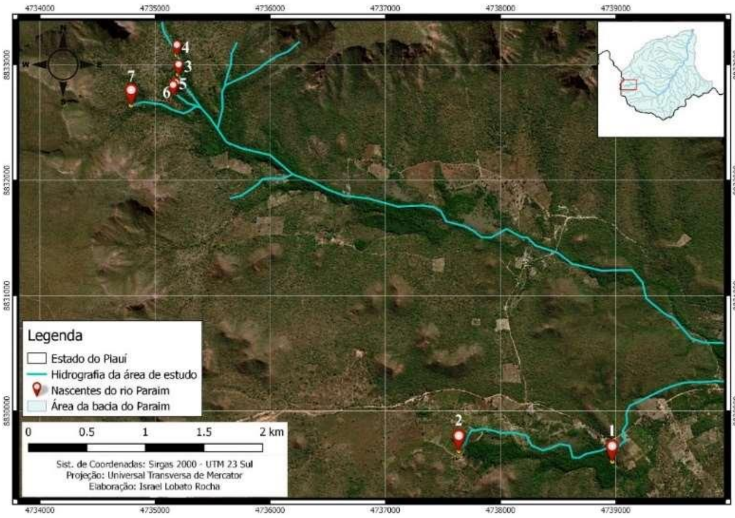
Class	Category	Ponderação
A	Great	$79 < WQI \leq 100$
B	Good	$51 < WQI \leq 79$
C	Acceptable	$36 < WQI \leq 51$
D	Bad	$19 < WQI \leq 36$
E	Poor	$WQI \leq 19$

Source: CETESB (2018)

3 Results and discussion

3.1 Macroscopic assessment of the springs

In the Paraim river basin, in addition to the springs of the Jia and Prata marshes, which had already been identified by the Corrente Environmental Superintendence (CORRENTE, 2017), five other springs were catalogued during the on-site visits. This makes a total of seven perennial springs evaluated, all located in the rural area of the municipality of Corrente - PI (Map 2).



Map 2. Location of springs Source: ANA (2006)

The source of the Tapera stream (NASC. 1) is located on a rural property. The Tapera stream is a sub-tributary of the Paraim river and the vegetation consists of gallery forest with the presence of Mauritia flexuosa (buriti). Due to its proximity to rural population centers and reasonably easy access, evidence was found of use by animals for desiccation purposes, as well as by humans for collecting buriti fruit from the banks. As a result of these uses, erosion processes were identified on the banks and some foam also appeared in the water. No oil or solid waste was found in the vicinity of the spring and the water was clear (Figure 1).

Also located on a private property, the Prata spring (NASC. 2) has vegetation consisting of flooded gallery forest with an altered state of conservation and moderate erosion of the banks. The nearby fencing hinders animal access and contributes to the natural regeneration of the vegetation. The waters of the spring are transparent, with no odor, foam, oil or floating materials (Figure 1). No waste or soil compaction was found on the banks. The Prata spring is the best known by the population and, consequently, the most visited. This is due to its proximity to rural population centers and a side road.

The Jia marsh spring (NASC. 3) is located in an area of veredas, hydromorphic soils, with the predominance of the Mauritia flexuosa palm tree amidst clusters of shrubby vegetation. Due to the distance from rural properties (residences), there is no evidence of the presence of animals or human use at the spring. The spring water is transparent, free of odor, foam, oil and floating materials, and there is no evidence of solid waste on the banks (Figure 2-B).

Figure 1. Tapera stream spring (A) and Prata spring (B)

Figure 2. Jia spring (A) and Cabeceira spring (B)

Upstream of the Jia marsh is the spring called "Cabeceiras" (NASC. 4). Located 370 meters from the foot of the Chapada das Mangabeiras, Cabeceiras had the lowest score of all the springs evaluated. Traces of fire in the adjacent areas, changes in the color of the water, odor, oils, the presence of floating materials and erosion processes on the banks of the spring were identified. The spring is located near an area that has recently been partially cleared of vegetation in order to fence it off for animal husbandry (livestock).

Grotas and Areais are two very close springs (NASC. 5 and 6) (Figure 3). Their outflows give rise to a single watercourse, which runs for around 200 meters until it flows into the main bed of the Paraim River. The phytophysiognomy of the spring is gallery forest with a closed canopy and typical savannah in the surrounding area. Despite the record of erosion and the lack of information about the area where the spring is located, the other parameters obtained the maximum score (3 points), i.e. in line with a preserved environment.

