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Monitoring and verification of the feasibility of using water from urban reservoirs located in the city of Caraúbas-RN

Monitoramento e verificação da viabilidade de uso da água de açudes urbanos localizados na cidade de Caraúbas-RN

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Resumo
O presente estudo teve como objetivo investigar a influência da variação espaço-temporal nas características físico-químicas da água em três açudes urbanos da cidade de Caraúbas-RN: Açude Saboia, Açude Grande e Açude Santa Bárbara. Este estudo pode fornecer informações relevantes sobre a qualidade desses recursos hídricos e embasar ações e políticas para a conservação e uso sustentável dos recursos hídricos urbanos, tanto para consumo humano, quanto para irrigação. As análises e métodos adotados seguiram as diretrizes estabelecidas no Standard Methods of APHA. Os resultados mostram que a qualidade físico-química das águas analisadas são afetadas diretamente pela variabilidade espaço-temporal, com destaque para a condutividade, salinidade, cloreto e turbidez. Apesar da influência constatada, a maioria dos parâmetros se enquadram dentro dos limites estabelecidos pela legislação vigente, evidenciando a possibilidade de uso da água para consumo humano e irrigação de acordo com esses parâmetros. No entanto, para uma avaliação abrangente e assertiva da viabilidade de uso, seriam necessárias análises complementares que englobassem outros parâmetros físico-químicos e microbiológicos.
Palavras-chave: Poluição. Análise Ambiental. Monitoramento. Qualidade da água.

Abstract

The present study aimed to investigate the influence of spatial and temporal variation on the physicochemical characteristics of water in three urban reservoirs in the city of Caraúbas-RN: Saboia Reservoir, Grande Reservoir, and Santa Bárbara Reservoir. This study can provide relevant information about the quality of these water resources and support actions and policies for the conservation and sustainable use of urban water, both for human consumption and irrigation purposes. The analyses and methods adopted followed the guidelines established in the Standard Methods of APHA. The results show that the physicochemical quality of the analyzed waters is directly affected by spatial and temporal variability, with particular emphasis on conductivity, salinity, chloride, and turbidity. Despite the observed influence, most of the parameters fall within the limits established by current legislation, indicating the possibility of using the water for human consumption and irrigation in accordance with these parameters. However, for a comprehensive and accurate assessment of usability, additional analyses encompassing other physicochemical and microbiological parameters would be required.

Keywords: Pollution. Environmental Analysis. Monitoring. Water Quality.

1. Introduction

It is known that the Earth is predominantly covered by water. Water plays a vital and indispensable role in the development of life on the planet. It is present as a fundamental component of living organisms, serving as a habitat for a wide variety of plant and animal species. Moreover, water is intrinsically linked to sociocultural issues and is an essential input in the production of various consumer goods, including food. Its importance as a natural resource is undeniable (Philippi Jr *et al*., 2004).

Overall, its percentage surpasses that of land, however, when it comes to potable water, this percentage drops dramatically. According to Camargo and Paulosso (2009), the majority of the world's water, approximately 97%, is saline, while 2% is found in glaciers and icebergs, and only 1% is freshwater available for human use in various activities, including consumption, agriculture, industry, and domestic use.

Despite water being a renewable natural resource, its availability is limited in various regions of the world. However, even in areas where there is a significant amount of water, the improper use and wastage of this valuable resource are common. Such irresponsible practices can lead to the degradation of water quality and a decrease in the available quantity of water (Garcia *et al.*, 2019).

Approximately one-third of the world's population lives in regions where water is scarce, which limits access and leads to improper use of this resource. Furthermore, in these areas, water quality is also compromised, affecting people's ability to reach their full human potential. In addition to the social implications, there are also significant environmental consequences arising from the excessive exploitation of surface water sources and the depletion of underground aquifers (Grafton, 2017). Given the increasing occurrences of water scarcity, monitoring water quality plays an increasingly crucial role. This is due to the reality that a portion of the population faces limitations or has limited options for accessing this vital resource (Boyd, 2015).

This inequality also affects Brazil, where there are regions with higher population density and insufficient resources to meet the demand for water supply (Betemps *et al*., 2014). The Northeast of Brazil presents climatic conditions characterized by high evaporation and long periods of solar exposure. Additionally, its crystalline geological structure hinders the recharge of the groundwater table. As a result of these factors, the region has limited water potential, making the construction of reservoirs essential to capture rainwater and, in certain cases, ensure the perennial flow of rivers. Thus, rainwater harvesting gains crucial importance in supplementing the water needs of cities facing water supply challenges (Carvalho Junior *et al*., 2022).

