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Analysis of the physical-chemical parameters of the water from the Lagoa do Carro dam – PE

Análise dos parâmetros físico-químicos da água da barragem de Lagoa do Carro - PE

Análisis de los parámetros físico-químicos del agua de la presa de Lagoa do Carro – PE

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ABSTRACT
This study addresses the issue of freshwater in the global and Brazilian contexts, highlighting the scarcity, poor distribution and contamination of water resources, in addition to the precariousness of basic sanitation. The research focuses on the Lagoa do Carro Dam, located in the Northern Agreste region of Pernambuco, analyzing physical and chemical parameters of the water and trace metals in the sediments. The methodology used was predominantly quantitative, complemented by a qualitative approach, considering the environmental and social aspects of the studied territory. The research also included educational actions aimed at sustainability and

citizenship education in the municipality of Feira Nova-PE, with interventions in the school curriculum. The results highlight the importance of monitoring water quality and environmental education as essential tools to ensure the availability of drinking water for current and future generations. The results found when measuring the physical and chemical parameters at two different times, one during the dry season and the other during the rainy season, provided important information regarding the "water health" of the Lagoa do Carro Dam.

Keywords: fresh water, basic sanitation, water quality, Lagoa do Carro Dam, physical-chemical parameters.

RESUMO
O presente trabalho aborda a problemática da água doce no contexto global e brasileiro, destacando a escassez, a má distribuição e a contaminação dos recursos hídricos, além da precariedade do saneamento básico. A pesquisa tem como foco a Barragem de Lagoa do Carro, localizada no Agreste Setentrional de Pernambuco, analisando parâmetros físico-químicos da água e metais traço nos sedimentos. A metodologia utilizada foi predominantemente quantitativa, complementada por uma abordagem qualitativa, considerando os aspectos ambientais e sociais do território estudado. A pesquisa também incluiu ações educativas voltadas para a sustentabilidade e a formação cidadã no município de Feira Nova-PE, com intervenções no currículo escolar. Os resultados destacam a importância do monitoramento da qualidade da água e da educação ambiental como ferramentas essenciais para garantir a disponibilidade de água potável para as gerações atuais e futuras. Os resultados encontrados quando da aferição dos parâmetros físico-químicos em dois diferentes momentos, um no período de estiagem e outro no chuvoso, trouxeram informações importantes quanto à "saúde hídrica" da Barragem de Lagoa do Carro.

Palavras-chave: água doce, saneamento básico, qualidade da água, Barragem de Lagoa do Carro, parâmetros físico-químicos.

RESUMEN
Este trabajo aborda la cuestión del agua dulce en el contexto mundial y brasileño, destacando la escasez, la mala distribución y la contaminación de los recursos hídricos, además de la precariedad del saneamiento básico. La investigación se centra en la presa de Lagoa do Carro, ubicada en la región Agreste Norte de Pernambuco, analizando parámetros físico-químicos del agua y metales traza en los sedimentos. La metodología utilizada fue predominantemente cuantitativa, complementada con un enfoque cualitativo, considerando los aspectos ambientales y sociales del territorio estudiado. La investigación también incluyó acciones educativas dirigidas a la sostenibilidad y la formación ciudadana en el municipio de Feira Nova-PE, con intervenciones en el currículo escolar. Los resultados resaltan la importancia del monitoreo de la calidad del agua y la educación ambiental como herramientas esenciales para asegurar la disponibilidad de agua potable para las generaciones actuales y futuras. Los resultados encontrados al medir los parámetros físico-químicos en dos momentos diferentes, uno durante la estación seca y otro durante la estación lluviosa, proporcionaron información importante sobre la "salud del agua" de la represa Lagoa do Carro.

Palabras clave: agua dulce, saneamiento básico, calidad del agua, presa de Lagoa do Carro, parámetros físico-químicos.

1 INTRODUCTION

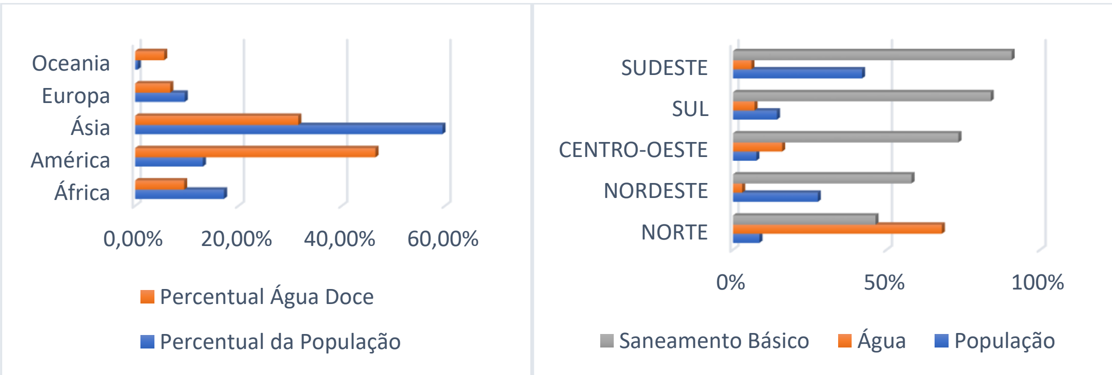
With over eight billion inhabitants spread across different continents (UN, 2022), our planet presents challenging scenarios, one of the most critical points being that related to water. Since the composition of water is a natural factor and does not result from anthropogenic actions, our positioning and attitudes influence its quantity and quality. Even though it is practically covered by water, it is important to note that only 2.5% of all water on the planet is fresh, but not entirely available for human consumption.

Concerns about the supply, distribution and quality of water have been a recurring topic at events that bring together leaders around the world in recent decades. The inclusion of discussions that seek alternatives to guarantee the supply of drinking water for this generation and future generations are supported by data presented, for example, by the Brazilian National Water Agency (ANA, 2023). The use and consumption of water contaminated by sewage, as well as pesticides and industrial waste, affects 1.4 billion people in 50 countries (WHO, 2022). These contaminants are substances used in pesticides, poisons, paints, ceramics, etc. The consumption of water contaminated by fecal coliforms is a reality for at least 2 billion people around the world (WHO, 2022). According to UNESCO (2023), approximately 46% of the world's population suffers from a lack of drinking water and access to basic sanitation. Data from UNICEF (2023) indicate that 3.5 million people die worldwide each year due to problems related to inadequate water supply. According to the World Health Organization (2022), it is estimated that 15,000 people die annually and 350,000 are hospitalized in Brazil due to diseases linked to poor basic sanitation. According to this organization, for every US$1.00 invested in sanitation, a return of almost six times is estimated, considering lower health costs, increased productivity and fewer premature deaths (WHO, 2022).

Since the 1990s, Brazil has created legal mechanisms to guarantee the supply of water in an equitable manner, such as Law 9,433, of January 8, 1997, which instituted the National Water Resources Policy, with one of the foundations being to manage such resources, providing multiple use, in line with objectives that ensure “the necessary availability of water to current and future generations, with quality standards appropriate to their respective uses” (Brasil, 1997, p.13). In fact, according to data from the World Bank and the Global Water Partnership (GWP, 2022), Brazil is a country whose freshwater reserves place it in a privileged position, taking first place, with approximately 12% of all freshwater on the planet.

