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Water quality and land use/occupation in the Sapo stream in the urban area of Rio Verde - GO

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ABSTRACT
The landscape modification by human activities has been altering water quality and compromising the use of water resources. Thus, the main objective of this study is to evaluate the water quality as well as the soil use and occupation in the urban section of the Sapo stream, located in the municipality of Rio Verde – Goiás, Brazil. The methodology of this research involved monitoring the Sapo stream watershed, including its microbasins, during a period of nine months. Laboratory analysis of water quality was conducted, and geoprocessing techniques were employed to determine land use and occupation in that region. And a water quality classification was carried out in the main water body and its tributaries, according to the CONAMA Resolution No. 357/2005. The results indicate that the São Tomás de Baixo and Buriti streams were classified as class 4, both showing high levels of punctual and diffuse pollution, compromising the water security for more demanding uses. On the other hand, the Barrinha stream presented the best water quality, with high water reaeration capacity and reduced sources of pollution.

KEYWORDS: Water pollution; Water resources; polluting activities.

1 INTRODUCTION

Water bodies located in urban areas play a vital role within these regions. They are useful for stormwater drainage, landscape harmony, recreational activities, bathing suitability, irrigation and fishing activities, dilution and disposal of wastewater, and human and animal water supply (ARAÚJO et al., 2017; HOEKSTRA; BUURMAN; VAN GINKEL, 2018).

In Rio Verde city, located in Goiás state, in the Sapo watershed stream, the use associated with the function of urban macro drainage, vegetable irrigation, fishing activities, animal drinking supply and dilution of treated or untreated liquid effluents stands out (SANTOS et al., 2019). It should be noted that the Sapo stream is one of the tributaries of the São Tomás River, the main water body responsible for the human supply in the city of Santa Helena de Goiás (PEREIRA et al., 2020).

Also, it is important to emphasize that the different uses of water resources in urban areas can be compromised by the reduction of water quality parameters. The Brazilian legislation, through Resolution No. 357/2005 of the National Environment Council - CONAMA, restricts water uses according to the water quality class.

The ways in which people use the water supplies and occupy the land can impact in the quality of water bodies (LIU; SHEN; CHEN, 2018). As a result of the increase in contaminants produced by human activities and the discharge of liquid effluents generated in cities, water quality parameters are degraded (NAZEMI; MADANI, 2018; SOARES, 2018). Thus, water pollution, whether it is punctual source or diffuse, can be originate from industrial, agricultural, and urban activities (SILVA et al., 2021).

The identification of activities that affect water quality parameters in the region of a watershed becomes an indispensable tool for those responsible for decision-making in water management (LIMA; MAMEDE; LIMA NETO, 2018). Therefore, knowing and showing the activities carried out and the water quality in the watershed of the Sapo stream is an important tool for environmental and water resource management, assisting decision-making by municipal management agencies regarding to a better urban and territorial planning.

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2 OBJECTIVES

The present work aims to analyze the water quality and use/occupation of the land in the Sapo stream watershed, in the urban section of the city of Rio Verde, identifying potential pollution spots and its sources.

3 METHODOLOGY

3.1 Delimitation of the watershed and land use / occupation

Initially, the delimitation of the watershed of the Sapo stream and its respective micro-watersheds was carried out. After, it was used a Digital Elevation Model (DEM), provided by the TOPODATA project of the National Institute for Space Research (INPE), with a resolution of 30 meters.

For the delimitation of the watershed and its micro-watersheds, the GRASS plugin available within the free QGIS platform, version 3.16.6, was used. The drainage network was named according to the database available for download on the Goiás State Geoinformation System (SIEG) website.

The process of identifying land use and occupation in the region began with the acquisition of images from the CBERS04-A satellite, obtained by the Multispectral and Panchromatic Wide-Scan Camera (WPM), with a spatial resolution of 2 meters. These images were collected from the INPE website.

The selected images encompassed the entire studied area, with good visibility, and low cloud interference during the evaluated period. The pictures corresponded to the months of September 2020 and March 2021. It must be said that the choice of dates for capturing satellite images was based on the dry and rainy periods of the region, seeking to obtain representative images of both seasons.