Thus, the strategy of creating artificial reservoirs, adopted as a policy to address drought in the semiarid region, gained prominence in the late 19th century and was subsequently assigned to the National Department of Works Against Droughts (Departamento Nacional de Obras Contra as Secas - DNOCS) as its area of operation. The implementation of this "hydraulic system" contributed significantly to mitigating the impacts of water scarcity and providing water supply to affected communities (Assunção and Livingstone, 1988). According to Lima and Mendes (2015), the Northeast of Brazil hosts the largest number of reservoirs in the country, serving various functions, with the main ones aimed at meeting the region's needs, such as human water supply, irrigation, animal watering, fishing, among others.

It is important to highlight that, in the urban context, reservoirs lose their original purpose due to various factors, such as the population growth around them, which compromises their water quality. Furthermore, reservoirs play a significant role in the drainage system of rainwater in urban areas, as mentioned by Torquato *et al*. (2016). This function is crucial to minimize the impacts of heavy rainfall as well as to prevent floods. Therefore, urban reservoirs serve a multifunctional role, combining water resource management, environmental preservation, and urban infrastructure.

However, due to recent activities carried out in urban reservoirs, it is common for contamination to occur in these places. This is due to the presence of microorganisms and pollutants that are released directly into the water or the environment, being dragged by the rains, which ends up damaging their quality (Torquato *et al.*, 2016). As mentioned by Moura *et al*. (2011), although many reservoirs face problems of salinization and contamination by pesticides and domestic and industrial sewage, they often become the only resource available for human and animal consumption.

Thus, it is important to constantly monitor water quality through physicochemical parameters such as pH, dissolved oxygen, conductivity, salinity, turbidity, chloride, and sodium. These analyses reveal the presence of pollutants, even when they are not noticeable (Torquato *et al.*, 2016). Continuous assessment of water quality is critical to ensuring the safety and adequate availability of this essential resource (Boyd, 2015).

In addition, it is crucial to consider the influence of time on the parameters analyzed. According to Diniz *et al.* (2006), in Northeastern semi-arid reservoirs, where evaporation is high and rainfall is irregular, studies of this type are essential to better understand water quality standards and the processes that affect them. Therefore, it is important to investigate the temporal variability of the analyzed parameters in order to obtain a comprehensive view of the behavior of water over time. Similarly, the characteristics of the region where these reservoirs are located, such as high population density or animal husbandry, for example, can influence the quality of their waters.

Thus, the present study aimed to examine the influence of spatial-temporal variability in the physical-chemical characteristics of the waters of the reservoir located in the urban area of the city of Caraúbas-RN (Saboia Reservoir, Grande Reservoir and Santa Bárbara Reservoir). The focus of the research was to analyze how these water properties vary over time and in different reservoirs of the city, providing relevant information about the quality of these reservoirs. This information is essential for the development of effective monitoring and management strategies for water resources. The results obtained in this study will contribute to the advancement of scientific knowledge in this area and may support actions and policies aimed at the conservation and sustainable use of urban water resources, whether for human consumption or irrigation.

2. Materials and Methods

The reservoirs studied in this research are located in the urban area of the city of Caraúbas - RN, as shown in Figure 1. It is important to emphasize that the three reservoirs under analysis are interconnected during flood periods. In other words, the overflow of the Saboia Reservoir occurs towards the Grande Reservoir, which in turn overflows to the Santa Bárbara Reservoir. This interconnection between the reservoirs is a relevant factor to be considered in the analysis of the hydrological characteristics of these water bodies.

