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Impacts of anthropic action on water quality from spring water

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Abstract: Due to the sensitivity of water to external effects such as precipitation, land use and management, water quality must be monitored. This information is essential for decisions on its multiple and integrated use, as well as helping to mitigate environmental impacts. The aim of this study was to assess the water quality of perennial springs in the Palmital stream watershed, in Urutaí - GO. Water samples were collected from these sites for physical, chemical and microbiological characterization, and the water quality index (WQI) was determined during the dry and rainy seasons of 2023. According to the results, it was found that point D (an area close to farming and extensive cattle breeding) showed the highest values for total and thermotolerant coliform counts in both periods. In addition, the WQI values ranged from 59.61 to 72.70 during the dry season and from 67.93 to 74.79 during the rainy season, being classified as "Good".
Key words: water; contamination; water quality index; springs

1 Introduction

Groundwater is important for human health, economic development and ecosystem services (Wang et al., 2018). However, if poorly managed, it can cause the spread of waterborne diseases (Castro et al., 2019). It is therefore crucial to monitor water resources through physical, chemical and microbiological analysis, and use this information as a tool for assessing and managing water quality in order to mitigate the impacts of anthropogenic activities (Santos et al., 2021).

The water quality index (WQI) was initially proposed by Horton in 1965, and the WQI-NSF was developed in the 1970s by the National Sanitation Foundation Institution, and later adapted by CETESB in 1975 for the conditions of the São Paulo basins (CETESB, 2008). The WQI is a tool developed to simplify the dissemination and interpretation of water quality data, summarizing the situation of a specific monitoring point in a single value (Von Sperling, 2018). The result of this index is interpreted according to the water quality range of each state, varying from excellent to unsuitable for human consumption (Seifi etal., 2020).

The research aims to analyze how human activities impact the quality of emerging waters and their suitability for human consumption. This study is important given the growing environmental challenges and the urgent need to preserve water resources for future generations. The aim of this study is to assess the water quality of perennial springs in the

Palmital stream micro-basin in Urutaí, Goiás, taking into account the influence of anthropogenic activities. To check that the physical, chemical and biological characteristics of the water are in line with the standards recommended by the World Health Organization (WHO), the data was compared with the potability standards (Ordinance GM/MS No. 888/2021 of the Ministry of Health, Brazil, 2021) and, for the quality of surface water under different uses, the results were compared with CONAMA Resolution No. 357 of 2005 (CONAMA, 2005). Comparisons between collection points were made using the water quality index.

2 Theoretical framework

The quality of both surface and groundwater intended for human consumption must meet quality and potability standards, ensuring that its physical, chemical and biological characteristics are within the standards recommended by the World Health Organization (WHO) (Rebouças et al., 2024). In Brazil, potability standards are defined in Ordinance GM/MS No. 888/2021 of the Ministry of Health (BRASIL, 2021), while the quality of surface water for different uses is established by CONAMA Resolution No. 357 of 2005 (CONAMA, 2005).

The qualitative and quantitative monitoring of water resources is fundamental for assessing the availability of water, providing essential information for decisions on its multiple and integrated use, as well as contributing to the mitigation of environmental impacts (Moreira et. al., 2023).

To facilitate the dissemination and interpretation of data on water quality parameters, water quality indices have been adopted which express, through a single value, the quality of the water at a specific monitoring point, which classifies the quality of the water (Von Sperling, 2018).

From the 1970s onwards, the WQI was adjusted by CETESB and began to be used by CETESB in São Paulo (ANA, 2017). Specifically in the area of water supply for human consumption, the WQI has been used (Moreira et al., 2023), due to its ability to provide precision and flexibility in the quantity and quality of the parameters analyzed (Nayak et al., 2020). Thus, it is possible to transform a set of analyzed parameters into a number representing the WQI index and subsequently classify its quality (Seifi et al., 2020).

3 Methodology

The study was carried out in springs in the micro-basin of the Palmital stream, located in Urutaí, Goiás. This area plays an important role in supplying water to the municipality of Urutaí, the Instituto Federal Goiano - Campus Urutaí and various rural properties. The local climate, according to the Köppen classification, is of the Cwa type, characterized by being humid tropical, with dry winters and rainy summers. The average annual rainfall is 2,000 mm and the temperature is 28 °C (Souza et al., 2023).