However, the Brazilian National Water Agency (ANA) points out that this reserve is distributed unevenly, which leads some regions to present very critical situations regarding the supply and distribution of fresh, potable water. This concern is reinforced when the data made available by the Brazilian Institute of Geography and Statistics (IBGE) (2023) show that 100 million Brazilians do not have access to a complete basic sanitation system, that is, around 48% of the population, and around 35 million Brazilians do not have access to treated water. The poor distribution of freshwater reserves in Brazil, associated with the absence of public policies for basic sanitation, further accentuates the issue of the supply and distribution of fresh, potable water to the population. The data presented by the UN and ANA/IBGE (2023) demonstrate how the supply of freshwater is distributed on the planet and in the different regions of Brazil, as well as the percentage of population and basic sanitation services, are clarifying this differentiation (Graph 1).

Graph 1: Population Distribution, Basic Sanitation Rate in Brazil and Availability of Fresh Water in Brazil and in the world.



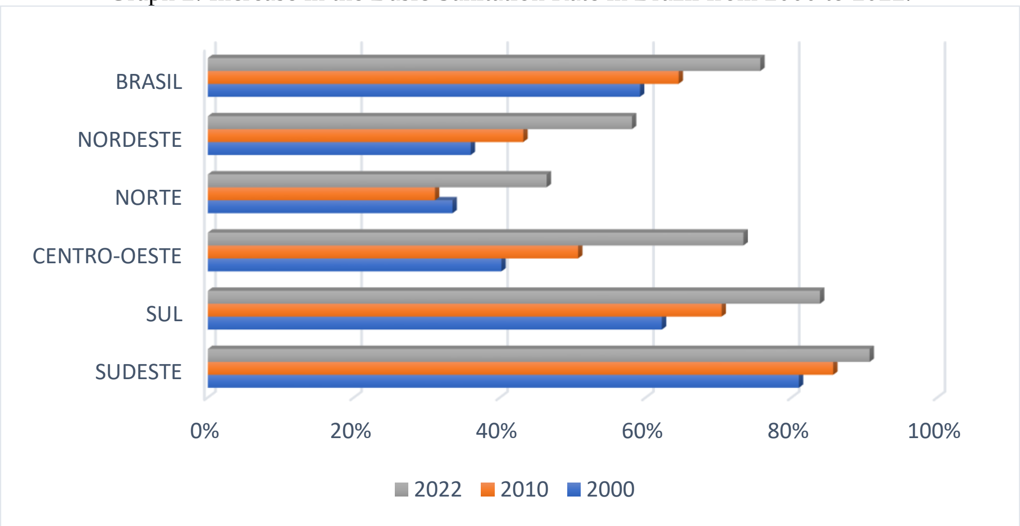
Source: UN, ANA/IBGE, (2023).

However, it is important to highlight the progress made in the last two decades in basic sanitation services in Brazil, as shown by data from IBGE (2023). According to Abdal (2019), the mandatory preparation of master plans for municipalities with a population of over 20,000 inhabitants, as determined by art. 41, items I and II, of Law No. 10,257/01, known as the Statute of Cities, enabled a real change in Brazilian paradigms in the framework of basic sanitation.

In this context, currently, around 55% of Brazilian municipalities already have their master plans. According to the Institute of Applied Economic Research – BRAZIL/IPEA (2020), those required by law to have the plan represent a percentage that varies from 75% for the range of 20 to 50 thousand inhabitants, 90% for those with between 50 and 100 thousand inhabitants and close to 98% for those with over 100 thousand inhabitants. As for the municipalities that are not covered by the obligation, the percentage is around 41%.

There was progress in all regions, with emphasis on the Central-West Region, with an increase of 33 points between 2000 and 2022, followed by the Northeast Region, with an increase of 22 points in the same period. In total, Brazil had a coverage of 59.2% in 2000, rising to 75.7% in 2022 (Graph 2). However, it is necessary to pay attention to the case of the North Region, which at the turn of the 20th to the 21st century had a higher rate than in 2010 (IBGE, 2023). The improvements in these indicators point to an equation in the quality of water supply and distribution in the Brazilian territory.

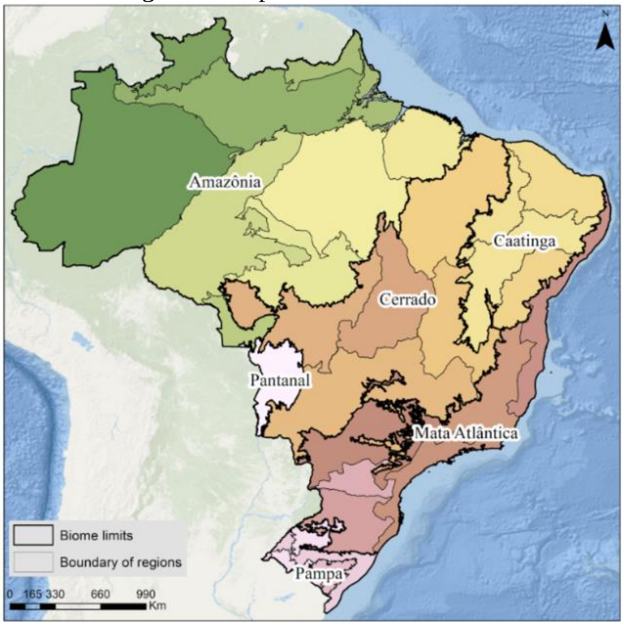
Graph 2: Increase in the Basic Sanitation Rate in Brazil from 2000 to 2022.



Source: IBGE, (2023).

As already explained, although Brazil is an abundant country in terms of fresh water, its territorial extension and the diverse ecosystems that exist within it must be taken into account. This diversity ranges from the largest equatorial forest on the planet, the Amazon Rainforest, to an extensive and vigorous strip of Atlantic Forest, which extends from the state of Paraná to the state of Paraíba, with almost 3,500 km in length, and the Pantanal Mato-Grossense, the largest floodplain in the world (Figure 1). But it also has semi-arid regions, which extend from the state of Minas Gerais to Piauí, cutting across a large strip of land in eight different states in the Northeast, bringing with it one of its greatest characteristics, which is water scarcity, in an area with approximately 28 million inhabitants (IBGE, 2023).

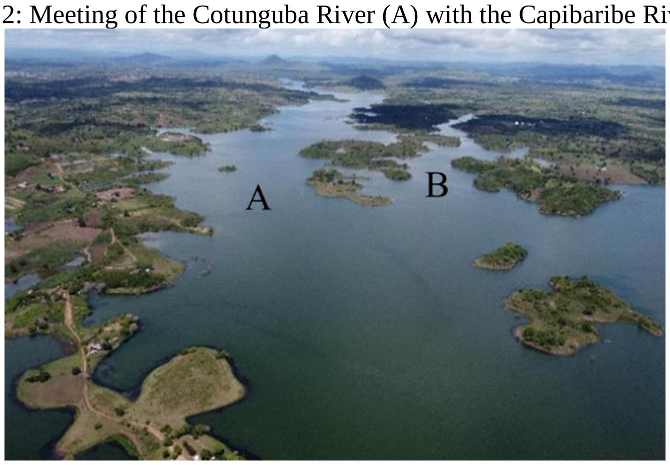
Figure 1: Map of Brazilian Biomes.



