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Comparative Study of Water Quality Across Different Seasons in the Gregório River Watershed, São Paulo, Brazil

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Original Article

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ABSTRACT: The goal of this study was to monitor the water quality in the Gregório river, São Carlos, São Paulo during the dry and rainy seasons using traditional methods such as physical and chemical analysis of the water and biological indicators. Six sampling points were monitored, ranging from the nearest location to the source of the river to its confluence with the Monjolinho river. Physical and chemical parameters of water (water surface temperature, dissolved oxygen, pH, and conductivity) were measured using a multiparameter probe. The distance between the points was determined according to the access to the site: from P1 to P2 (1328 m), from P2 to P3 (1278 m), from P3 to P4 (201 m), from P4 to P5 (820 m), and finally from P5 to P6 (1814 m). The biotic index used in conjunction with the environmental variables was the Biological Monitoring Working Party (BMWP), a qualitative index that utilizes benthic macroinvertebrates to classify water quality. Ceratopogonidae, Chironomidae, *Chironomus*, Enchytraeidae, Hirudinea, and Naididae were recorded at sites P1, P2, and P6 during both the dry and rainy seasons. In this study, particularly at P6, it was observed that despite the higher concentration of dissolved oxygen compared to the other analyzed sites, which would indicate good water quality, the BMWP indicated that the location had a strongly polluted water quality, suggesting that environmental factors must be associated with biological indicators. It was concluded that the use of biological indicators along with environmental data provided a more reliable understanding of water quality.

Estudo Comparativo da Qualidade da Água em Diferentes Estações na Bacia do Rio Gregório, São Paulo, Brasil

RESUMO: O objetivo deste estudo foi monitorar a qualidade da água no rio Gregório, São Carlos, São Paulo, durante as estações seca e chuvosa, utilizando métodos tradicionais, como análises físicas e químicas da água e indicadores biológicos. Seis pontos de amostragem foram monitorados, variando desde o local mais próximo da nascente do rio até sua confluência com o Rio Monjolinho. Parâmetros físicos e químicos da água (temperatura da superfície da água, oxigênio dissolvido, pH e condutividade) foram medidos usando uma sonda multiparâmetro. A distância entre os pontos foi determinada de acordo com o acesso ao local: de P1 a P2 (1328 m), de P2 a P3 (1278 m), de P3 a P4 (201 m), de P4 a P5 (820 m) e, finalmente, de P5 a P6 (1814 m). O índice biótico usado em conjunto com as variáveis ambientais foi o Biological Monitoring Working Party (BMWP), um índice qualitativo que utiliza macroinvertebrados bentônicos para classificar a qualidade da água. Ceratopogonidae, Chironomidae, *Chironomus*, Enchytraeidae, Hirudinea e Naididae foram registrados em P1, P2 e P6 durante as estações seca e chuvosa. Neste estudo, especialmente em P6, observou-se que, apesar da maior concentração de oxigênio dissolvido em comparação com os outros locais analisados, o que indicaria boa qualidade da água, o BMWP indicou que o local apresentou uma qualidade da água fortemente poluída, sugerindo que fatores ambientais devem estar associados aos indicadores biológicos. Concluiu-se que o uso de indicadores biológicos juntamente com dados ambientais proporcionou uma compreensão mais confiável da qualidade da água.

Introduction

The city of São Carlos, in São Paulo state, encompasses two Water Resources Management Units: Mogi-Guaçu and Tietê/Jacaré. It is situated above the Guarani Aquifer, from which it extracts water for the supply of 28 artesian wells (SAEE, 2022). Due to human activities and increased soil impermeability caused by real estate developments and/or agricultural activities, only 28% of all water withdrawn for supply, considering the total area of the municipality, returns to the aquifer (Freitas & Santos, 2020). In addition to wells, water abstraction in São Carlos also occurs from two surface sources: the Monjolinho river and the Ribeirão do Feijão (SAEE, 2022).