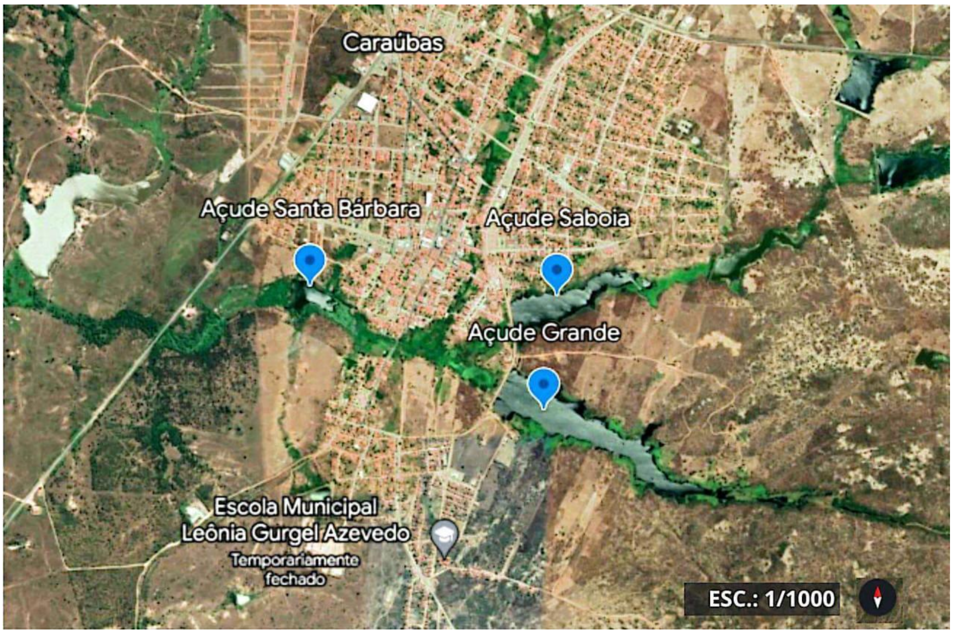

Figure 1 - Reservoirs located in the city center.

The physicochemical studies of the water samples collected in the three urban reservoirs of the city were conducted in the chemistry laboratories of the Federal University of the Semi-Arid Region, Campus Caraúbas. To perform the analysis, analytical quality reagents and equipment previously calibrated according to the instructions in the manual of each piece of equipment were used. The methods of analysis adopted followed the guidelines established in the Standard Methods of APHA (2005).

During a continuous period of five months, between August and December 2022, water samples were collected monthly in a time interval of 12:00 p.m. - 1:00 p.m. The collection procedure began at the Saboia Reservoir (Point 1), proceeding to the Grande Reservoir (Point 2), and finally to the Santa Bárbara Reservoir (Point 3).

The water samples were s collected near the edge of the reservoir, with a depth of approximately 50 cm, and stored in 1000 mL PET bottles previously identified, after going through a triple washing process with the water from the site itself. The samples were then transported to the laboratory and underwent specific treatments, such as filtration, to enable subsequent analysis.

During the collections, *in loco* analyses were also carried out at each point using an Akso multiparameter probe, model AK88. With the aid of the probe pH, dissolved oxygen, conductivity, and salinity were determined. Turbidity was determined by a Del Lab turbidimeter, model DLT-WV.

With the collected samples it was possible to perform the other analysis, all in triplicate. The chloride was determined by the Mohr method, using as titrant standard solution silver nitrate ($AgNO_3$) 0.1 N and indicator potassium chromate (K_2CrO_4). For sodium analysis, a flame photometer was used, calibrating it with a standard Na^+ solution at a concentration of 140 mmol/L.

3. Results and Discussions

In this section, the results of the physical-chemical analysis carried out in the three reservoirs located in the urban area of Caraúbas-RN will be discussed: Saboia Reservoir (Point 1), Grande Reservoir (Point 2) and Santa Bárbara Reservoir (Point 3). The objective of this analysis is to evaluate the influence of temporal and spatial variability on the physicochemical parameters measured during the five months of collection.

The first parameters that will be analyzed are those that were determined *in loco*, starting with the hydrogen-ionic potential (pH). Figure 2 shows the pH values for the three points studied during the five months.

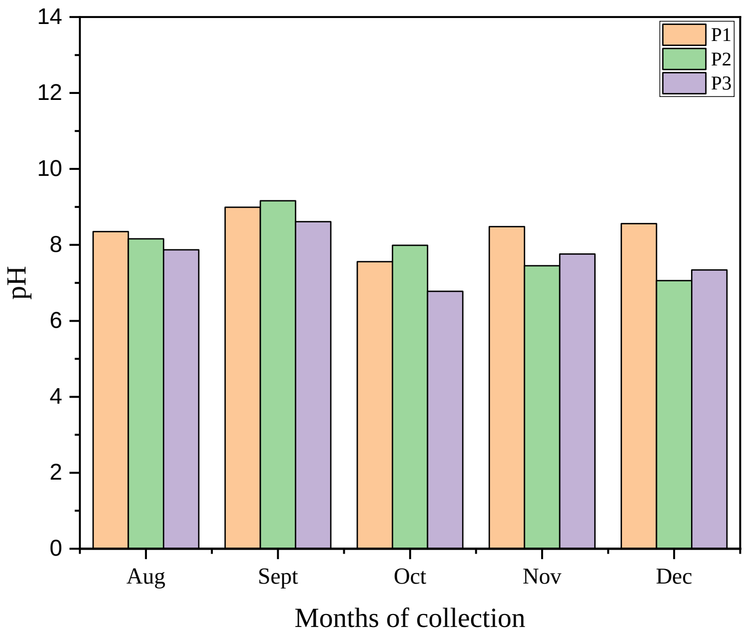

Figure 2 – pH values for the three points during the collection months.