It is worthwhile mentioning that according to the Köppen-Geiger classification, Rio Verde area has two predominant seasons, a raining and a dry one, they are very characteristic of the tropical climate (CASTRO; SANTOS, 2021). The dry period usually occurs from May to October, being more critical in winter, while the highest rainfall occurs typically between November and April, especially in summer (PARREIRA et al., 2019; SANTOS et al., 2019; BRITO; SANTOS; RODRIGUES, 2020; LOPES SOBRINHO et al., 2020; CASTRO; SANTOS, 2021).

After defining and acquiring the images, the RGB composition (color system) with the spectral bands was performed in the QGIS free software. Subsequently, the created composition was fused with the panchromatic dataset, generating images with a 2 meters resolution per pixel.

The supervised classification of the images within the GIS environment was performed using the Semi-Automatic Classification Plugin (SCP), a QGIS add-on. For the identification of land use and occupation, three study classes were adopted: such as vegetation (native and reforested), exposed soil, and impermeable soil (urban area), collecting 40 (forty) samples of pixels representing each class.

The significance analysis of the values presented by each class of land use and occupation was carried out using the statistical software Jamovi, version 1.6.23. The two-tailed

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Student t test was used to assess whether there were significant differences between the independent samples from the two studied periods. A significance level (α) of 5% was considered in the research.

After the characterization of the studied area by satellite images, possible sources of punctual polluting loads, able to altering the water quality of water bodies, were evaluated. In this stage, it was considered places that could release wastewater or that had dams with water retention, altering the natural flow of water bodies.

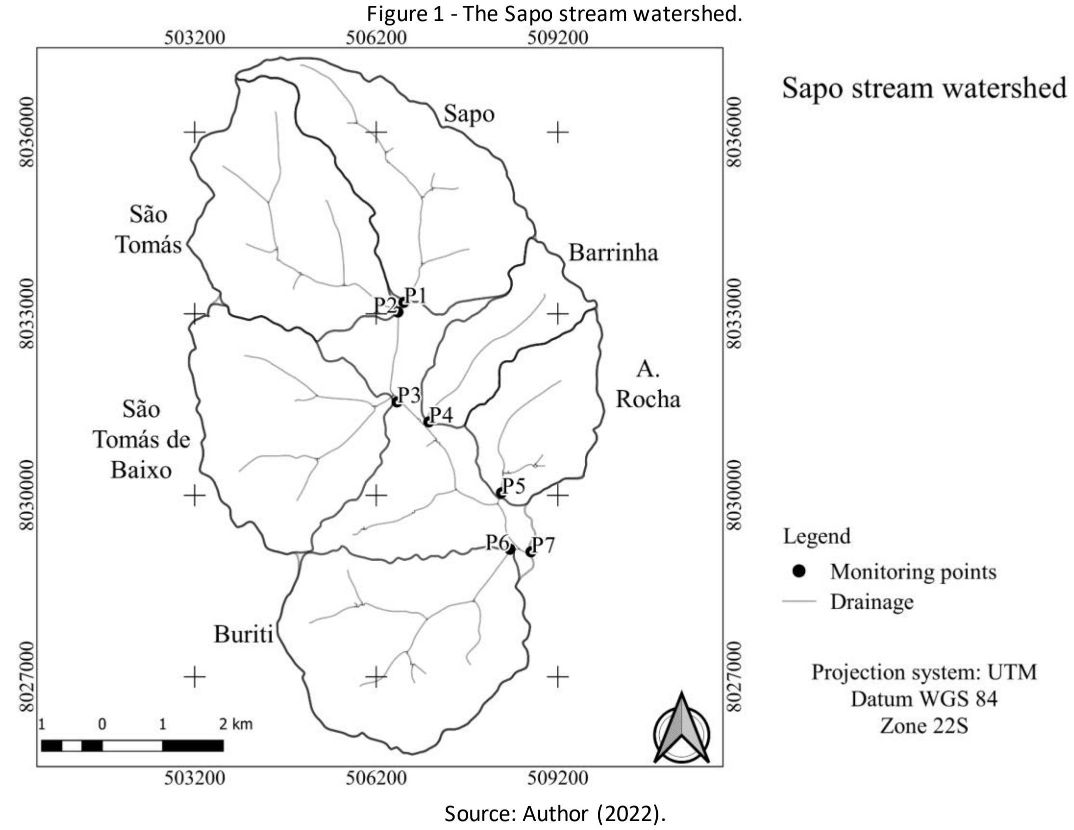
To identify critical points, the database registered in the Google Earth Pro software was initially used. Subsequently, field inspections were carried out, in addition to consultation with the environmental management agency of the municipality of Rio Verde. Additionally, data provided by the municipality's sanitation company were consulted.