Nascente das Pedras (NASC. 7), little known even to the population of the surrounding localities, is located in the area with the most difficult access (Figure 3C). The vegetation is characterized as gallery forest, with a high degree of preservation, a closed canopy and no trace of erosion processes. The spring water was transparent and free of color, odor, oils, floating materials, waste, foam, and there was no evidence of use of the spring by humans or animals. These characteristics meant that NASC. 7 obtained the best degree of preservation among the springs evaluated.

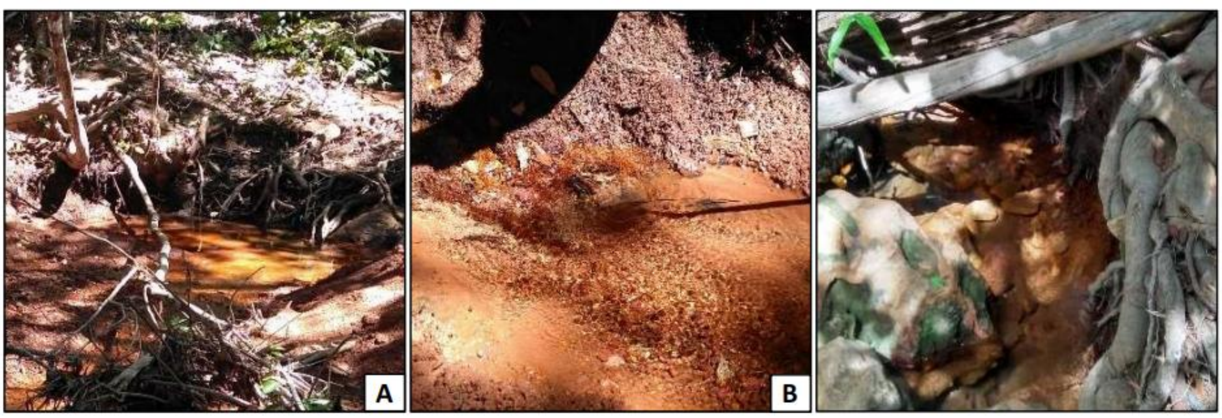


Figure 3. Grotas spring (A), Areais spring (B) and Pedras spring (C)

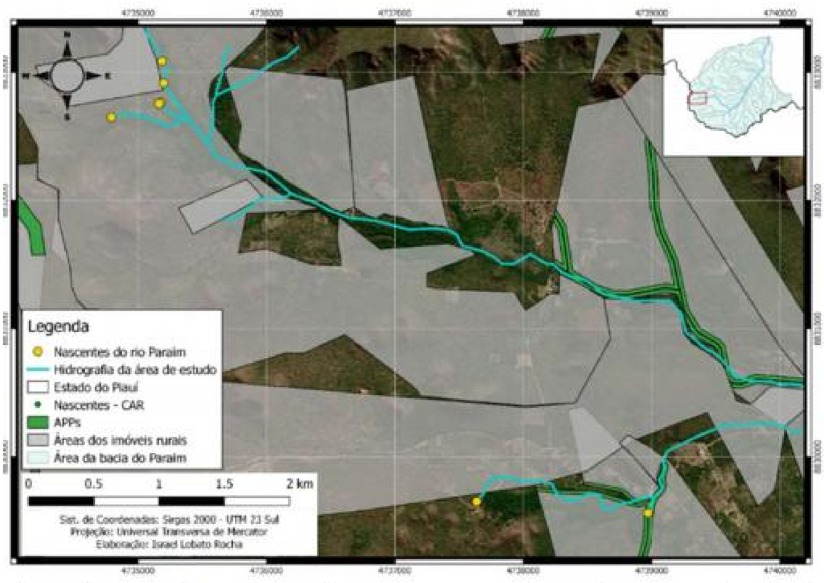
There were no records of solid waste or sewage disposal in any of the springs evaluated, even in the most accessible springs. These results indicate that the springs are less likely to be contaminated (LEAL et al., 2016). Among the springs evaluated, 42.9% showed some type of foam, and the record in three springs is associated with the presence of amphibians in the areas. Neves et al. (2013) recorded the presence of amphibians in the springs of the Mandacaru stream in Maringá/PR. Amphibians deposit their eggs in foam nests located on the surface of water bodies (VASCONCELOS et al., 2005).

The assessment showed that the vegetation is preserved in 57.2% of the springs, with native vegetation from the Cerrado biome and predominantly in the gallery forest physiognomy (RIBEIRO et al., 2008). None of the springs had completely exposed soil and three springs showed some kind of alteration, mainly due to the effects of fire in the areas.

The presence of springs was observed predominantly on private properties (71.42%). The vegetation showed some kind of alteration (partial suppression) in 60% of the springs located on rural properties. Rural property owners in the region under study have not registered the Paraim river springs in the Rural Environmental Registry (CAR) system (Map 3).