Precipitation can have a significant impact on the water quality of aquatic ecosystems. During periods of rainfall, rainwater can carry pollutants present on the soil surface, such as pesticides, fertilizers, among other contaminants, into rivers through surface runoff (Dellamatrice & Monteiro, 2014). This runoff increases the pollutant load, sediments, and toxic substances in the rivers, negatively affecting water quality especially for economic activities (Bastos et al, 2018). Additionally, precipitation can also alter the chemistry of water (Silva et al., 2020) In the Purus River, Amazonas, Brazil, a negative correlation between precipitation and turbidity was observed, and a positive correlation between precipitation and temperature, conductivity, dissolved oxygen, total suspended solids, and pH. (Silva et al., 2008).

According to Ordinance 888/21, water quality at collection sites can be measured by parameters such as dissolved oxygen and pH (Brasil, 2021). Moreover, the use of complementary analysis is recommended as stated in CONAMA resolution 357/05, which allows the use of bioindicators (organisms and/or communities) in water quality monitoring (Brasil, 2005). Among these organisms, benthic fauna, that is, sediment-dwelling organisms, has been widely used, including by water treatment plants, to monitor water quality and ecosystem integrity where abstraction occurs. Sediment is important because all modifications in aquatic ecosystems, such as the discharge of polluting sources, ultimately reflect sediment directly or indirectly.

Among the methods for assessing sediment fauna, the BMWP (Biological Monitoring Working Party) stands out for several reasons, such as its low cost and satisfactory results in assessing ecosystem integrity (Barrilli et al, 2021; Delgado et al, 2023; Rodrigues et al, 2016). The BMWP allows the qualitative use of macroinvertebrate families inhabiting the sediment to infer water quality, which can range from very clean to heavily polluted (Alba-Tercedor & Sánchez-Ortega, 1988). The index is based on previous studies of invertebrate sensitivity to environmental variables, allowing the assignment of values (scores) to each sampled taxon family at each location, with the most resistant families receiving the lowest scores and the most sensitive ones receiving the highest scores (Junqueira & Campos, 1998). The BMWP plays a crucial role in the sustainable management of water resources by providing information about ecosystem health and water quality. Its use can assist in mitigating the use and occupation of ecosystems by human action on conservation, contributing to environmental management, and ultimately contributing to the protection and preservation of aquatic ecosystems for future generations.

Considering the above, the present study aimed to evaluate the effects of precipitation on water quality in the Gregório river, using physical-chemical variables, while also incorporating biotic index as a complementary tool during the dry and rainy seasons.

Material and Methods

Gregório river watershed is in the municipality of São Carlos, state of São Paulo, 18,86 km^2 and a perimeter of 29.07 km (Figure 1). Thirty years of studies on precipitation demonstrate that the driest periods in São Carlos occur from April to September, while the rainiest ones happen from October to March (CLIMATEMPO, 2024).

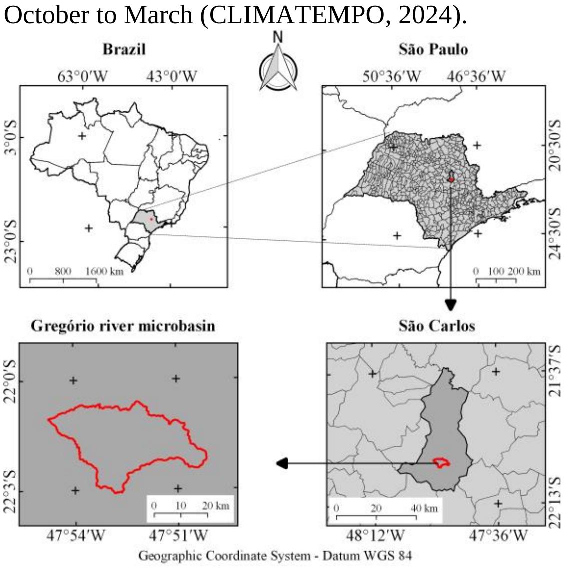

Figure 1. Location of the Gregório river watershed, São Paulo, Brazil (Fornaziero et al. 2022).

The data was collected on 11/09/2021 considering the rainy season and on 04/03/2022 considering the dry season. The sampling locations were named P1 (22.032797° S; 47.864701° W), P2 (22.024417° S; 47.879799° W), P3 (22.020757° S; 47.886705° W), P4 (22.020516° S; 47.888636° W), P5 (22.016744° S; 47.900331° W), and P6 (22.018882° S; 47.912991°), following subsequently from upstream to downstream. The linear distances between the points were: P1 and P2: 1833 m; P2 and P3: 819 m; P3 and P4: 202 m; P4 and P5: 1278 m; P5 and P6: 1199 m.