Source: IBGE, (2022).

Located in one of the driest regions of the Northeast, nestled in the state that has the lowest per capita water ratio in Brazil (ANA, 2023; APAC, 2023), more precisely in the Northern Agreste of Pernambuco, is the Lagoa do Carro-PE Dam, the result of the confluence of the Capibaribe and Cotunguba Rivers (Figure 2). Its storage capacity is approximately 270 million cubic meters (COMPESA, 2023), a value that places it among the five largest water reservoirs in Pernambuco.

Figure 2: Meeting of the Cotunguba River (A) with the Capibaribe River (B)



Source: Albuquerque, (2023).

In view of all that has been previously explained, actions are needed to preserve these water bodies, in order to guarantee the supply of water for this and future generations. One way in which this can occur is by monitoring water quality, which is done through the study of physical-chemical parameters, important indicators of water quality, and which can also reflect the context in which these facilities are located (Bocanegra 2021; Sharma et al. 2021; Monteiro, et al. 2021).

These studies are part of a broader project, which also involves the analysis of the presence of trace metals in the dam sediments, resulting from the transport of domestic and industrial effluents, the result of a universal lack of basic sanitation in the municipalities that make up the Lower Capibaribe Microbasin, namely Carpina, Feira Nova, Lagoa do Carro, Lagoa de Itaenga, Limoeiro and Passira (Albuquerque et al., 2024a).

Based on the analysis of sediments and the measurement of the physical-chemical parameters of the dam water, the problem was also addressed from an educational perspective, when interventions were carried out in the school curriculum, aiming to include in the training of teachers and in the daily lives of students in the Feira Nova Education Network, in a transdisciplinary approach, the issue of sustainability and environmental education, with drinking water as a focal point (Albuquerque et al., 2024b).

2 METHODOLOGY

Methodology is the backbone of any good research work. To this end, what should be highlighted in a methodology is its coherence with the objectives and the context in which this process occurs. Therefore, the choice of the path to be followed will define what is intended to be done, how to proceed with data collection, as well as the developments based on this information (Amado, 2020).

The methodological path outlined for this work was primarily quantitative, because according to Marconi and Lakatos (2010), it is based on what appears to be logical, rational and measurable, allowing for assertive and efficient decision-making. However, numbers are not always able to show everything that is needed in a work, especially when it comes to collecting data on elements of nature. This is because the territory is a geosystem, and as such, it is necessary to have a perspective that integrates the physical environments, spatial organizations, interactions of chemical, physical and biological elements, anthropogenic factors, among others, thus enabling the understanding of the processes that exist there. Therefore, the data were also analyzed from a qualitative perspective, when the environmental forces are considered, identified and inserted in this context (Cristofoletti, 2015).

2.1 INSTRUMENTS USED

Cartographic materials processed in specific software (Q-GIS, Google Earth) were produced, based on data from SIRGAS 2000. These data made it possible to locate the study area, as well as the collection sites for materials for analysis, in addition to the territorial layout of the Lower Capibaribe basin, for a better understanding of the space. To this end, visits were made to the Lagoa do Carro Dam, to select the points to be studied and to analyze the materials. The aerial recordings were made with an Unmanned Aerial Vehicle - UAV (DJ3 PRO RYSE TECH TELLO), and terrestrial photographic records and interviews with the riverside population were also made to obtain information that is not found in the literature about the dam.

In the second stage of this work, the materials that were removed from the dam at five different points were analyzed, duly georeferenced, using GPS equipment, model GARMIN, version ETREX 10, taking into account the social, economic and spatial importance of the points demarcated for collection.

Visits to the dam to measure the physical and chemical parameters of the water began in May 2021 and continued until June 2023, including collection during the rainy months, with March and April being the months with moderate rainfall and May and June with heavy rainfall, which allowed the entry of a large volume of water and, therefore, the transport of various materials. Drought months were also considered, which historically tend to be between October and February. This dry period allowed the stability of the materials through the natural process of sediment decantation. The collection points were previously selected, georeferenced and took into account the social, environmental and economic relevance and can be seen in table number 01.

Table 1 - Water Sample Collection Points at the Lagoa do Carro Dam.

POINT	WEST LONGITUDE	SOUTHERN LATITUDE	CHARACTERIZATION
PBLG 01	35º, 24’ e 36”	7º, 55’ e 17”	EEA FEIRA NOVA/GLÓRIA DO GOITÁ
PBLG 02	35º, 22’ e 21”	7º, 54’ e 22”	EEA LIMOEIRO
PBLG 03	35º, 17’ e 13”	7º, 52’ e 48	EEA LAGOA DO CARRO
PBLG 04	35°, 20' e 23"	7°, 53' e 33"	EEA LAGOA DE ITAENGA

Source: Albuquerque, (2023).

The measurement was always carried out in the afternoon. In the months that included the rainy season, when it was not raining, there were a lot of clouds and reduced light. At other times, the weather was predominantly sunny with few clouds. The equipment used to measure the water parameters was the Multiparameter Meter (pH/Cond/SDT/Temp) - AK88, responsible for measuring pH, Conductivity, Total Dissolved Sediment and Temperature. The measurement ranges and margins of the device are shown in Table 2 below.

Table 2: Metric Range of the AKSO 88 Multiparameter Meter

Measuring Range		Resolution	Accuracy	Calibration
pH	2.00 a12.00	0.01	±0.1	4.00, 7.00 e 10.01
Condutividade	01µS/cm (0.0 a 199.9 µS/cm)	01µS/cm (0.0 a 199.9 µS/cm)	± (1%FS + 1 dígito)	60 a 170 uS/cm
SDT	0~199.9	0.1 ppm	SP	SP
Temperatura	SP	0.1	± 0.5°C	SP

SP: No parameters presented by the manufacturer.
Source: Albuquerque, (2024). Adapted from the Akso88 Manual.

The equipment was factory-calibrated and calibrated, with a validity of 30 days, as stated in the user manual and document sent with the product, which occurred on May 14, 2021. However, before each material collection, it undergoes a new calibration, performed in the manufacturer's application, through a software update, to guarantee the results obtained.

In addition to the parameters evaluated by AKSO 88, the method set out in the Standard Methods for the Examination of Water and Wastewater - SMEWW, 24th Ed. (2022) was also adopted. In the SMEWW method, the parameters of Nitrite, Nitrate and Turbidity were analyzed, based on the following standards: Chromatographic - 4120C; and Nephelometric - 2130 B. Table 3 below shows the reference standard for the parameters analyzed here.