It can be seen that point 1 (Saboia Reservoir) had a pH variation between 7.56 and 8.99, point 2 (Grande Reservoir) had a variation between 7.06 and 9.16, and point 3 (Santa Bárbara Reservoir) obtained the variation from 6.78 to 8.61. Given these values, it is possible to affirm, in general, the waters of the three reservoirs are alkaline or slightly alkaline, except point 3, in October.

For point 1 and point 3, the possible justification for these pH values would be due to the discharge of domestic wastewater containing high levels of detergents, considering the presence of several houses located in close proximity to the banks of the reservoirs, which discharge sewage directly in its waters. In the case of point 2, the results are possibly associated with agricultural activity, considering that it does not have as many residences close to its margins, compared to the other two points.

As established by Ordinance 2914/2011 of the Ministry of Health, quality criteria are defined to ensure that the water is safe for human consumption, with an acidity level (pH) ranging between 6 and 9.5. Thus, it can be concluded that, despite the anthropic action existing at the three collection points, the values obtained are in accordance with what was established by the government (Brazil, 2011).

Concerning use for irrigation, Holanda *et al*. (2016) establish different levels of limitation for the use of water, due to the danger of obstruction in spot irrigation systems. According to the authors, the allowable pH range is 6.0 to 8.5. Thus, it can be seen that the maximum allowed value was exceeded in the three points in the month of September, and in December only by point 1. The other values are within the allowed range for irrigation.

The following parameter to be analyzed is dissolved oxygen. This parameter can be changed according to changes in temperature and atmospheric pressure, in addition to the presence or absence of decomposing organic matter. The values for the three collection points in the respective five months are shown in Figure 3.

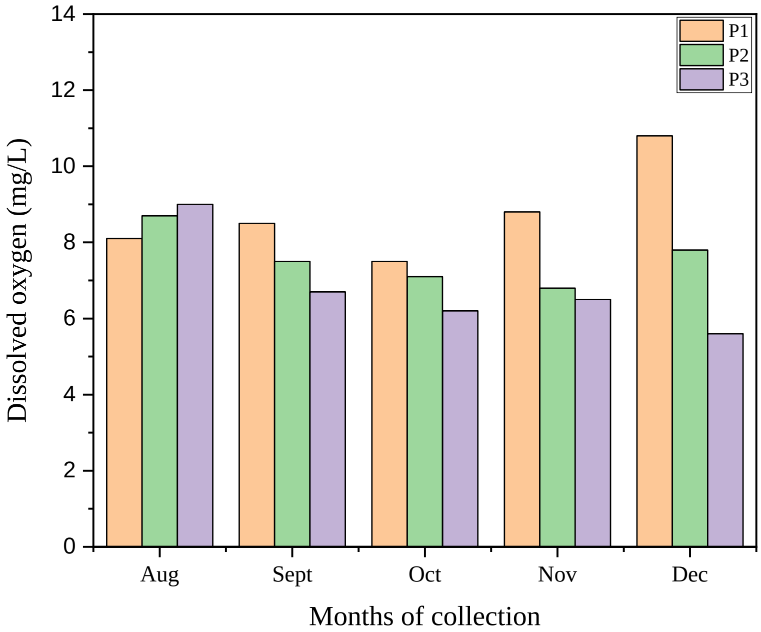

Figure 3 – Dissolved oxygen values for the three points during the months of collection.

The dissolved oxygen values for point 1 (Saboia Reservoir) ranged from 7.5 to 10.8 mg/L between the five months, point 2 (Grande Reservoir) ranged between 6.8 and 8.7 mg/L, and point 3 (Santa Bárbara Reservoir) between 5.6 and 9 mg/L. In Figure 3, it is possible to observe that in point 1 there was an increase over the months of collection and in points 2 and 3 a decrease in their values.

Measuring dissolved oxygen plays a crucial role in detecting environmental impacts such as eutrophication and organic pollution. In addition, it is essential, since most organisms depend on oxygen for their survival.

Generally, the concentration of dissolved oxygen decreases or disappears as a body of water receives loads of organic substances present in sewage (Garcia and Barreto, 2011). Point 3 showed a greater decrease in values during the months when compared to the other two points, possibly due to the greater amount of sewage that is released into its waters and the large number of floating aquatic plants, which prevent the entry of sunlight, further indicating the existence of a eutrophic environment.

CONAMA Resolution 357/05 establishes three permitted values of dissolved oxygen for each category of fresh water. For Class 1, the minimum value is 6 mg/L, for Class 2 it is 5 mg/L and for Class 3 it is greater than 3 mg/L. Therefore, it is clear that points 1 and 2 enter as Class 1 fresh water, and point 3 as Class 2 with their respective permitted values (Brazil, 2005).