In Figure 2, it was possible to observe the urban area occupying a large part of the watershed, and it's also possible to observe the sampling points.

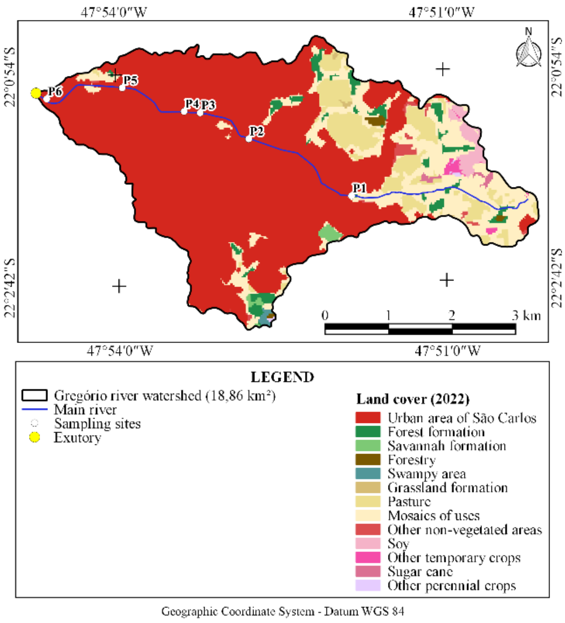

Figure 2. sampled locations in the study (P1, P2, P3, P4, P5 e P6).

Figure 3 shows the urban area (69.03%) and the agricultural area (22%) of the Gregorio watershed that contribute to soil impermeability.

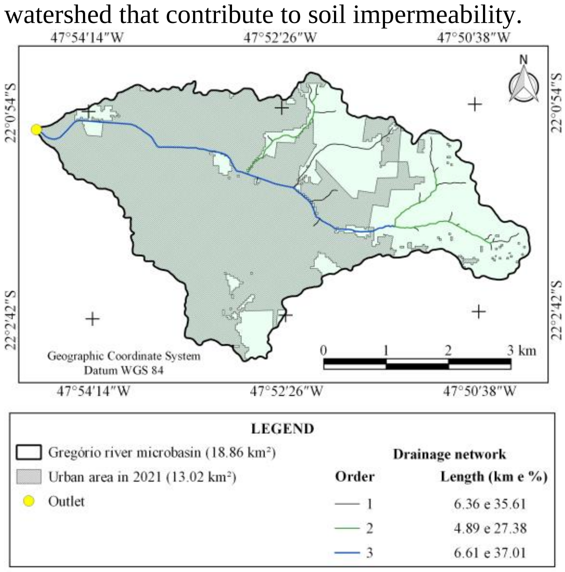

Figure 3. Drainage network and river order of the Gregório river watershed, São Paulo, Brazil (Fornaziero et al. 2022).

At six sites, monitoring was conducted from the closest location to the spring to the confluence zone of the Gregório river with the Monjolinho river. Abiotic factors were measured in three replicates, that is, three samplings were repeated at each location using a Horiba U-52 multiparameter probe. The following variables were measured at each site: air and surface water temperatures, pH, dissolved oxygen, and conductivity. A 3-liter Van Veen grab sampler was used to collect benthic macroinvertebrates, which were placed in plastic bags and later sorted and identified under a stereomicroscope using specific identification keys for families. The macroinvertebrates were sampled to calculate the BMWP biotic index.

Results and discussion

At P1 during the dry season, all measured environmental variables showed the lowest values. In the same season, the pH was more acidic at P1 and P2, and conductivity was higher at P5 and P6. In the rainy season, P1 had the highest concentration of dissolved oxygen, while the lowest values of conductivity and pH were recorded at P6 and P1, respectively. In P5, both in the rainy seasons, the concentration of dissolved oxygen was extremely low, falling below 1.84 mg/L (Table 2). The results indicated that precipitation did not show an apparent influence on increasing the availability of oxygen in P5.