Table 3: SMEWW Method Metric Range 24th Ed (2022)

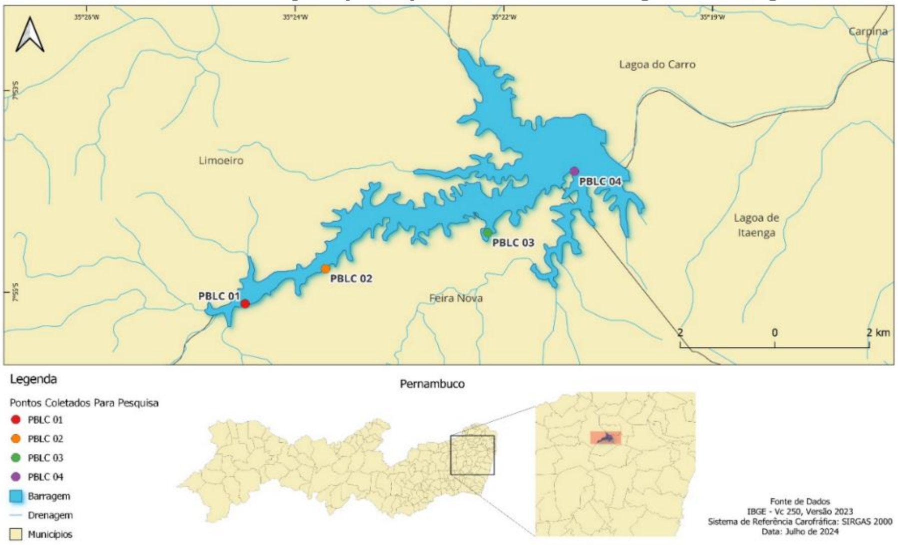
Parameter	Reference Value	Unit of Measurement	Method
Nitrito	< 1,0 mg/L N	mg/L N	Cromatográfico - 4110 C - SMEWW - 24° Ed. - 2022
Nitrato	< 10,0 mg/L NO3	mg/L NO3	Cromatográfico - 4110 C - SMEWW - 24° Ed. - 2022
Turbidez	< 100 UNT	UNT	Nefelometrico - 2130 B - SMEWW - 24° Ed. - 2022

Source: Albuquerque, (2024). Adapted from SMEWW 24th Ed. (2022)

2.2 CHARACTERIZATION OF THE COLLECTION SITES OF THE LAGOA DO CARRO DAM

The following four points where the physical-chemical parameters of the water from the Lagoa do Carro Dam were analyzed on a map will be described below. They are called Lagoa do Carro Dam Point – PBLC (figure 3). The points were selected due to their proximity to the Compesa Water Pumping Stations – EEA, for the municipalities of the Lower Capibaribe Microbasin. They were duly georeferenced and recorded with satellite images and/or aerial photos from drones.

Figure 3: Location of Points for water quality analysis and Satellite Image of the Lagoa do Carro Dam – PE



Source: Albuquerque, (2023) and PE3D (2024).

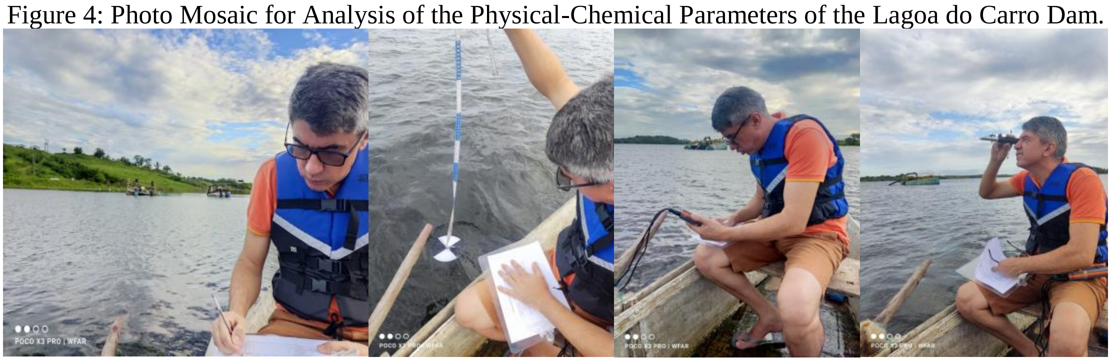
PBLC 1 is in the catchment area of the water pumping station – EEA-, owned by COMPESA, which supplies water to the population of the municipalities of Feira Nova and Glória do Goitá (two separate pumps).

PBLC 2 is also located close to the slope, however, on the west side, considering the dam's spillway/gates. This point was selected because it is where the Water Pumping Station – EEA - is located, for the municipality of Lagoa do Carro, one of the six that make up the Lower Capibaribe Micro Basin.

PBLC 3 is located on the west side of the dam's containment barrier, called "bucket" by the riverside population and technically called slope, where the water pumping station – EEA- is also located, for collecting water for the city of Lagoa de Itaenga. PBLC 4 is located at the site of the water pumping station (EEA) in the municipality of Limoeiro, the largest of the municipalities selected for parameter measurement, with a population of nearly 60,000 inhabitants and a total area of 269 km2.

The collection of materials from the Lagoa do Carro Dam, when analyzed using the AK88 Multiparameter Meter data verification method, was carried out using a support boat. The first visits involved selecting, marking and georeferencing the collection points. On subsequent visits, the parameters were measured at a depth of up to 1.5 meters from the water surface at all five collection points. For parameterization purposes, collections always took place in the afternoon, starting at point 1, around 2:00 p.m. Brasília time. The analyses of the other points also always took place at the same times, that is, there was an average interval of 20 minutes between one point and another. As a result, each collection point had its analysis at similar times (Figure 4).

Figure 4: Photo Mosaic for Analysis of the Physical-Chemical Parameters of the Lagoa do Carro Dam.



Source: Albuquerque, (2023)

Regarding the collection of material for analysis using the SMEWW method, it is important to emphasize that it occurred at the same points and times as the previous method. Thermal boxes were used to store the collected material. The collected water was stored in plastic bottles, which had been properly sanitized beforehand with the reagents. The collected material was sent to the water analysis laboratory of the Pernambuco Sanitation Company (COMPESA), located in the city of Paudalho. The methodology adopted for collecting the material for physical and chemical analysis of the water followed the standards of the Brazilian Association of Technical Standards (ABNT NBR 9897:1987 and ABNT NBR 9898:1987). These standards deal with the planning and preservation of samples of liquid effluents and receiving bodies. They were also based on CONAMA Resolution No. 430/2011, which provides guidance on the discharge of effluents into bodies of water, establishing standards, conditions, parameters and guidelines.

3 RESULTS AND DISCUSSIONS

After the end of the material collection process, whether through the AK88 Multiparameter or the SMEWW, the results were analyzed and discussed. At this stage, in addition to presenting the data found, a comparison was made with similar studies in the region, in Brazil and in other countries. As referenced in the methodology, the measurement was carried out in two moments, one during the rainy season and the other during the dry season. The physical-chemical parameters chosen for analysis in this work were: Temperature, Conductivity, Total Dissolved Solids, Nitrite, Nitrate, Hydrogen Potential and Turbidity. However, it is necessary to understand the importance and role of each parameter. Temperature influences the density, viscosity and concentration of dissolved gases (Dodds; Perkin; Gerken, 2013). Turbidity makes it difficult or easier for the light beam to enter the water (Chen, 2019; Wang, 2020 and DAI, 2021). The ability to conduct electric current in water is measured through conductivity, while the presence of organic and inorganic materials is measured through STD (Jones; Lennon, 2021; Smith; Alexander, 2022). The Hydrogen Potential - pH determines the degree of acidity of the water, defining it as acidic, neutral or basic, and Nitrite and Nitrate indicate the presence of decomposition of animals and plants in certain aqueous spaces (Bocanegra 2021; Monteiro et al. 2021). Changes in these parameters can cause health problems in humans, including Blue Baby Syndrome, which can lead to death if not treated in a timely manner, and can potentially complicate pregnancy, causing spontaneous abortions and low birth weight, in addition to inducing cancer (WHO, 2022). It can also cause eutrophication of water bodies, reducing the level of oxygenation and leading to the death of aquatic plants and animals.