This hinders environmental regularization actions at the property level, making it impossible to effectively monitor, plan the environment and combat deforestation (BRASIL, 2012). Information on the conservation status of rural springs helps to plan actions to reverse this situation of degradation and recurrent abnormality (COUTINHO et al., 2018).

Among the springs evaluated, none scored the maximum in the macroscopic evaluation and a single spring was classified as "very bad". Only one spring was classified as having an "excellent" degree of preservation and three were in a "good" situation. As a result, 57.1% of the springs were rated as being in "excellent" or "good" condition (Table 6).



Map 3. Rural properties in the study area registered in the Rural Environmental Registry (CAR) system

Source: SICAR (2019)

Table 6. Macroscopic assessment of the springs evaluated

Parameter	Springs evaluated*						
	Spring 1	Spring 2	Spring 3	Spring 4	Spring 5	Spring 6	Spring 7
Water color	3	3	3	2	3	3	3
Odor of the water	2	3	3	2	3	3	3
Waste around	3	3	3	3	3	3	3

Floating materials	3	3	3	2	3	3	3
Foams	2	3	2	2	3	3	3
Oils	3	3	3	1	3	3	3
Sewage in the spring	3	3	3	3	3	3	3
Vegetation	3	2	2	2	3	3	3
Use by animals	2	3	3	3	3	3	3
Use by humans	2	3	3	2	3	3	3
Access	2	2	2	3	3	3	3
Proximity (rural)	3	2	3	3	3	3	3
Erosion on the banks	2	2	1	1	2	2	2
Insertion area	2	2	2	2	1	1	2
Total score	35	37	36	29	39	39	41
Class	C	B	C	E	B	B	A
Grade	Acceptable	Good	Acceptable	Terrible	Good	Good	Great

*Spring 1 - Tapera Spring; Spring 2 - Prata Spring; Spring 3 - Gia Spring; Spring 4 - Cabeceira Spring; Spring 5 - Grotas Spring; Spring 6 - Areais Spring; Spring 7 - Pedras Spring

3.2 Spring water quality

The admissible values for the parameters were based on the National Environmental Council (CONAMA) resolution 357 of 2005, which provides for the classification of bodies of water according to their classification class. The Paraim River - from its sources to its outlet - does not have a formal document approving its classification, so it is considered to be class 2 (CONAMA, 2005).

The evaluation of the physical-chemical and microbiological parameters of the first water collection campaign, carried out during the dry season, showed that only the Gia and Grotas springs did not show any changes in the WQI parameters. Dissolved oxygen is one of the main water quality parameters, providing the necessary support for the association between water quality and self-depuration capacity (AMORIM, 2017). All the springs evaluated had DO values in line with current legislation, ranging from 10.97 mg/L to 16.2 mg/L, indicating an optimum aeration capacity for these bodies of water.

The highest concentrations of DO were recorded in the Grotas, Pedras and Areais springs (average of 15.4 mg/L). This can be explained by the greater degree of intertwining of the tree canopies, which influences the water temperature and consequently increases the solubility of oxygen (CUNHA et al., 2010). None of the springs evaluated had a BOD concentration above the maximum limit established by CONAMA Resolution 357 of 2005. According to the resolution, the BOD value may not exceed 5 mg/L (CONAMA, 2005).

According to the analyses, there is a relationship between BOD and thermotolerant coliforms: spring 4 and spring 1 had the highest BOD values (3.4 mg/L and 2.0 mg/L, respectively) and high concentrations of thermotolerant coliforms. Agrizzi et al. (2018) found that in the springs with cattle around, the high presence of coliforms was due to the feces of these animals and this influenced the increase in BOD.

The springs with records of the presence of thermotolerant coliforms have a direct influence on the livestock activities carried out in the region. Despite the absence of animal traces in the springs (Spring 1 and Spring 4), the proximity to animal husbandry sites made it possible for this group of bacteria to be present in the water of the Tapera and Cabeceira springs through surface runoff. These had values of 560 CFU/100 mL and 1520 CFU/100 mL (respectively), significantly high concentrations for this type of classification (Class 2), which establishes the absence of this group of bacteria (CONAMA, 2005).