At P1, P2, and P6, where macroinvertebrates were recorded during both the dry and rainy seasons, and the BMWP could be applied, the conditions of the sections were considered critically poor in terms of water quality, indicating a strong human influence on the river. However, when analyzing the environmental variables, it was observed that P5 recorded the highest conductivity during the dry period. Precipitation seems to have a strong influence on reducing this variable in the water.

Benthic macroinvertebrates were identified only in P1, P2, and P6 during both the dry and rainy seasons. The macroinvertebrates identified in these sites were Ceratopogonidae, Chironomidae, Chironomus, Enchytraeidae, Hirudinea, and Naididae. The utilization of the BMWP index revealed that all the surveyed sites indicated extremely polluted water quality during both the dry and rainy seasons, meaning that the score value remained below 15. The BMWP scores for points P1, P2, and P6 during the dry season were, respectively, 8, 6, and 2. Meanwhile, during the rainy season, they were, respectively, 6, 4, and 2. These values indicate that the water quality at these locations was consistently deemed extremely polluted, regardless of the season.

Table 1: Mean and standard deviation (in parentheses) of the environmental variables measured in the Gregório river during the dry season.

Parameters	Unit	P1	P2	P3	P4	P5	P6
Air Temperature	ºC	25.10 (0.00)	26.20 (0.00)	28.30 (0.00)	28.50 (0.00)	32.70 (0.00)	26.78 (0.00)
Water Temperature	ºC	23.13 (0.10)	25.47 (0.01)	27.56 (0.00)	27.57 (0.01)	26.21 (0.01)	30.27 (0.01)
pH	-	3.93 (0.00)	5.07 (0.00)	5.65 (0.00)	5.24 (0.00)	6.10 (0.00)	7.18 (0.00)
Dissolved Oxygen	mg/L	5.18 (0.13)	5.86 (0.01)	6.96 (0.00)	6.96 (0.01)	6.25 (0.02)	7.18 (0.04)
Conductivity	µ/cm	87 (0.00)	142 (0.00)	200 (0.00)	200 (0.00)	286 (0.00)	247 (0.00)

A study conducted less than 50 km away from the study area, Descalvado, São Paulo, Brazil recorded a reduction in dissolved oxygen concentration in the water during the rainy season due to the inverse relationship between dissolved oxygen (DO) concentration and water temperature (Fonseca & Salvador, 2005). According to the authors, in addition to temperature, another contributing factor to the reduction of DO in the rainy season was the higher amount of organic matter released into lotic ecosystems during this period. Therefore, it was expected that in locations where the water temperature was higher, there would be a lower amount of DO, as described by other authors (Chapman & Kimstach, 1992; Von Sperling, 2014).

In the dry period, the highest water temperature was recorded at 30.27°C in P6, while the lowest oxygen concentration was observed elsewhere, at 5.18 mg/L in P1. However, during the rainy season, the highest water temperature (27.02°C) was also recorded in P6, and the oxygen concentration in P5 was 1.84 ml/L. The results indicated that the water temperature at the study site does not seem to have significantly affected the oxygen concentration.The Monjolinho basin has an approximate area of 275 km^2, with most of it located in the municipality of São Carlos. It is a well-studied area by several authors in different fields, such as water quality, sediment, environmental indicators, and ecotoxicological studies (Espindola, 2000; Novelli, 2005; Ferreira & Cunha-Santino, 2014; Silva et al., 2017; Santos et al. 2018). Ferreira & Cunha-Santino (2014) recorded DO values higher than 7.95 mg/L during the flood period in the Monjolinho, indicating that the better oxygenation in P6 may be related to the positive influence of Rio Monjolinho DO on the Gregório river at its mouth.

In general, when comparing DO at the same site but in different seasons, a reduction in this variable was observed during the rainy period compared to the dry period in all sites except P1. The lowest concentration of the entire study (1.84 mg/L) was recorded in the rainy season at P5, for reasons to be studied later, but there is a high probability that it is due to organic matter. This concentration is well below the minimum concentration established by CONAMA Resolution 357/05 for the preservation of life, which should be above 5.0 mg/L (Brasil, 2005).