The WHO does not establish a temperature parameter for water bodies that provide drinking water, but recognizes that extreme temperatures can affect the taste, palatability and effectiveness of some treatment processes (WHO, 2022). In addition, temperature can also influence: the percentage of dissolved oxygen - DO; the metabolic rate of fish, aquatic plants and microorganisms; it can increase the level of Ammonia (NH3) if the temperature is too high; increase carbon dioxide; increase electrical conductivity; enhances the growth and reproduction of algae, among others, (Smith ;Alexander, 2022).

High conductivity may indicate the presence of pollutants, such as industrial or agricultural effluents, which increase the concentration of dissolved ions in the water (JONES & LENNON, 2021). In extreme cases, both high and low conductivity can be harmful to aquatic life. Some aquatic organisms are adapted to specific conductivity ranges and may be affected by changes outside this range. High conductivity can affect the taste of the water and may indicate the presence of dissolved substances that may be harmful to human health (WHO, 2022; Wilkes; Auerbach, 2019).

The presence of Total Dissolved Solids (TDS) naturally increases in water during rainy periods. This occurs due to the washing of soluble materials present in the soil, such as mineral salts, nutrients, dissolved organic compounds, among others, which are transported by rainwater to bodies of water. Like conductivity, TDS are an indicator of the amount of dissolved substances in water, and tend to increase during rainy periods due to the increased load of nutrients and other dissolved compounds carried into watercourses.

It is important to highlight that low pH, in addition to causing large-scale fish mortality, can corrode water distribution system pipes, releasing heavy metals such as lead and copper, can cause skin and eye irritation in humans who have prolonged contact with water, and leads to a decrease in biodiversity in aquatic ecosystems. Problems in agriculture can also be mentioned, reducing soil fertility, increasing aluminum solubility, releasing toxicity to plants and reducing their growth, among others (Zhang et al., 2020).

Water turbidity generally increases during the rainy season for water bodies such as rivers, lakes and dams. This occurs due to the increased transport of sediments, organic particles and suspended materials to water bodies. When it rains, rainwater can wash away loose soil, plant debris, and other particles that had settled on the surface of the soil or on the banks of rivers and lakes, making the water more cloudy.

With the results obtained during the analysis in the period corresponding to the rainy months (March to August) in the region of the Lower Capibaribe Microbasin, the aim was to observe how the arrival of the volume of water from the dam's tributary rivers can interfere with water quality (table 4).

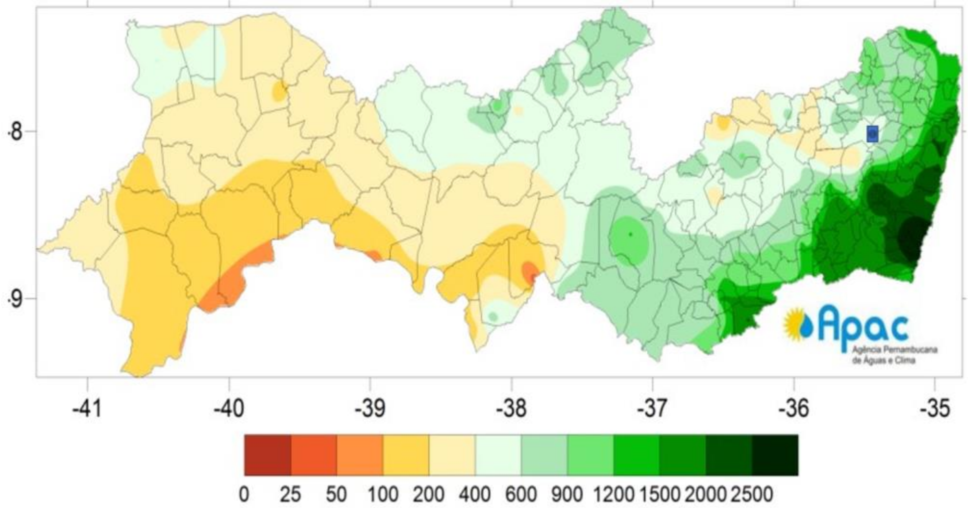
Table 4: easurement of the Physical-Chemical Parameters of the Lagoa do Carro Dam-PE during the rainy season, on 05/16/2023.

Physical-Chemical Parameters	Units of Measurement	Reference Value	New Fair	L. Itaenga	L. of the Car	Limoeiro
Temperatura da água	°C	SP	22	22	22	22
Condutividade	Ms/cm	50~1500	2508	1751,0	1037,0	2300,0
STD	mg/L	1000	128	97	141	80
Nitrito	mg/L em N	<1,0	< 0,001	< 0,001	< 0,001	< 0,001
Nitrato	mg/L em N	<10,0	0,377	0,305	0,322	0,438
pH	*	6,0~9,0	8,4	8,5	7,7	8,5
Turbidez	NTU	<5,0	11	8	8	5

Source: Albuquerque (2024) SP: No parameter defined by the method. * It is a dimensionless unit.

Considering the storage capacity of the Lagoa do Carro Dam, around 270 million cubic meters, as well as the volume of water it receives in the rainy months, commonly occurring between March and August, with the autumn/winter rains, typical of the Agreste Region of Pernambuco, with an average that varies between 1200mm and 1500mm, as observed in the APAC data (2023), in figure 4, below. The results of the parameters may present specific particularities, however, this does not make this study unfeasible or neutralize it, since it is necessary to analyze the data, considering all the aspects that make up the space where the object of study is inserted (Cristofoletti, 2015).

Figure 5: Pernambuco Rainfall Index



Source: APAC, (2023)

According to the Pernambuco Water and Climate Agency - APAC, the average water temperature in the Lower Capibaribe Region, where the Lagoa do Carro Dam is located, in May 2023 ranged from 20ºC (nighttime) to 25ºC (daytime) (APAC, 2023). On the day and time of the measurement, May 16, 2023, the water temperature found at the four points was 22ºC.

In the period preceding the collection, between May 13 and 15, 2023, that is, in the three days before the analysis of the material, around 15mm of rain was recorded in the municipalities surrounding the dam, as can be seen in the mosaic in figure 6, below.