Four perennial springs were selected to assess the impacts of human activities on water potability (Figure 1), and their descriptions are shown in Chart 1.

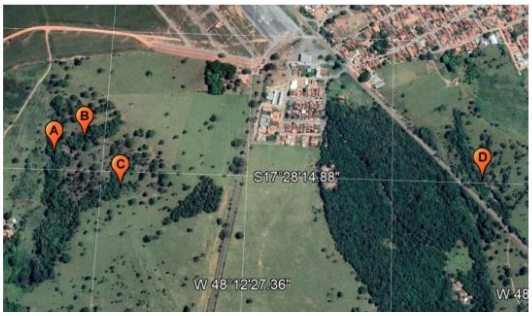


Figure 1. Location of the collection points monitored in the Palmital stream micro-basin (Source: Adapted from Google Earth)

Chart 1. Description of the characteristics of the sites evaluated

Point A - preservation area with a spring protected by a fence. It contains riparian vegetation and is difficult to access.
Point B - preservation area with a spring protected by a fence. It contains riparian vegetation and there is a small dam where water is collected.
Point C - preservation area with a spring protected by a fence. It contains riparian forest, located on the side of the GO 330 highway and receives surface runoff.
Point D - preservation area with a spring protected by a fence. It contains riparian vegetation and is close to farming and extensive cattle breeding.

Source: Prepared by the authors

At these sites, the physical, chemical and microbiological characteristics of the water were monitored during the dry season (August 2023) and the rainy season (December 2023). Physical, chemical and microbiological analyses were carried out on the water samples, determining nitrate (SMEWW 4500 NO_3 E - Cadm), phosphorus (SMEWW 4500-PE - Ascorbic Acid Method), total solids (ST) (SMEWW 2540 C - Total Dissolved Solids Driedat 180ºC), dissolved oxygen (DO) (SMEWW 4500-O C - Azide Modification), biochemical oxygen demand (BOD) (SMEWW 5210 B - 5 Days BOD Test), hydrogen potential (pH) (SMEWW 4500-H+ - Electrometric Method), turbidity (SMEWW 2130 - Turbidity), electrical conductivity (EC) (SMEWW 2510 - Laboratory Method), total coliforms (Colif. Termo) (SMEWW 9223 A, B - Enzyme Substrate Coliform Test), according to the methodology described in APHA (2017). The water temperature and pH values were determined "in situ" and the other characteristics were determined at the Research and Chemical Analysis Laboratory of the Instituto Federal Goiano - Campus Urutaí.

After characterizing the parameters, the WQI was determined using Equation 1, according to Cetesb (2018).

$$WQI = \prod_{i=1}^{n} q_i^{w_i} \quad (1)$$

Where:

WQI = Water Quality Index (varies from 0 to 100);

qi = quality of the ith parameter, obtained from the average quality variation curve for each parameter, as a function of the value obtained;

wi = weight assigned to the ith parameter according to its relevance; n = number of parameters (n = 9).

To discuss the results, the parameters evaluated were compared with the standards established by CONAMA Resolution 357/2005 (CONAMA, 2005) for class II freshwaters and supplemented with GM/MS Ordinance No. 888/2021, as well as the different WQI values.

4 Results and discussions

The temperature of the water samples ranged from 18.00º - 20.60ºC for both seasons (Figure 2). The low variation in temperature shows that there was no effect from anthropogenic activity at the sites sampled. Variation in the temperature of a watercourse can also be influenced by a decrease in water flow, abstractions, rainfall, discharges of pollutants and agricultural activities near watercourses (Hamid et al., 2020). In contrast, changes in temperature levels were verified, due to an increase in the temperature of the ara over the course of the collections, which may be related to the average annual temperature of the municipality, varying between 23ºC and 26°C, as reported by Moreira et al. (2023).