In the study area, the results of the measured environmental variables, as well as the biological indicators, support the presence of anoxia. The highest percentage of DO reduction, approximately 62%, was recorded in P6, indicating that precipitation played an important role in reducing the availability of oxygen in the water during the rainy period, consistent with the results of several authors (Fonseca & Salvador, 2005; Viana, 2005).

In addition to the commonly used environmental variables to study water quality, biological indicators were also measured in the Gregório river. These indicators are already recognized and included in CONAMA Resolution 357/05 as a tool for environmental diagnosis (Brasil, 2005). In this study, the BMWP index was used, where benthic macroinvertebrates are used as a tool for environmental diagnosis. The importance of benthic macroinvertebrates lies in the fact that any modification that occurs in the aquatic ecosystem, directly or indirectly, ultimately reflects in the sediment, where the macroinvertebrates inhabit.

Several authors have successfully used the BMWP index to assess water quality using biological indicators (Junqueira & Campos, 1998; Cota et al., 2002; Mustow, 2002; Monteiro et al. 2008; Zeybek, 2014; Silva et al., 2016).

Table 2: Mean and standard deviation (in parentheses) of the environmental variables measured in the Gregório river during the rainy season.

Parameters	Unit	P1	P2	P3	P4	P5	P6
Temperature	ºC	26.81 (0.00)	27.28 (0.00)	27.28 (0.00)	27.25 (0.00)	28.20 (0.00)	25.10 (0.00)
Water Temperature	ºC	24.83 (0.00)	25.44 (0.00)	25.50 (0.00)	26.96 (0.00)	26.74 (0.00)	27.02 (0.00)
pH	-	7.04 (0.00)	7.31 (0.01)	7.32 (0.00)	7.89 (0.00)	7.88 (0.02)	7.16 (0.00)
Dissolved Oxygen	mg/L	7.28 (0.00)	4.84 (0.00)	4.90 (0.00)	5.00 (0.00)	1.84 (0.00)	6.35 (0.00)
Conductivity	µ/cm	40 (0.00)	100 (0.00)	100 (0.00)	170 (0.00)	240 (0.00)	0 (0.00)

Among all the families identified, Chironomus (Chironomidae) was the most prevalent. The use of the BMWP index indicated that water quality at the sites where macroinvertebrates were identified was considered heavily polluted, while no taxa were collected at the other sites, indicating unfavorable environmental conditions. The anoxia recorded in P5 during both the dry and rainy seasons may have been one of the determining factors for the absence of invertebrates at that location, although some authors report that some groups can survive in oxygen-depleted conditions (Piedras, 2006; Correa-Araneda, 2010).

As previously mentioned, P6 had one of the highest dissolved oxygen concentrations in the water during both the dry and rainy seasons but was classified as heavily polluted according to the BMWP index. The presence of Chironomus (Chironomidae) in P6 drew attention since this genus is typically found in low oxygen concentration environments. Chironomus has a distinct reddish coloration due to the presence of hemoglobin, which aids in more efficient absorption and storage of available oxygen in the water (Hamburger et al. 1994; Armitage et al. 1995; Lacerda et al. 2005). Due to the characteristics of the genus, several authors have associated its presence with a reduction in water quality and degradation of aquatic ecosystems (Coimbra et al., 1996; Callisto et al. 2001).

The presence of fish was observed in situ at the mouth of the Gregório river in P6 during both the dry and rainy seasons, we can conclude that it may be due to the influence of the Monjolinho river, which meets the Gregório in P6.

Conclusions

The point P6 showed better dissolved oxygen quality compared to the locations with higher environmental integrity located upstream like P1. The presence of Chironomus, associated with the BMWP index, indicated that P6 has extremely polluted water quality, despite the high oxygen levels. This study highlights the importance of using biological indicators in addition to traditional methods for water quality analysis. Therefore, the identification and subsequent characterization of the macroinvertebrate communities of the watershed under study serves as a basis for them to be used as indicators of local environmental conditions, since possible changes in these communities indicate the existence of activities that contribute to local degradation. Furthermore, this study enables other analyses with the objective of evaluating and carrying out the maintenance of water quality and efficient drainage.

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