3.2 Water quality

The water monitoring of the Sapo stream watershed lasted for nine months and was carried out periodically with intervals of fourteen days between the months of August 2020 and April 2021, totaling eighteen campaigns.

A total of seven water quality monitoring points were selected, distributed along the selected stretch, as shown in Figure 1, with five points located in tributaries of the Sapo stream (P2, P3, P4, P5, P6), and two points situated in the main water body itself (P1, P7).

Figure 1 - The Sapo stream watershed.



Source: Author (2022).

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Six micro-watersheds were studied in the region, namely: Sapo (P1), São Tomás (P2), São Tomás de Baixo (P3), Barrinha (P4), A. Rocha (P5), and Buriti (P6). Point P7 corresponded to the outlet of the entire watershed of the Sapo stream.

Table 1 presents the main information of the monitoring points.

Table 1 – Characterization of monitoring points.

Point	Latitude	Longitude	Stretch	Size of the stretch (km)	Watershed	Area (km²)
P1	17°47'19.35"S	50°56'13.92"O	-	-	Sapo	9.23
P2	17°47'24.56"S	50°56'17.23"O	1-2	0.194	São Tomás	9.36
P3	17°48'12.91"S	50°56'17.71"O	2-3	1.599	São Tomás de Baixo	9.13
P4	17°48'23.63"S	50°55'59.88"O	3-4	0.618	Barrinha	3.68
P5	17°49'1.72"S	50°55'19.03"O	4-5	2.485	A. Rocha	4.59
P6	17°49'32.06"S	50°55'14.31"O	5-6	1.004	Buriti	10.70
P7	17°49'33.47"S	50°55'2.49"O	6-7	0.200	Sapo	54.54

Source: Author (2021).

It is evident that the distance between the two most extreme points, P1 and P7, corresponded to 6.1 km.

3.2.1 Flow and precipitation measurement

At first, the accumulated precipitation data in the municipality of Rio Verde were collected, considering the five days preceding each water quality monitoring date during the research period. This information was obtained from the website of the National Institute of Meteorology (INMET) and was collected with reference to meteorological station 83470.

During the monitoring period in the Sapo stream, flow measurements were carried out at each designated point using an adapted Lounchen ZM flowmeter, designed for measuring water flow in closed conduits.

For the calibration of the flowmeter, a rectangular weir without lateral contraction was inserted into the flow channel of the test rig, and the flow velocity of the water in this situation was calculated. The flow rate was determined using the Francis' formula, and subsequently, the flow velocity in the test rig and the flowmeter was determined using the continuity equation.

By using the velocity data obtained in the hydraulic test rig and the flowmeter, a calibration curve was generated with a coefficient of determination (R-squared) equal to 0.9278. Thus, the flowmeter calibration curve was utilized to correct all flow velocity values of the analyzed water bodies.

3.2.2 Variables analyzed

The specific flow rate, the five-day biochemical oxygen demand at a temperature of 20°C ($BOD_{5,20}$), the chemical oxygen demand (COD), the dissolved oxygen (DO), and the suspended solids (SS) were also studied. Then, the flow rate and DO values were measured in the field, while $BOD_{5,20}$, COD, and SS values were obtained in the laboratory through assays.