The parameters total nitrogen, turbidity and total residue were in line with CONAMA resolution 357/2005. Total phosphorus, on the other hand, was the parameter with the highest concentrations above the recommended limit for class 2 bodies of water. Four of the seven springs showed changes in the levels of total phosphorus in their water. The highest concentrations of total phosphorus were observed in the Gia, Cabeceira, Areais and Pedras springs, which showed values of 0.22 mg/L, 0.15 mg/L, 0.17 mg/L and 0.24 mg/L, respectively (Table 7). The proximity of these springs to the Chapada das Mangabeiras may show that the application of fertilizers in agricultural enterprises on the chapada is causing phosphorus to be carried to the springs. Alves et al. (2017) linked the increase in phosphorus concentration in the Abóboras stream in Rio Verde (GO) with the application of phosphates for agricultural production and, consequently, the transfer to the watercourse.

Sperling (2014A) pointed out that phosphorus can be present in water due to the application of fertilizers in the vicinity. The presence of agricultural areas near water sources is the "runoff of fertilizers and pesticides that enhances the eutrophication of aquatic environments" (HAAS et al., 2018).

The hydrogen potential of the samples analyzed did not vary significantly between the springs and showed values close to neutrality. In all the springs evaluated, the pH values were within the permitted range. These results were satisfactory, since water bodies with a pH between 6 and 9 allow for the proper development of aquatic life (VIGIL, 2003, cited by ABREU et al., 2017).

Table 7. Physico-chemical and microbiological parameters from the first water collection campaign - Dry Period (May/2018)

Parameter	Unit.*	Springs evaluated**							MPV***
		Spring 1	Spring 2	Spring 3	Spring 4	Spring 5	Spring 6	Spring 7	
DO	mg/L	13,9	14,02	10,97	12,33	16,2	14,8	15,2	> 5
BOD	mg/L	2,0	1,3	1,1	3,4	1,2	0,9	0,8	Up to 5
Temperature	°C	26,35	26,9	25,1	27,2	27,2	26,8	27,1	-
Total phosphorus	mg/L	0,1	0,22	0,01	0,15	0,04	0,17	0,24	< 0,1
pH		6,3	6,6	6,1	6,7	7,1	6,4	6,5	6 a 9
Turbidity	NTU	5,88	1,63	2,99	11,6	0,41	0,13	0,77	Up to 100
Total Nitrogen	mg/L	0,32	0,56	1,23	0,26	1,3	1,4	0,98	Up to 2,18
Total waste	mg/L	13	14	53	118	17	14	15	Up to 500
T.C ****	CFU	560	0	0	1520	0	0	0	Absent

*Unit of measurement, Spring 1 - Tapera Spring; Spring 2 - Prata Spring; Spring 3 - Gia Spring; Spring 4 - Cabeceira Spring; Spring 5 - Grotas Spring; Spring 6 - Areais Spring; Spring 7 - Pedras Spring. ***Maximum Permitted Value for class 2 water bodies, CONAMA n. 357/2005; T.C**** - Thermotolerant Coliforms

Water temperature influences a number of variables, including pH (CETESB, 2017). In the springs evaluated, those with the lowest pH values were those with the lowest temperatures. This positive proportional relationship is also supported in the studies by Sperling (2014B) and Correio et al. (2016).

The temperature, in turn, varied between 25.1°C and 27.2°C. This variation was considered compliant, as it did not exceed the thermal tolerance limits of the ecosystems studied. Temperature outside these limits can negatively influence the growth and reproduction of aquatic organisms (ANA, 2018).

In the second collection campaign (rainy season), there was a significant reduction in the concentration of DO in all the springs, three of which, close to Chapada das Mangabeiras, showed values below those permitted by CONAMA Resolution 357/2005: Prata spring (3.7 mg/L), Grotas (3.2 mg/L) and Areais (3.4 mg/L). This can be explained by the fact that higher rainfall rates (in the rainy season) allow for an increase in surface runoff (AMORIM et al., 2016), carrying organic matter from adjacent areas and allowing for the leaching of diffuse organic matter of forest and anthropogenic origin (ABREU et al., 2017; CETESB, 2017).

The reduction in DO implies an increase in BOD (AMORIM et al., 2016; CETESB, 2017; ANA, 2018). BOD indicates the potential consumption of DO by the organic matter present in the water (VON SPERLING, 2014). Thus, the high concentration of BOD can be explained as a result of the consumption of DO, mainly by nutrients (phosphorus) and forest organic matter.

Another highlight - for the period investigated - was the presence of total phosphorus above the maximum limit allowed by legislation in all the springs (Table 8). Excess phosphorus may be associated with excess agricultural fertilizers (OLIVEIRA et al., 2013; MARMONTEL et al., 2015). Excess phosphorus in the water, together with nitrogen, results in the process of eutrophication of watercourses (CETESB, 2017). This process consists of an increase in organic matter in the water and can reduce the concentration of dissolved oxygen and cause the death of aquatic organisms (MELO et al., 2019; NOGUEIRA et al., 2015).