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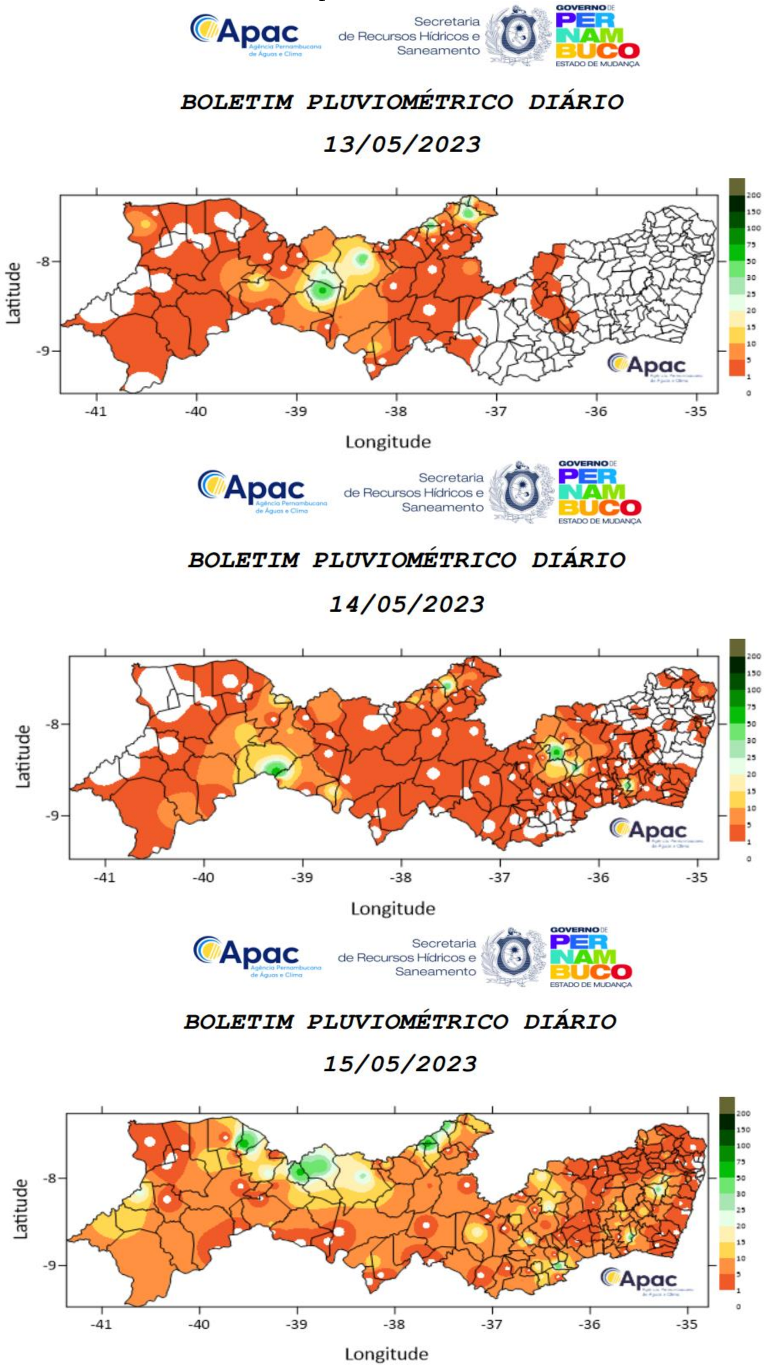
Figure 6: Rainfall Index in the Lower Capibaribe Microbasin, between 05/13 and 05/15/2023.



Source: APAC, (2023)

CONAMA Resolution nº 357/2005 establishes that, for special class and class 1 water bodies (multiple uses, including human supply and protection of aquatic life), the temperature variation should not exceed 3°C in relation to the natural temperature of the water body, (BRAZIL, 2005). This range was observed in the study in question, when the average water temperature was 22°C and the atmospheric temperature was around 25°C.

In the electrical conductivity parameter, in all measurements, the numbers were above the indicated limit, except in the EEA of Lagoa do Carro, whose number found in the measurement was 1,037 µS/cm, the lowest of all. At the EEA in Feira Nova, this number was 2508 µS/cm, the highest result among the four measurements, while at Lagoa do Itaenga, it was 1751 µS/cm and, finally, at Limoeiro, 2,300 µS/cm, all values higher than the reference.

The electrical conductivity of water generally decreases during the rainy season. This happens because the rain dilutes the ions and other substances dissolved in the water, resulting in a lower concentration of these particles and, consequently, lower electrical conductivity.

However, there are situations in which conductivity may temporarily increase during the rainy season, especially if the rain causes floods that carry a lot of sediment, pollutants and other dissolved materials to bodies of water. This increase, however, is generally followed by a greater dilution as more rainwater accumulates, reducing conductivity over time.

Based on these considerations and according to CONAMA Resolution 357/2005 (Brazil, 2005), conductivity in rivers and dams generally ranges from 50 to 1500 microsiemens per centimeter (µS/cm), but it is common for these numbers to increase during rainy periods, as is the case in the study in question.

According to Ordinance No. 888 of the Brazilian Ministry of Health, dated May 4, 2021, endorsed in CONAMA Resolution 357/2005, the maximum STD limit for drinking water is 1000 mg/L. In the case of the parameters found in the measurements carried out at the Lagoa do Carro Dam-PE, all ranges were within acceptable standards.

During the rainy season, the levels of nitrite (NO_2) and nitrate (NO_3) in the water increase. This occurs because the rains wash the soil and drag nitrogen fertilizers applied to agricultural crops and other sources of pollution into water bodies. These compounds, especially nitrates, are soluble in water and can be easily transported to rivers, lakes, and aquifers during rainfall. For the WHO (2021), the acceptable numbers are up to 50 mg/L for Nitrate and up to 0.1 mg/L for Nitrite. As for the values admitted by the National Council for the Environment of Brazil – CONAMA (Brazil, 2005) and by Directive 98/93 of the European Union (EU, 1993), the values are 50 mg/L and 0.5 mg/L, respectively. The values found at the Lagoa do Carro Dam for Nitrite and Nitrate are within the acceptable standards of the control agencies.

In the case of the measurement of Turbidity at the Lagoa do Carro Dam, it was found that at three of the four points, the indices found were above the range accepted by the WHO, CONAMA and the European Union's own Directive 98/93/EC. In the three agencies, the ranges vary from a minimum of 0.5 to 5 UNT for human consumption. In the specific case of the dam, the data varied from 5 UNT at the Limoeiro EAA, the only one within the parameter, but at the acceptable limit, to 8 UNT at the Lagoa de Itaenga and Lagoa do Carro EAA, and 11 UNT at the Feira Nova EEA. These data above the limit are explained by the fact that these EEA are located near the mouths of the Cotunguba and Riacho Feira Nova Rivers, which end up carrying more sediment during the rainy season.

The presence of turbidity above what is set by control agencies can negatively affect aquatic life and the potability of water. In addition to reducing the penetration of light into the water, hindering the photosynthesis process, it affects aquatic ecosystems and compromises water quality (Niyazi, et al., 2023).

The Northeast Region of Brazil, especially the Agreste and Sertão Physiographic Zones, have very high temperatures throughout the year, with these numbers increasing during dry periods, when the sun shines on practically every day of the so-called dry season, which runs from September to March.