Currently, there is no specific regulation that establishes limits for dissolved oxygen levels in water intended for irrigation. However, the importance of this parameter is recognized, since plant roots depend on oxygen to carry out cellular respiration and absorb nutrients (Paulilo *et al*., 2015).

With regard to conductivity, a parameter that is related to the presence of dissolved ions in the water, the values for the three points and five months of the collection are expressed in Figure 4.

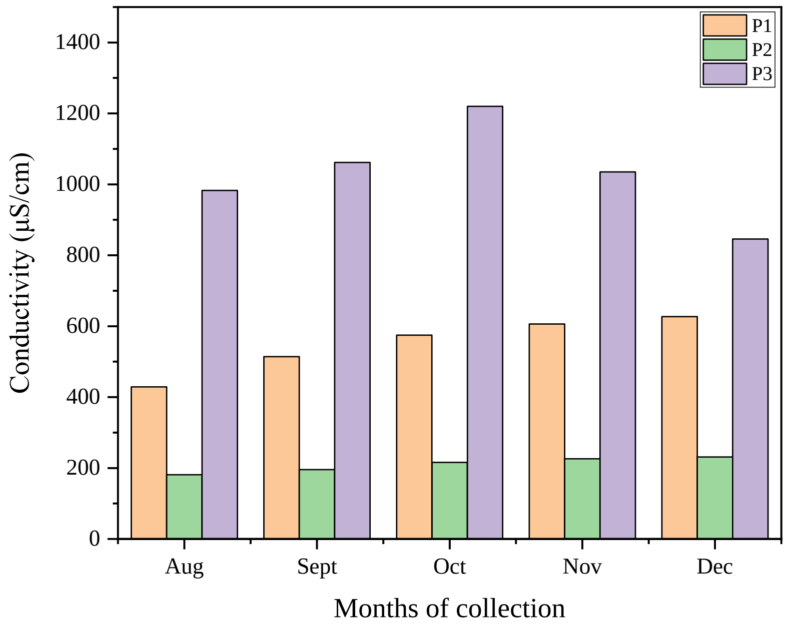

Figure 4 – Conductivity values for the three points during the collection months.

The conductivity results found for point 1 (Saboia Reservoir) ranged from 429 µS/cm to 627 µS/cm, for point 2 (Grande Reservoir) the values ranged from 181.3 µS/cm to 231 µS/cm and, for Finally, at point 3 (Santa Bárbara Reservoir) the values were between 846 µS/cm and 1220 µS/cm. It can be observed in Figure 4 that for points 1 and 2 the values increased over the months, while point 3 increased until October and then declined.

This behavior observed for points 1 and 2 is due to the decrease in the volume of water in the reservoirs, given the absence of regular rains in this period, which causes an increase in the concentration of salts in the water and, consequently, in conductivity. Regarding point 3, this situation may probably occur due to the discharge of domestic sewage without adequate treatment (more evident in this location), since there are several residences located near the banks of the reservoir (located in the city center), which directly discharge their effluents into the waters. Thus, depending on the flow of these discharges, there is a variation in the values obtained.

Temperature is an additional variable that can influence conductivity measurements. This phenomenon arises from the impact of temperature on the ions present in a solution. As the temperature of a solution rises, the ions become more agitated, leading to a decrease in resistance and a subsequent increase in conductivity (Hanna Instruments, 2020).

CONAMA Resolution 357/05 does not specify a specific limit established for this indicator. Nevertheless, the significance of this parameter in water quality assessment is becoming increasingly acknowledged. According to a study conducted by São Paulo (2016), values exceeding 100 µS/cm indicate impacted environments.

Hence, it is evident that the values obtained from the three analyzed points over the five months of collection exceed the minimum threshold, signifying environments directly or indirectly impacted by the release of substances contributing to increased conductivity or due to the high rate of water evaporation characteristic of this time of year. Concerning irrigation use, Holanda *et al.* (2016) mention a maximum permissible value of 3000 µS/cm. Consequently, the values fall within the prescribed range.

The salinity values obtained are depicted in Figure 5. They demonstrate a similar pattern to the conductivity results, as a higher content of salts present in the water leads to increased electrical conductivity.