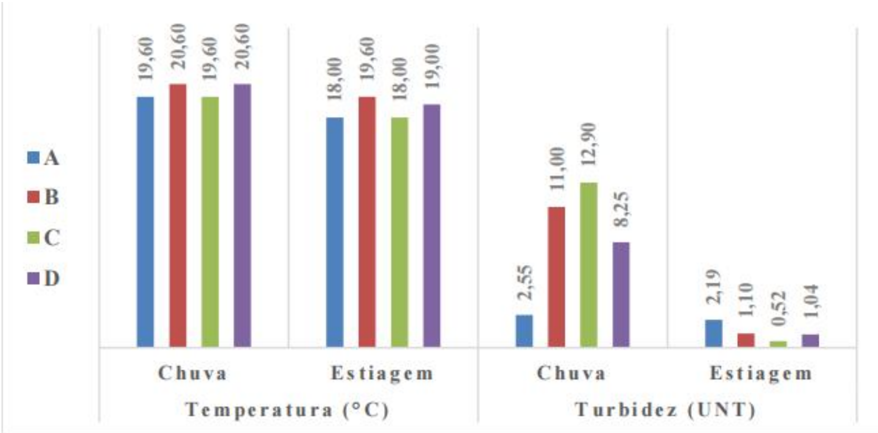


Figure 2. Temperature and turbidity of spring water during the periods evaluated. Source: Prepared by the authors

Turbidity is a parameter that is highly correlated with time (Cunha; Calijuri, 2010). The highest turbidity values were recorded during the rainy season, as was expected, since in rainy periods sediment can be carried away by surface runoff (Figure 2). This increase during the rainy season suggests a possible effect of sediment transport along the watercourse (Pratte-Santos et al., 2023).

Ordinance GM/MS No. 888/2021 established a maximum permitted value for water turbidity of 5 UNT as the acceptance standard for human consumption. In contrast, for Class II rivers it is up to 100 UNT, according to CONAMA Resolution 357/05. Thus, around 25% of the samples in the rainy season and all the samples in the dry season had acceptable turbidity, according to GM/MS Ordinance 888/2021. In relation to CONAMA Resolution 357/05, all the points evaluated showed values lower than those established by the legislation.

The highest results obtained for the total solids and electrical conductivity parameters were those collected during the rainy season (Figure 3). Comparing the results with Ordinance GM/MS No. 888/2021, the maximum value allowed for total dissolved solids is 500 mg L-1, while CONAMA Resolution 357/2005 does not set a limit for this parameter. Thus, the results obtained are in line with the established standards.

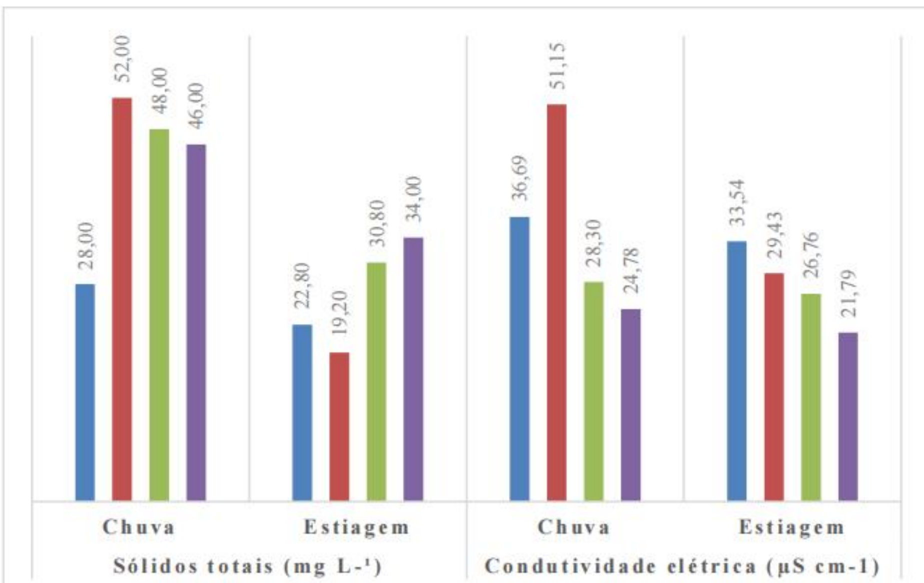


Figure 3. Total solids and electrical conductivity of spring water during the rainy and dry periods

Source: Prepared by the authors

There are no reference values for electrical conductivity in CONAMA Resolution 357/2005. However, values between 10 and 100 mS cm-1 for natural waters have been described by Von Sperling (2018) as unpolluted waters. Considering this information, it can be seen that all the springs monitored were not polluted.