On November 19, 2023, the date chosen to measure the physical and chemical parameters of the water in the Lagoa do Carro Dam, the sky was cloudy and sunny. The temperature found in the water at the time of measurement was 26º C at all four points, while the average air temperature was around 29º C, according to data in Table 03. There had been no record of rainfall that could have contributed to the change in the results of the analyses since the end of August 2023 (APAC, 2023). In the mosaic in figure 6 below, as in the analysis of the rainy season, the rainfall index of the municipalities surrounding the dam is presented, in the three days prior to the collection of the material.

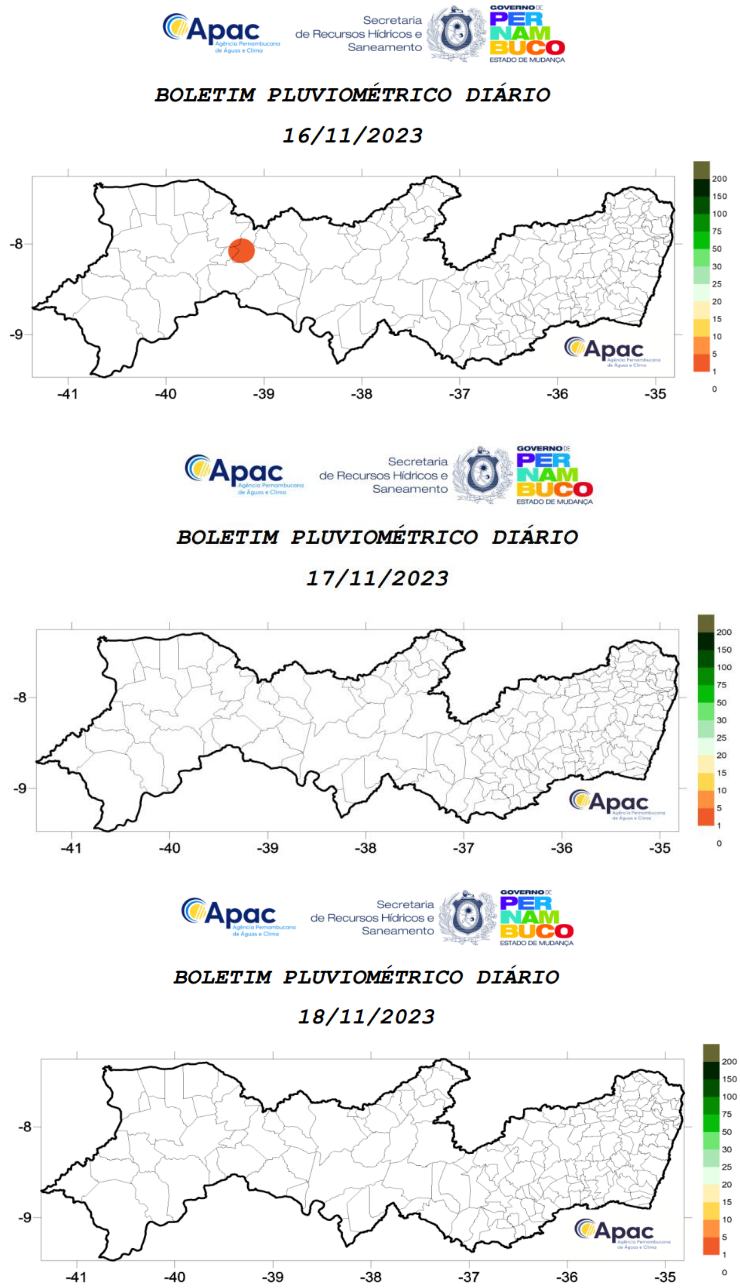
Table 5 - Measurement of the Physical-Chemical Parameters of the Lagoa do Carro Dam during the dry season, on 11/19/2023.

Physical-Chemical Parameters	Units of Measurement	Reference Value	New Fair	L.Itaenga	L. of the Car	Limoeiro
Temperatura (°C)	°C	SP	26	26	26	26
Condutividade (Ms/cm)	Ms/cm	50~1500	2904	2424,0	1730,0	2439,0
STD (mg/L)	mg/L	1000	67	54	29,0	54
Nitrito (mg/L em N)	mg/L em N	<1,0	0,001	< 0,001	< 0,001	< 0,001
Nitrato (mg/L em N)	mg/L em N	<10,0	< 0,400	0,344	0,170	0,457

pH	*	6,0~9,0	8,6	8,7	8,1	8,5
Turbidez (NTU)	NTU	<5,0	8	4	1	4

Source: Albuquerque (2024) SP: No parameters * It is a dimensionless unit.

Figure 7: Rainfall index in the Lower Capibaribe Microbasin, between 16 and 18/11/2023.



Source: APAC, (2023)

Water temperatures around this value lead to an increase in carbon dioxide and electrical conductivity, and enhance the growth and reproduction of algae, among other factors (Jones; Lennon, 2021).

As for the electrical conductivity parameter in water, it generally increases during the dry season. This occurs because the amount of water decreases due to the lack of rain, concentrating ions and other dissolved substances. This effect is more intense in surface waters, such as rivers, lakes, and dams, where evaporation and the reduction in the flow of new water have a direct impact.

These data are corroborated when analyzing the measurement points. In all four research locations, according to table 03, the numbers presented were above those referenced by CONAMA Resolution 357/2005, which indicates a variation of 50 to 1500 microsiemens per centimeter (μS/cm) in lakes and dams. At the EEA in Feira Nova, the value was 2904 (μS/cm), at Lagoa de Itaenga the data showed a result of 2424 (μS/cm), followed by 1730 (μS/cm) at Lagoa do Carro and 2439 (μS/cm) at Limoeiro.

As previously mentioned, the justification for some points having a higher conductivity index than others is explained by their position in the body of the dam. While some are close to the slope, others are located in the riverbeds that make up the Lagoa do Carro Dam watershed. Even though it is a dry season, some of these rivers are perennial and, as they run through urban areas, receive domestic and industrial effluents, which in turn carry materials to the waters of the dam.

Cristofoletti (2015) states that environmental analyses, including in this case studies of physical-chemical parameters, need to be carried out with a view that transcends the pure and simple analysis of data. It is important to understand other factors that make up the context. In this sense, it would be expected that the STD would increase during the dry season, since the evaporation process increases, the percentage of domestic and industrial effluents enters the soil more intensely, and salinity increases, among others. However, due to the large volume of water in the dam, associated with the low inflow of river water, the reduction in sediment transport and the stability of the materials deposited at the bottom of the dam, the numbers found in the water layer at the time of measurement were well below the parameters determined by CONAMA Resolution 357/05 and the Brazilian Ministry of Health ordinance no. 888, of May 4, 2021. At none of the four points measured were the numbers above the stipulated level, which is 1000 mg/L (Table 05).

During periods of drought, nitrite (NO_2) and nitrate (NO_3) concentrations in dams can be affected in several ways. Droughts, characterized by a significant reduction in rainfall and, consequently, in the supply of new water, can lead to changes in the dynamics of these compounds. As can be seen in Table 03, the data presented for Nitrite and Nitrate are within the range of the control agencies.