The Laboratory assays were carried out in accordance with the Standard Methods for Examination of Water and Wastewater (2017), using section 5210 B for $BOD_{5,20}$, section 5220 D

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for COD, section 4500-O G for DO, and sections 2540 D and E for the SS. It must be noted that the determination of $BOD_{5,20}$ and COD parameters were performed in triplicate experiments, while duplicate form was used for DO and SS assays.

3.2.3 Water Quality Classification

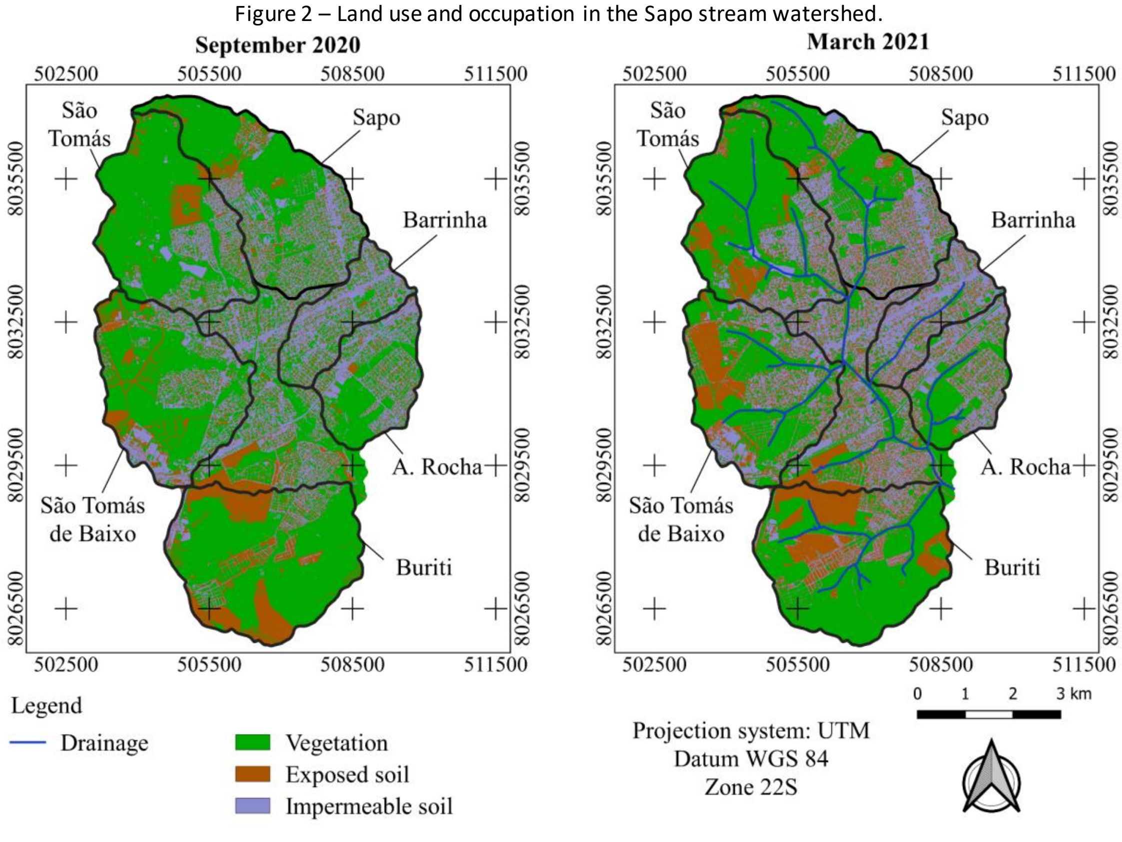
After obtaining the results of $BOD_{5,20}$ and DO from the water samples of the studied water bodies, the classification of the water quality in the watershed of the Sapo stream was conducted according to the criteria established by CONAMA Resolution No. 357, in 2005, prioritizing the most restrictive parameter. For the classification process of the stretches, the predominant class (the longest time) in each water body was considered, based on the results obtained from the monitoring points.