Table 8. Physico-chemical and microbiological parameters from the second water collection campaign - Rainy Period (December/2018)

Parameter	Unit.*	Springs assessed**							MPV***
		Spring 1	Spring 2	Spring 3	Spring 4	Spring 5	Spring 6	Spring 7	
DO	mg/L	8,5	3,7	5,9	7,1	3,2	3,4	8,4	> 5
BOD	mg/L	2,3	6,6	4,5	2,1	8,3	7,1	2,2	Up to 5
Temperature	°C	27,6	27,4	27,3	27,6	27,5	27,3	27,6	-
Total phosphorus	mg/L	0,27	0,78	1,26	0,28	1,19	1,25	0,65	≤ 0,1
pH	UpH	6,9	7,4	7,6	7,3	7,4	7,1	7,1	6 a 9
Turbidity	NTU	5,21	3,19	0,68	4,64	1,11	0,19	0,22	Up to 100
Total nitrogen	mg/L	0,37	0,7	0,52	0,89	0,61	0,43	0,12	Up to 2,18
Total waste	mg/L	20	13	14	67	13	14	14	Up to 500
T.C ****	CFU	1360	0	0	0	0	80	0	Absent

*Unit of measurement; *Spring 1 - Tapera Spring; Spring 2 - Prata Spring; Spring 3 - Gia Spring; Spring 4 - Cabeceira Spring; Spring 5 - Grotas Spring; Spring 6 - Areais Spring; Spring 7 - Pedras Spring. ***Maximum Permitted Value for class 2 water bodies, CONAMA n. 357/2005; T.C **** - Thermotolerant Coliforms

3.3 Water quality index - WQI

Determining the WQI of the springs resulted in values ranging from 59 to 86 in the dry season and from 56 to 89 in the rainy season. In the first sampling campaign at the springs, 71.4% of the springs had an "excellent" WQI and the remaining springs (28.6%) were assessed as having a "good" WQI. In the dry season, due to the influence of DO, the proportion was reversed: five (71.4%) springs had "good" WQIs and two springs (28.6%) had WQIs classified as "excellent".

In this way, all the springs evaluated had satisfactory WQIs ("good" or "excellent"). However, since DO is the parameter with the greatest weight in the index (CETESB, 2017), it influenced the reduction in the qualification of the springs during the rainy season (Table 9). This is due to the high rainfall in the period (SPERLING, 2014a), which allows for increased surface runoff and leaching of agrochemicals (herbicides and fertilizers) into the springs, causing an increase in the concentration of nutrients (ROSENBOM et al., 2009; SILVA-JUNIOR et al., 2015; LEAL et al., 2017; VALENTE et al., 2018).

Although total phosphorus changed in all the springs during the rainy season, it did not contribute significantly to the reduction in the WQI classification, but only influenced the reduction in the index value when compared with springs that had a low concentration during the dry season (Gia spring).

Table 9. Summary of the MQIS and WQI results for the Paraim river springs

Spring	Name	MQIS value*	IQMN grade	WQI value[1]	WQI class[1]	WQI value[2]	WQI class[2]
1	Tapera	35	Acceptable	64	Good	66	Good
2	Prata	37	Good	81	Great	72	Good
3	Gia	36	Acceptable	84	Great	74	Good
4	Cabeceira	29	Terrible	59	Good	89	Great
5	Grotas	39	Good	86	Great	66	Good
6	Areais	39	Good	82	Great	56	Good
7	Pedras	41	Great	81	Great	85	Great

*MQIS - Macroscopic quality index of springs; WQI[1] - water quality index (dry period); WQI[2] - water quality index (rainy period)

4 Conclusion

The springs macroscopic quality index (IQMN) showed that the negative environmental impacts on the springs are mainly related to the erosion processes in the vicinity, the lack of effective protection of these spaces and the ease of access to the areas, making it possible for animals and humans to use them, even occasionally. The water quality index (WQI) showed considerably high values, demonstrating the environmental quality of the springs. Although some parameters were altered, the WQI was consistent with the framework established and in accordance with CONAMA Resolution 357/2005.

With the assessment of water quality, it was possible to observe the relationship between the quality parameters and their influence on the macroscopic characteristics of the springs. This relationship was supported by the relationship observed between an increase in the concentration of nutrients (phosphorus), a reduction in DO and a consequent increase in BOD. The non-conformities identified in some parameters show that pollutants of anthropogenic origin can be transported to the spring areas. In this way, the information obtained indicates that, despite the good quality of the water, the assessment of the environmental situation of the springs warns of the need for future strategies aimed at planning for land use and environmental management of micro-watersheds.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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