In general, the values obtained during the rainy season were higher than those obtained during the dry season for the nitrogen and phosphorus parameters (Table 1). All the collection points comply with the legislation for both the nitrogen and phosphate parameters.

Table 1. Nitrogen, nitrate and phosphate content of water from monitored springs in the stream micro-basin Palmital

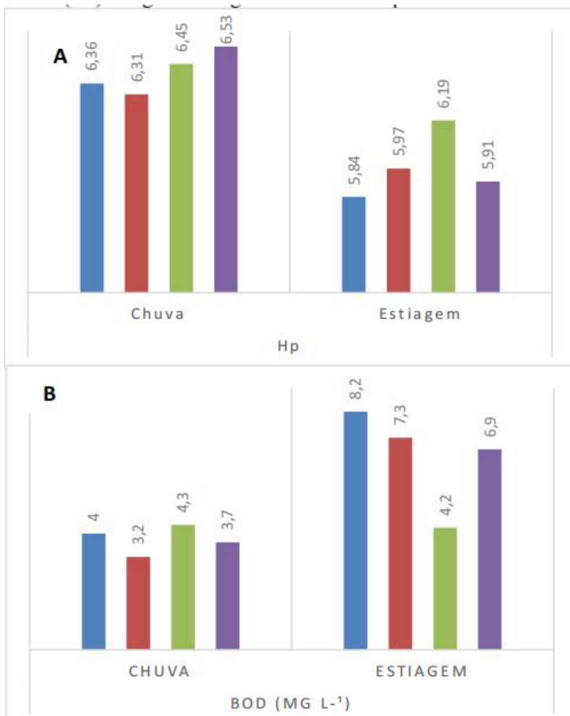
Points	N ($mgN\ L^{-1}$)		$N\text{-}NO_3^-$ ($mg\ L^{-1}$)		$PO4^{3-}$ ($mg\ L^{-1}$)	
	Drought	Rain	Drought	Rain	Drought	Rain
A	nd	0,56	nd	2,49	0,005	0,01
B	nd	nd	nd	0,0	0,002	0,032
C	nd	0,53	nd	2,36	0,007	0,007
D	nd	1,48	nd	6,56	0,001	0,012

PO_4^{3-} = total phosphate; $N\text{-}NO_3^-$ = nitrogen in nitric form; N= total nitrogen; nd = not detected

Source: Prepared by the authors

The maximum value allowed by Ordinance GM/MS No. 888/2021 and CONAMA 357 for nitrogen content is 10 mg $N\text{-}NO_3^-\ L^{-1}$ in drinking water. For the phosphate parameter, CONAMA Resolution 357/05 set the limits for lentic environments at a maximum value of 0.030 mg L^{-1}. Nitrate is a highly soluble element and can be easily leached into the soil (Lone et al., 2021). In contrast, phosphate has low solubility and can originate from the dissolution of rocks, reaching waters through agricultural waste and fertilizers (Dohare et al., 2014; Lone et al., 2021).

The results for the pH and DO parameters were higher during the rainy season than during the dry season. As for BOD, the highest values were obtained in the dry season (Figure 4). The pH range in the rainy and dry periods varied from 5.84 to 6.53 (Figure 4A), which is in line with the surface water quality standard set out in CONAMA Resolution 357/2005 for Class II rivers (6 to 9.5) and with the potability standard set out in Ordinance GM/MS 888/2021.