4 RESULTS

4.1 Land use and occupation

The results of the land use and occupation identification process conducted using the September 2020 and March 2021 images for the Sapo stream watershed are shown in the classification presented below in Figure 2.

Figure 2 – Land use and occupation in the Sapo stream watershed.



Source: Author (2021).

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In addition to the visual representation of land use and occupation displayed in Figure 2, the percentages of vegetation, exposed soil, and impermeable soil classes in each micro-watershed for the months of September 2020 and March 2021 are shown in Table 2.

Table 2 – Characterization of monitoring points.

Classification	Month	Sapo (P1)	São Tomás (P2)	São Tomás de Baixo (P3)	Barrinha (P4)	A. Rocha (P5)	Buriti (P6)	Total
Vegetation (%)	Sep/20	56.65	69.45	57.91	27.84	48.97	66.95	**56.09**
	Mar/21	50.37	62.90	46.68	17.16	43.22	64.23	**49.03**
Exposed soil (%)	Sep /20	15.19	13.18	18.85	17.21	13.55	25.69	**18.62**
	Mar/21	18.34	18.40	26.73	22.69	18.52	26.03	**23.29**
Impermeable soil (%)	Sep /20	28.16	17.37	23.24	54.95	37.47	7.36	**25.29**
	Mar/21	31.29	18.71	26.59	60.15	38.25	9.74	**27.68**

Source: Author (2021).

Evaluating each class of land use and occupation, by means of Student's t test, between the two studied periods, it was obtained that p-value in all cases was greater than the significance level (α) of 5%. Therefore, the analysis indicated that there was no significant difference between the periods of September 2020 and March 2021. However, the observed differences could be attributed to inherent errors in the land use and occupation classification process itself.

In September 2020, the P2 micro-watershed had the highest percentage of vegetated area, while in March 2021, the highest value was found in the P6 micro-watershed. Both regions showed the lowest areas of impermeable soil when compared to the other micro-watersheds. Regarding to the impermeable soil, the area where the P4 point is located had the highest percentage in both evaluated periods and also exhibited the lowest values of vegetation, reflecting its high level of urbanization.

In terms of exposed soil, the P6 and P3 micro-watersheds exhibited the highest percentage values for this class. Both areas are subject to fluctuations due to the agricultural calendar and the installation of new residential developments.

Considering the entire watershed region, it can be hypothesized that the extension of the second corn crop planting until mid-March may have influenced the increase in the percentage of exposed soil and the decrease in the vegetation percentage in March 2021. In contrast, in September 2020, as the soybean planting in the region had not yet begun, the soil still had vegetative cover from crop residue, a commonly used technique during the offseason (CREMONEZ, 2018; NASCENTE; STONE, 2018; SOARES et al., 2021).

Regarding to the specific land uses, three water retention dams were identified in the watershed region, located in the micro-watersheds of points P1, P2, and P3. In the micro-watershed of point P3, in addition to the dam near the confluence with the Sapo stream, there was also the presence of a grain industry that discharged its liquid effluents into the water body after treatment. In the micro-watershed of point P6, there was a sewage pumping station (SPS) operated by the sanitation company, as well as a dairy plant that also discharged its treated liquid effluents into the water body.

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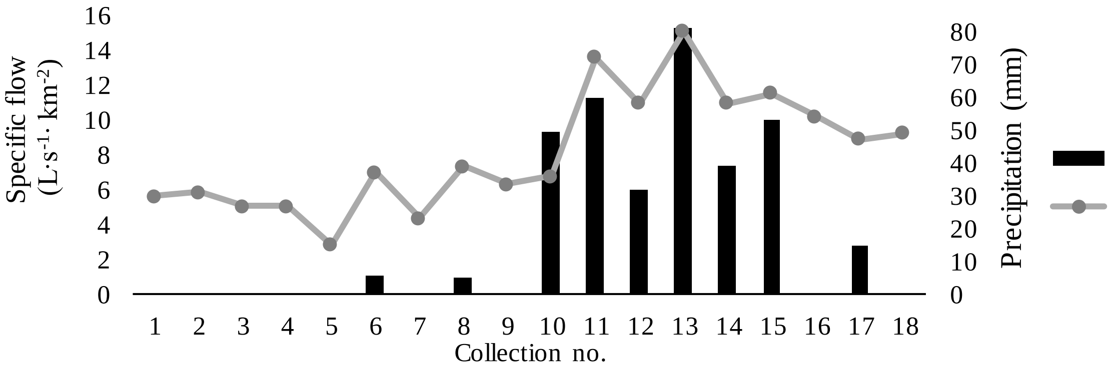
4.2 Specific flow and precipitation