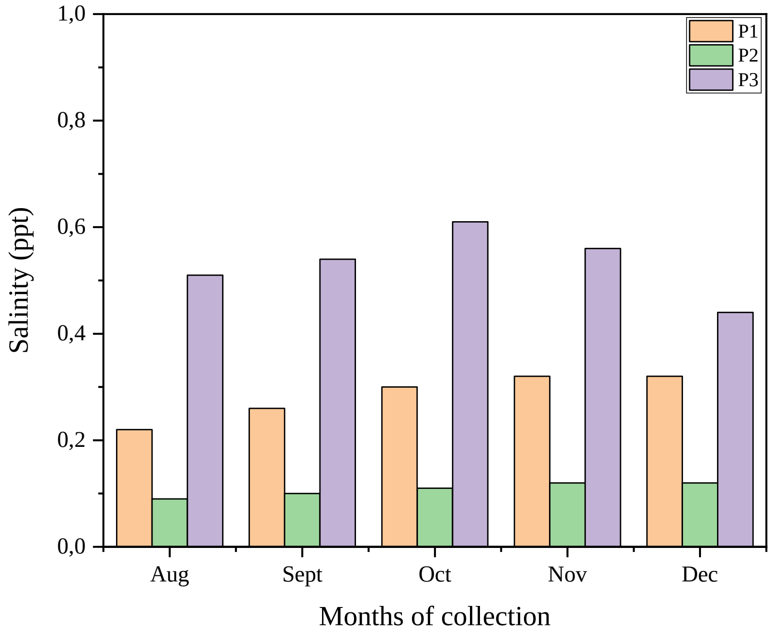

Figure 5 - Salinity Values for the Three Sampling Points Across the Collection Months.

The salinity values for Point 1 (Saboia Reservoir) ranged from 0.22 ppt to 0.32 ppt for Point 2 (Grande Reservoir), the values ranged from 0.09 ppt to 0.12 ppt, and for Point 3 (Santa Barbara Reservoir), the values obtained ranged from 0.44 ppt to 0.61 ppt. Figure 5 depicts an increasing trend in values over the months for Points 1 and 2, whereas Point 3 showed an initial increase followed by a subsequent decrease. This behavior aligns with the reasons previously mentioned for conductivity. Based on the classifications established in CONAMA Resolution 357/05, the water bodies fall into the category "I," signifying fresh waters (Brazil, 2005).

Elevated salinity levels have been acknowledged to exert adverse effects on plant growth. Consequently, the assessment of water quality utilized for irrigation assumes paramount importance to ascertain that salinity levels remain within acceptable thresholds (Holanda *et al*., 2016).

Regarding this aspect and, consequently, the conductivity parameter, it is important to mention the classification developed by the United States Salinity Laboratory, located in Riverside, California, and led by Pfaltzgraff *et al*. (1954). Despite its limitations, this classification stands out compared to others and remains widely adopted to this day. Considering the interpretations presented by Holanda *et al*. (2016), point 2 exhibits values below the minimum threshold, indicating no restrictions or adverse effects on its use. However, both point 1 and point 3 were classified as category C2, representing moderate salinity and implying the existence of moderate risks related to salinity-induced problems. This classification system provides valuable insights into the implications of the conductivity parameter and aids in identifying potential risks associated with salinity. Its practicality and widespread acceptance have solidified its continued use in the field.

Concerning the turbidity parameter, the data presented in Figure 6 includes the values observed at the three designated points during the five-month collection period. As per Macêdo (2004), turbidity can be defined as changes in the penetration of light caused by suspended particles, resulting in light diffusion and absorption. These particles comprise plankton, algae, bacteria, clays, suspended silt, and organic debris. Consequently, heightened levels of turbidity have a detrimental impact on the entire aquatic ecosystem, as they hinder the process of photosynthesis.

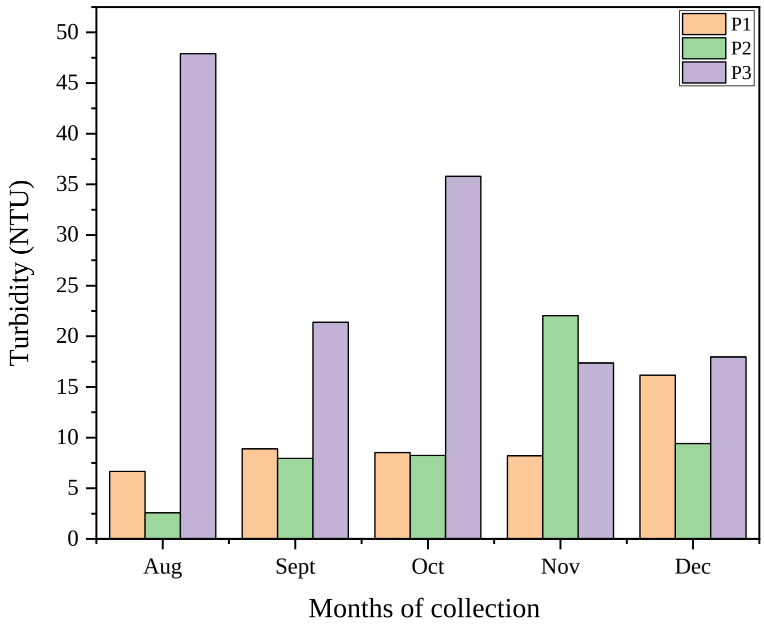

Figure 6 - Turbidity values for the three points during the collection months.