As with the other parameters, there is not necessarily a fixed rule to state whether the pH increases or decreases during the dry season (Zhang, Z. et al., 2020). Various factors can contribute to the increase, such as the reduction in photosynthesis, as the water level can decrease, exposing aquatic plants to more sunlight, increasing the rate of photosynthesis and this can consume CO2 and increase the pH of the water.

On the other hand, there are also factors that during the dry season can contribute to the decrease in pH. Increased organic decomposition, leading to low oxygen availability during the dry season, can lead to greater anaerobic decomposition of organic matter, releasing acids and CO2, which can lower the pH. The concentration of acidic pollutants, such as certain organic or inorganic acids, can increase as the volume of water decreases, and intense evaporation can increase the concentration of salts and other compounds that affect alkalinity and can reduce the pH depending on their chemical nature.

In the specific case of this study, practically all measurement points presented a higher pH during the dry season than during the rainy season, except for the EEA in Limoeiro, which presented the same index in both measurement moments. (Table 03).

Finally, regarding the turbidity parameter, a decrease is expected during the dry season, since the inflow of river waters is reduced, as well as the transport and movement of sediments from the bottom of lakes and dams. This can be seen when observing the numbers measured at the four points chosen for this study. At none of the four points were the numbers found higher than during the dry season. At the Lagoa do Carro EEA there is an 800% difference between the rainy and dry seasons. At Lagoa de Itaenga this number was 100%. In the cases of the Feira Nova and Limoeiro EEA, the numbers were 28% and 20%, respectively (Table 03). The data presented here demonstrate that, in general, the parameters analyzed at the Lagoa do Carro Dam are within the ranges recommended by the control agencies and their resolutions (CONAMA Resolution 357/05 and MS Brazil Ordinance, No. 888, of May 4, 2021), and also when compared with the works of Zhang, Z. et al. (2020), Jones; Lennon (2021) and Niyazi, et al. (2023).

4 CONCLUSION

Considering the large volume of water in the Lagoa do Carro Dam, in the state of Pernambuco, approximately 270 million cubic meters, associated with the fact that it is located in a highly populated region (approximately 300 thousand inhabitants) and in a territory where water is scarce, the analysis of the physical and chemical parameters of this body of water is extremely important for the six municipalities that make up the Lower Capibaribe Microbasin (IBGE, 2022).

The analysis of the physical and chemical parameters of water in dams is essential for the sustainable management of water resources and for the preservation of aquatic ecosystems. These parameters provide critical information about water quality, influence the health of aquatic life, and are fundamental for human, agricultural, and industrial supply.

The results found when measuring the physical and chemical parameters at two different times, one during the dry season and the other during the rainy season, provided important information regarding the “water health” of the Lagoa do Carro Dam.

The results found during the calibration process at the Lagoa do Carro Dam in Pernambuco, above the parameters stipulated by the main environmental agencies, including CONAMA, with Resolution 357/05, Directive 98/93/EC of the European Union and USEPA of the United States of America, with regard to conductivity, demonstrate that both in the rainy season and in the dry season, numbers are found that pose risks to the balance of the dam. At all points measured, the ranges are above the tolerable. High conductivity may indicate the presence of pollutants, such as industrial or agricultural effluents, which increase the concentration of dissolved ions in the water. In addition to indicating the presence of pollutants, conductivity above the acceptable level compromises aquatic life, can affect the taste of the water and can indicate the presence of dissolved substances that can be harmful to human health (WHO, 2022). Regarding pH, in the measurements taken in May 2023, when there was a lot of rain and a large volume of water, the data found were within the range stipulated by the WHO (2022), which states that the pH considered ideal is between 6.5 and 8.5. When this parameter was measured during the dry season, more precisely in November 2023, at the measurement points of the EEA in Feira Nova and the EAA in Lagoa de Itaenga, the pH was slightly above the acceptable range, that is, 8.6 and 8.7, respectively. However, as stated in the methodology, the margin of error for these analyses is up to 5%, therefore, it can be concluded that the pH of these measurement points is considered acceptable. At the other points, namely the EEA in Lagoa do Carro and Limoeiro, the numbers found were within the WHO range (2022 and CONAMA 357/2005). Turbidity was the parameter that varied the most between the two measurement times. During the rainy season, three of the four points (Feira Nova, Lagoa de Itaenga and Lagoa do Carro) showed values above the range indicated by the WHO (2021). Only the point located in the EEA of Limoeiro was within the acceptable standard. During the dry season, only the EEA located in the municipality of Feira Nova showed a result above the stipulated level. The other points behaved within the range established by the WHO.

Despite being a highly populated region and which, according to the IBGE (2023), has problems related to the universalized basic sanitation system, some of the parameters are within the numbers acceptable by the control agencies. The issues of Nitrate (NO3-), Nitrite (NO2-) and Total Dissolved Solids – STD can be mentioned here. In both the May and November 2023 measurements, the results obtained remained within the stipulated range, a fact that should be related to the volume of water in the dam.

This paper's primary objective is to analyze the physical and chemical parameters. However, it is a continuation of a previous study that analyzed the quality of the bottom sediments of the Lagoa do Carro Dam in Pernambuco, regarding the presence of heavy metals, resulting from the lack of a universalized basic sanitation system in the municipalities surrounding the dam. After analyzing the results of the two studies, a proposal for intervention in the curriculum of the Feira Nova Education Network was constructed, with the aim of maintaining the debate on the importance of caring for the planet, based on what is set out in the SDGs, especially number 6. Paulo Freire (1996) states that education does not change the world, education changes people and people change the world. In this context, offering possibilities to care for and maintain the quality of the water in the Lagoa do Carro Dam in Pernambuco, whether through education, the most appropriate way to do so, or through other actions by the government, will ensure water security for the citizens of the six municipalities of the Lower Capibaribe Microbasin, precisely in a state that has the lowest per capita water ratio in Brazil (APAC, 2023).

Based on the data presented here, the actions that can be taken on the set of information that makes up this thesis, especially with regard to a pedagogical intervention, more precisely curricular, are necessary and timely. As Goodson (1997) states, a curriculum needs to be alive, dynamic, reflecting the demands of society and seeking ways to respond to its desires. This is consolidated in what is stated in the 2018 BNCC, when it repeatedly speaks of the need to act with a view to sustainability, in line with the 2015 SDGs, when it stipulates that nations have goals and deadlines for their fulfillment.

In addition to formal educational actions, namely curricular and training interventions, thinking about an educational territory project is a top priority. Cordeiro et al. (2024) state that the school is responsible for providing different educational experiences, following paths and pedagogical models that contribute to the consolidation of argued and long-term knowledge, but allowing everyone to constitute themselves as subjects of their own education and to experience themselves collectively as responsible agents of knowledge and integrated and sustained transformation of their life contexts (Cordeiro et al., 2024).

The actions of the public authorities and the entire community reverberate in the parameters under analysis. What can or cannot be done will determine whether, in future analyses, the numbers will remain within the tolerance range of the regulatory bodies. Therefore, the implementation of public policies, such as the execution of structural works, with a socio-educational scope, with a view to establishing an educational territory, that is, one that calls on everyone to understand that the dam is a common good and that the obligation to take care of it is the collective's.

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