Figure 3 shows the variation of the specific flow in the outlet, point P7, of the Sapo stream watershed, and presents the accumulated precipitation values in the municipality of Rio Verde, considering the five days prior to each monitoring date.

Figure 3 – Specific flow and accumulated precipitation of the monitoring days



Source: Author (2021).

It can be realized that P7 presented its highest values of specific flow in collections number 13 (15.06 $L{\cdot}s^{-1}{\cdot}km^{-2}$), 11 (13.57 $L{\cdot}s^{-1}{\cdot}km^{-2}$) e 15 (11.52 $L{\cdot}s^{-1}{\cdot}km^{-2}$), coinciding with the three highest accumulated precipitations, all from the year 2021.

Considering the data on accumulated precipitation, it was identified that the lowest rainfall volumes happened between August and early December 2020, while the highest accumulated precipitations occurred between mid-December 2020 and April 2021.

4.3 Water quality parameters

The results of the water quality parameters evaluated during the monitoring dates are displayed in Chart 1.

The highest values of $BOD_{5,20}$ were observed at point P6. At this point, the maximum concentration of $BOD_{5,20}$ was 173.70 $mg{\cdot}L^{-1}$. The second point with higher $BOD_{5,20}$ values was P7, with a maximum concentration of 68.37 $mg{\cdot}L^{-1}$, noting that this point was located approximately 200 meters away from point P6.

The third location with the highest concentration of $BOD_{5,20}$ was P3, exhibiting a maximum of 29.31 $mg{\cdot}L^{-1}$. As for the other points, P1, P2, P4, and P5, together they showed an average concentration of 6.06 $mg{\cdot}L^{-1}$ of $BOD_{5,20}$.

Regarding to the DO, point P6 obtained the lowest values, its median concentration was 2.00 $mg{\cdot}L^{-1}$, with 75% of the data being below 2.70 $mg{\cdot}L^{-1}$. The grouped points P1, P2, and P3 had an overall average of 4.63 $mg{\cdot}L^{-1}$.

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Chart 1 – Characterization of monitoring points.

Point	BOD$_{5,20}$ (mg·L^{-1})					DO (mg·L^{-1})				
	Value Min.	Percentile 25%	Percentile 50%	Percentile 75%	Value Max.	Value Min.	Percentile 25%	Percentile 50%	Percentile 75%	Value Max.
P1	1.10	1.43	2.82	6.21	8.81	3.20	4.30	5.05	5.60	5.90
P2	1.05	1.20	1.35	6.65	7.47	3.50	3.90	4.70	5.20	5.70
P3	1.83	2.44	3.45	15.25	29.31	2.60	3.70	4.50	4.80	5.70
P4	1.10	2.11	3.89	7.87	12.94	5.40	6.30	7.05	8.70	11.90
P5	2.05	3.00	4.96	8.66	8.66	4.50	5.10	5.55	6.00	6.60
P6	13.07	32.85	46.24	94.07	173.70	1.30	1.80	2.00	2.70	3.40
P7	4.42	6.96	13.31	32.09	68.37	2.20	3.90	4.40	5.40	6.90
Point	COD/BOD ratio					SS (mg·L^{-1})				
	Value Min.	Percentile 25%	Percentile 50%	Percentile 75%	Value Max.	Value Min.	Percentile 25%	Percentile 50%	Percentile 75%	Value Max.
P1	5.91	23.14	32.86	71.82	86.76	3.00	7.00	8.00	13.00	20.00
P2	14.67	46.38	63.19	82.72	95.61	1.50	3.00	6.00	10.00	19.00
P3	4.97	10.55	39.91	55.48	81.60	11.00	17.00	30.00	47.00	76.00
P4	7.21	13.27	30.78	47.89	70.19	1.00	3.00	8.00	24.00	25.00
P5	3.71	4.39	33.47	41.14	54.97	2.00	7.00	13.00	22.00	40.00
P6	1.43	1.99	3.85	8.56	9.35	23.00	40.00	64.50	100.00	166.00
P7	2.25	4.96	10.58	20.02	27.68	9.00	16.00	19.00	30.00	34.00