The recorded turbidity values at point 1 (Saboia Reservoir) ranged from 6.67 NTU to 16.17 NTU during the monitored months. At point 2 (Grande Reservoir), the turbidity values exhibited a variation between 2.59 NTU and 22.03 NTU. As for point 3 (Santa Bárbara Reservoir), the recorded turbidity values fell within the range of 17.37 NTU and 47.9 NTU.

Following the guidelines outlined in CONAMA Resolution No. 357/05, the maximum permissible limit (VMP) for turbidity in Class 2 freshwaters is set at 100 NTU. Considering this standard, it becomes apparent that the measured turbidity values at the three weirs fall within the prescribed parameters (Brazil, 2005). It is noteworthy that, presently, there exists no specific regulation defining water turbidity limits for irrigation purposes.

The values achieved with the chloride analysis for point 1 (Saboia Reservoir) during the collection months were between the range of 64.16 mg/L and 144.4 mg/L, for point 2 (Grande Reservoir) the values were between 32.08 mg/L and 61.09 mg/L, and point 3 (Santa Bárbara Reservoir) between 133.29 mg/L and 224.58 mg/L. It can be observed from Figure 7 that point 1 and point 2 had the same behavior, wherein in the first months there is an increase in values and in December a decrease. Point 3 did not show a standard behavior. This is most likely due to the greater discharge of domestic sewage present in this location.

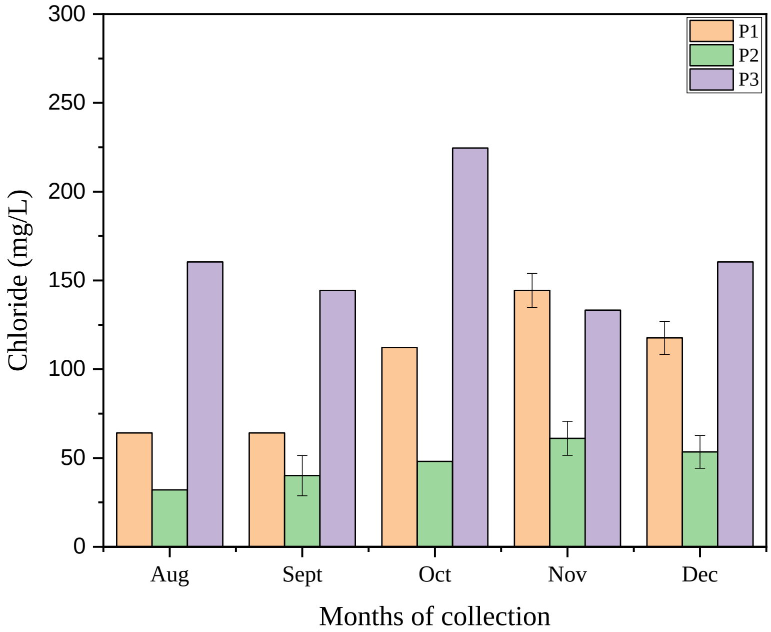

Figure 7 - Chloride values for the three points during the collection months.

In the reservoirs located in the Northeast region of Brazil, fluctuations in the concentration of chloride ions are often noted, primarily due to high evaporation rates and the limited rainfall season. The presence of chlorides in water is associated with the dissolution of salts and the discharge of domestic and industrial sewage (Libânio, 2005).

When considering the established criteria in CONAMA Resolution 357/05, which defines the highest value allowed for consumption of 250 mg/L, it is possible to verify that all samples collected in the three reservoirs presented values below the established limit. These results indicate compliance with the standards established for water quality in the reservoirs in this case (Brazil, 2005).

Regarding the use of water for irrigation, it is pointed out by Freitas (2001), that high levels of chloride can have a negative impact on plant development. According to Nascimento (2020), the excess of Cl^- ions results in chlorosis and necrosis on the edges of the leaves, thus emphasizing the importance of considering the levels of this parameter in the water used for irrigation. Holanda *et al.* (2016) highlight a limit of 1,063.6 mg/L as a normal value for chlorides, and, thus, it is found that all the evaluated points are within this corresponding limit.

Lastly, there is the final parameter to be analyzed, the sodium, in which their respective results for the three points analyzed in the five consecutive months and the Tukey test are presented in Figure 8.