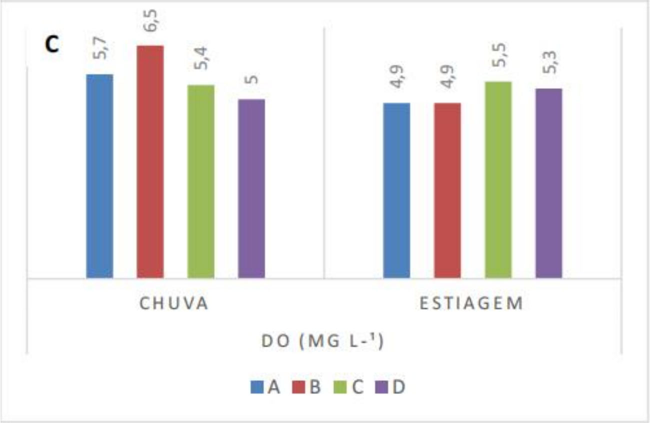


Figure 4. Values of hydrogen potential HP (4A), biochemical oxygen demand BOD (4B) and dissolved oxygen DO (4C) in the spring water during the rainy and dry periodsm Source: Prepared by the authors

Low DO content in the water can be interpreted as an indicator of pollution in the watercourse (Moreira et al., 2023), and the minimum DO value established by CONAMA Resolution 357/05 is 5.0 mg L^{-1}. Thus, the emergence samples analyzed had moderate levels of DO (Figure 4C), varying during the rainy season (5.0 to 6.5 mgL^{-1}) and the dry season (4.9 to 5.5 mgL^{-1}). It can be seen that points A and B (Figure 4C), during the drought period, had DO levels lower than those considered necessary to maintain full aquatic life.

With regard to BOD (Figure 4B), all the points evaluated in the rainy season had BOD values lower than those recognized by CONAMA Resolution 357/05 (maximum limit for Class II rivers of 5 mg L^{-1}) and, in the dry season, only point C had a value lower than the maximum limit. These results may be related to increased biological activity and decomposition of organic matter (Lone et al., 2021; Matos et al., 2023).

Table 2 shows the results of the microbiological analysis of the water at the monitored points. It can be seen that all the points analyzed during the rainy season and 50% of the points evaluated during the dry season had total coliforms above the established limits. With regard to thermotolerant coliforms, all the points evaluated had coliform counts below the limit established by CONAMA 357/2005, which should not exceed 1,000 NMP/100 mL. The presence of coliforms in spring water can occur due to access by animals or even the disposal of sewage at the site (Soares; Costa, 2020).

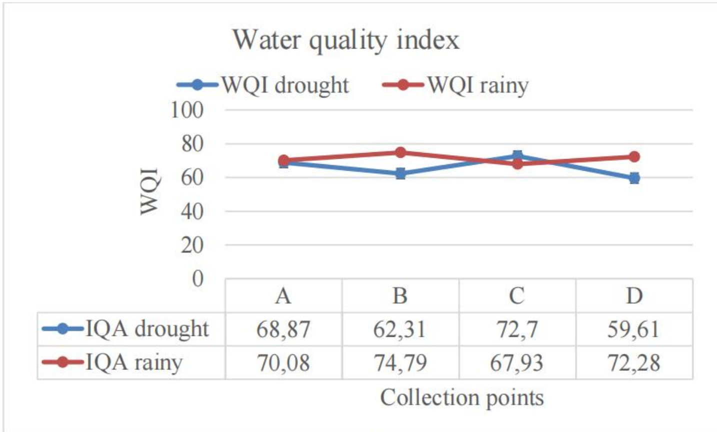
Table 2. Microbiological water analysis values at the monitored points

Points	Total coliforms (MPN/100mL)		Thermotolerant coliforms (MPN/100mL)	
	Rainy	Drought	Rainy	Drought
A	1553,10	290,80	48,30	45,9
B	1011,20	800,50	47,60	9,7
C	9931,50	86,00	205,50	22,8
D	1732,90	901,20	521,20	52,7

MPN = most probable number Source: Prepared by the authors

With the exception of the BOD parameter, all the other parameters evaluated showed higher results during the rainy season. This was to be expected, as erosive effects and particle loads can occur with heavy rainfall (Hamid et al., 2020) and thus result in changes to water quality parameters. Point D showed higher values for total and thermotolerant coliforms in both evaluation periods, while BOD was higher in the dry season and nitrate concentration was higher in the rainy season. This may have occurred because it is close to the highway and is influenced by crops.