Source: Author (2022).

In relation to the highest values of DO, they were present at points P4 (11.90 mg·L^{-1}), P7 (6.90 mg·L^{-1}), and P5 (6.60 mg·L^{-1}), respectively. However, even though P7 had the second highest DO value, it also had the second lowest concentration of DO (2.20 mg·L^{-1}). The critical value was observed during sample collection number 7, on which a field visit confirmed the discharge of raw sewage into the water body through a sewage pumping station (SPS), located upstream of point P7.

To analyze the degree of biodegradability of the water body studied, the COD/BOD ratio was used. According to Von Sperling (2011), it follows that: COD/BOD ratio less than 2.5 represents a high biodegradable fraction; COD/BOD ratio between 2.5 and 3.5 represents a moderately biodegradable fraction; and COD/BOD ratio greater than 3.5 and 4.0 represents a high non-biodegradable (inert) fraction.

As noted in Chart 1, points P1, P2, P3, P4, P5, and P7 exhibited COD/BOD ratios above 4 in more than 75% of the analyses, indicating a high inert fraction. Only P6 displayed values that characterized it as having a high biodegradable fraction, with more than 25% of the data below 2.5, indicating the presence of raw domestic sewage pollution (VON SPERLING, 2011).

Evaluating the behavior of SS for each point it can be observed that the highest values of this parameter were exhibited by point P6. The maximum SS value recorded at this point was 166.00 mg·L^{-1}. Additionally, it should be emphasized that the watershed of point P6 displayed the highest percentage of exposed soil in September 2020 and the second highest in March

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2021. This fact may also be related to the high concentration of suspended solids observed at point P6, favoring the silting process of water bodies in the region (SANTOS *et al.*, 2019).

Another important situation observed during the field sampling was the works to modify the stream bed and slopes near point P6, which probably contributed to the increase in the concentration of SS in its waters.

The second point with higher concentrations of SS was P3, with a maximum value of 76.00 mg·L^{-1}, followed by P5, with a maximum value of 40.00 mg·L^{-1}. The lowest values of SS were observed at points P4, with a minimum of 1.00 mg·L^{-1}, and P2, with a minimum of 1.50 mg·L^{-1}.

Five points studied (P1, P2, P3, P4, P5) obtained their highest concentrations of SS in the two monitoring campaigns with the highest accumulated precipitation in the previous five days, they were the collections number 13 and 11. The only points that did not have their peak values of SS coinciding with the mentioned days were P6 and P7, places where the water quality was also influenced by probable sources of punctual pollution.

4.4 Water quality classification of the Sapo stream watershed

Table 3 displays the percentages of residence time, presented by the points, for each water quality class.

Table 3 – Percentage of residence time in water quality class.

Points	Class 1 (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
P1	-	38.9	**50.0**	11.1
P2	-	**44.4**	27.8	27.8
P3	5.6	16.7	22.2	**55.6**
P4	**38.9**	27.8	22.2	11.1
P5	12.5	**43.8**	25.0	18.8
P6	-	-	-	**100.0**
P7	5.6	5.6	22.2	**66.7**

Source: Author (2022).