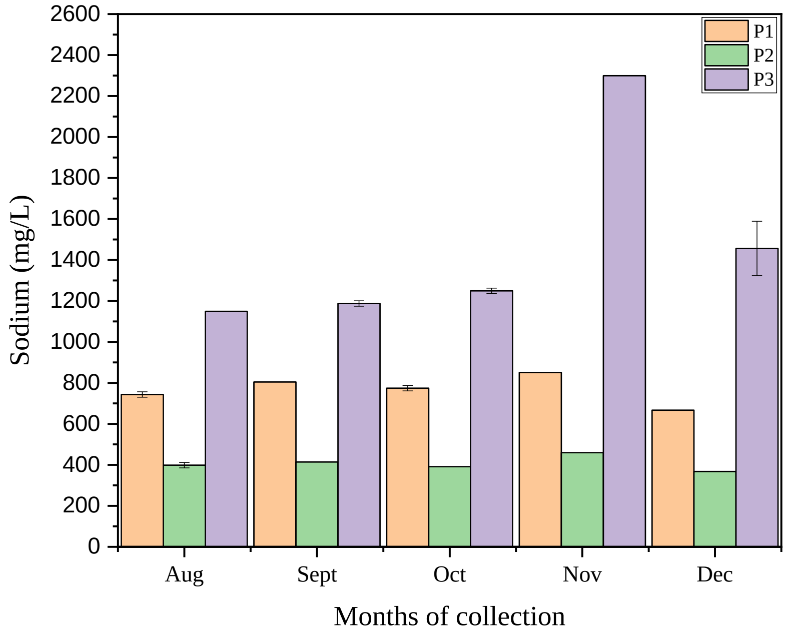

Figure 8 - Sodium values for the three points during the collection months.

The values for sodium analysis at point 1 (Saboia Reservoir) were between the range of 666.7 mg/L and 850.6 mg/L, at point 2 (Grande Reservoir) the values were between 367.8 mg/L and 459.8 mg/L, and point 3 (Santa Bárbara Reservoir) was between 1149.5 mg/L and 2299 mg/L.

It is perceived that point 3 during all months was the point with the highest value. It is important to emphasize that point 3 has a lower volume of water compared to the other points, in addition to receiving a greater amount of sewage in its waters due to being located in the central region of the city of Caraúbas. The increase in sodium content in water is mainly associated with the presence of domestic sewage discharges and industrial waste (Garcia and Barreto, 2011), which justifies the high values during the five months of collection for point 3.

Sodium is an abundant element throughout the planet and is present in all natural waters due to the high solubility of its salts. However, the concentration of sodium in natural waters is usually less than 50 mg/L (Garcia and Alves, 2006).

According to the guidelines established in Ordinance N° 518/04 of the Ministry of Health, the maximum permitted value (MPV) of sodium in drinking water for human consumption is 200 mg/L (Brazil, 2004). In view of the values obtained, it can be concluded that all points present values much higher than the maximum value.

In irrigation, it is highlighted by Nascimento (2020), that it is essential to consider the presence of sodium in the water to be used since its high concentration can cause toxicity in plants. Holanda *et al*. (2016) establish a limit of 920 mg/L for sodium concentration in water intended for irrigation. Thus, it is evident that points 1 and 2 are within the allowed value, and point 3 exceeds this limit and cannot be used for irrigation.

4. Conclusion

At the end of this study, the findings of this research reinforce the evidence of a spatiotemporal influence on the physicochemical properties of the waters in the three sites investigated (Saboia Reservoir, Grande Reservoir, and Santa Bárbara Reservoir). This variation is most likely related mainly to human factors and their impacting activities on the aquatic environment.

In general, the analyses of pH, dissolved oxygen, salinity, turbidity, and chloride indicate that the waters of the three points analyzed can be used for human consumption, only the conductivity and sodium analyses showed values above the maximum allowed. There was a restriction on the use of water because of the pH only during the month of September as well as in the sodium analysis for point 3, however, in general, the waters of the three study sites can possibly be used for irrigation in view of the analysis performed.

Adjustment measures can be implemented for the parameters that exceed the limits established by the legislation. Among these measures, one can mention dilution, the addition of corrective substances, and other actions aimed at regularizing the physicochemical characteristics of the analyzed waters. These correction factors are adopted in order to ensure compliance with the established standards, thus ensuring the proper and safe use of water resources.

It is important to emphasize that, due to the limitations of this study and the few analyses performed, the suitability of the waters for established uses cannot be fully affirmed. For a comprehensive assessment of the use feasibility, further analyses encompassing other physicochemical parameters as well as microbiological analyses would be required. These additional analyses would provide a more comprehensive insight into the water quality.

Acknowledgments

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