The WQI values ranged from 59.61 to 72.70 during the dry season and from 67.93 to 74.79 during the rainy season (Figure 5). The analyses carried out during the experimental period determined that all the sampling points were classified as "Good". These results indicate the need to carry out at least simplified treatments such as chlorination before consumption.



Source: Prepared by the authors.

Figure 5. Water quality index during the dry and rainy seasons

The Person's correlation was carried out to verify a possible relationship between the results of the parameters and the values obtained in the IQA during the dry and rainy periods (Figure 6).

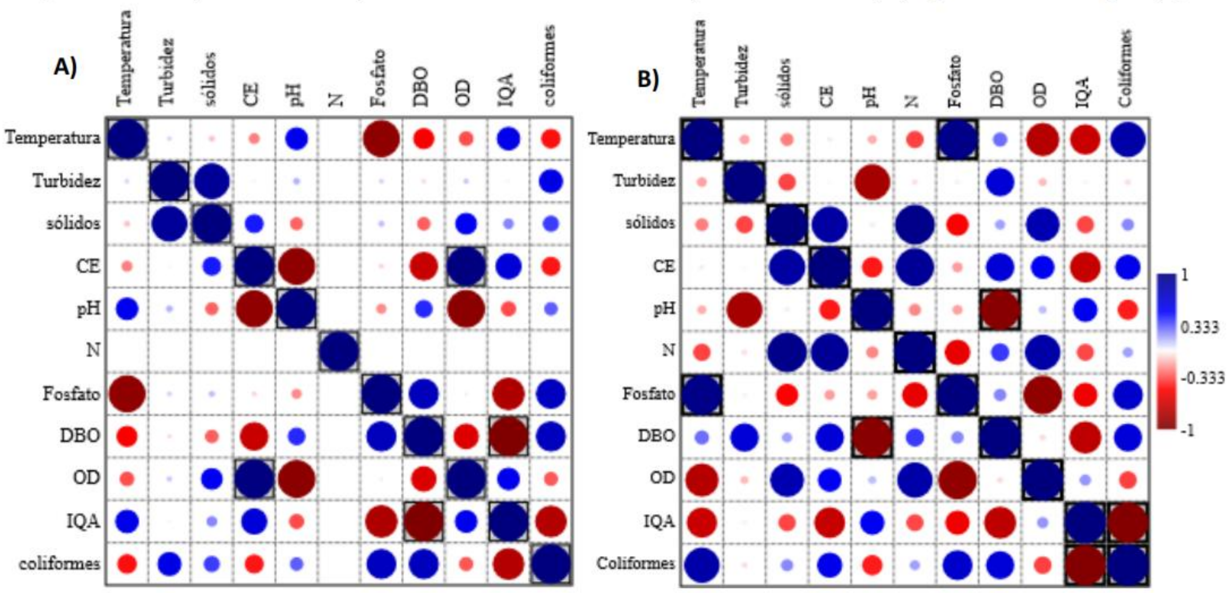


Figure 6. Pearson's correlation for the variables in the rainy season (A) and dry season (B) collections

Significance of parameters represented by filled dot, $p<0.05$ Source: Prepared by the authors

The parameter with the greatest significance for the WQI during the rainy season was BOD, which showed a strong negative correlation, justifying the fact that when BOD increases, the WQI decreases. In contrast, DO was directly correlated with EC (Figure 6A). This infers that the effects on the WQI were strongly related to the quality of the oxygen present in the water, as well as anthropogenic action. For the dry season (Figure 6B), the parameter with the highest correlation to the WQI was coliforms, which in turn reflects water contamination, as mentioned above.

5 Conclusion

For the conditions of the experiment and according to the results, we conclude: The WQI of the rainy and dry periods was classified as "Good" .

Anthropogenic effects and access by animals were reflected in the changes in water quality.

Point D (area close to farming and extensive cattle rearing) showed the highest values for total and thermotolerant coliforms, BOD and nitrate. This spring therefore needs special attention.

We recommend isolating the area around point D, as well as constant monitoring of the springs evaluated.

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Conflicts of interest

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

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