According to the classification conducted on the studied watershed, it can be observed that only the tributary of point P4 remained within the parameters established for class 1 for most of the time. The water bodies upstream of points P2 and P5 were classified as class 2. The Sapo stream, at point P1, was classified as class 3, while the tributary streams of points P3, P6, and the outlet of the Sapo stream, P7, were classified as class 4.

It can be noted that the locations with poorer water quality classes were those downstream of dams (point P3), near neighborhoods without complete sewage network coverage, and in areas where industrial activities are carried out (points P6 and P7).

4.5 Analysis of water quality in the watershed

Analyzing the water quality parameters, it was found that point P6 exhibited the worst performance. consequently, that mentioned water body showed the highest values of $BOD_{5,20}$,

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the lowest levels of DO, and the highest concentrations of SS. During the monitoring, the stream appeared turbid with a strong odor. One of the sources of pollution in this watershed is the discharge of untreated sewage by the sanitation company (sewage collected from the network is released without treatment into the stream). Additionally, a dairy company releases inadequately treated liquid effluents into this water body.

Due to the proximity between points P6 and P7, it is believed that the water quality parameter values at point P7 may have been influenced by the release of the tributary from point P6.

Another water body that stood out negatively was the tributary of point P3, being the third to exhibit higher concentrations of $BOD_{5,20}$ and the third to present the lowest concentrations of DO. Also, that location was in the second rank to show the highest concentrations of SS.

It is important to say that during the research, the presence of algae was found in the bed of the water course belonging to P3, indicative of the eutrophication process in the stream (MOLINARI, 2015; VON SPERLING, 2011), a factor that may have contributed to the lower values of OD and high levels of $BOD_{5,20}$. The existence of algae in the stream may be related to the elevation of nutrients (BLAAS; KROEZE, 2016), by the release of effluents from the grain industry and also due to the presence of the water dam upstream of the monitoring point.

Furthermore, the watersheds of points P6 and P3 had the highest percentage of exposed soil, which likely contributed to sediment transport into the streambeds, with the flow of rainwater being one of the main ways for the occurrence of the elevation of nutrients in the aquatic environment (MEDEIROS, 2020; PEREIRA et al., 2020).

With a better performance in terms of quality regarding to DO and $BOD_{5,20}$, point P4 recorded the highest DO values; showed low values of $BOD_{5,20}$, registered a low biodegradable fraction, since all of its COD/BOD ratios were greater than 4; and it was the only water body classified as class 1. It can be noticed that point P4 had a small water depth, contained hydraulic ladders, which favored its capacity for reaeration and the purification of biodegradable pollutants.

Regarding to the water uses, it is noted that the most restrictive indications are present in the tributaries of points P3, P6 and P7, classified as class 4, according to CONAMA Resolution No. 357/2005. It is noteworthy that in the P3 region, the presence of fishing, human recreation, and landscape harmony was observed, while in the P6 and P7 areas, the water was used for animals drinking and gardening the landscape.

Comparing the use of water carried out with that recommended by federal regulations (Resolution No. 357/2005), it was noted that in sections classified as class 4, the main activities carried out should not occur, because in these places the only permitted uses should be those involving navigation and landscape harmony.

5 CONCLUSION

It was observed that the Barrinha Stream watershed (P4), which has the highest percentage of impermeable soil, obtained the best water quality aspects. This positive behavior is credited to the fact that the water body has hydraulic stairs (which helps in water reaeration

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process) and also due to the low presence of industrial activities, good coverage of the collection network and removal of sewage system and low levels of exposed soil.

The watersheds with the worst water quality levels were São Tomás de Baixo Stream (P3) and Buriti Stream (P6). The main cause of pollution of those water bodies is the improper discharge of sanitary sewage and industrial wastewater. In the case of São Tomás de Baixo Stream, the presence of a dam also contributes to the eutrophication process of the water source.

Furthermore, it was found that some activities are contrary to the correct uses of water resources indicated by CONAMA Resolution No. 357/2005, which could cause harm to human and animal health. The streams where this situation was observed were São Tomás de Baixo and Buriti, both classified as class 4.

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