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Water Quality Analysis (IQA) of Lake Uhe Lajeado in Porto Nacional- TO

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***Abstract*—*Water is a source of life and an essential element of nature for human survival. Currently, this water resource has gone through a constant crisis over the centuries, especially when it comes to crises caused by the pollution aspect that affects this water resource and affects its efficiency in terms of consumption. The use of water is a demand that is present in several areas, in agriculture it has a resource role with consultative use. The present study aimed to obtain qualitative information about the quality of the water resource available in the lake located in the Araguaia-Tocantins Hydrographic Basin. Monitoring has the purpose of obtaining biological, chemical, physical, ecological information and classification into classes specified in the NSF IQA. In the case study, the water quality monitoring procedure was carried out, through the water quality standards - IQA NSF, carried out with the samples collected at a point of the Lake UHE Lajeado in the municipality of Porto Nacional - TO. These analyzes are important because the site, in the future, will serve as a new point of water collection for public supply. The Water Quality Index was evaluated by permissible limits established by CONAMA resolution nº 357/2005 and NSF - National Sanitation Foundation, which was evaluated in 9 parameters that made it possible to calculate the IQA - Water Quality Index.*

I. INTRODUCTION

Water is a source essential to life and is a necessary element for most human activities, that is, it is an integral part of the landscape and the environment. Because it is a necessary resource, it must be conserved and protected. It has the most diverse purposes, whether for domestic and industrial supply, power generation, irrigation of agricultural crops, recreation, navigation, fishing, aquaculture, fish farming, and also for assimilation and removal of sewage (SETTI et al., 2001).

Over the years the water on the planet has remained the same, about 70% (seventy percent) of our planet is bathed by water, of this percentage only about 2% (two percent) is considered drinkable water, or in other words, fit for consumption. In this regard, it is possible that Brazil is considered a privileged country for the large amount of this resource available, it has the largest freshwater reserve in the world, the Guarani Aquifer, and also has the largest hydrographic basin in the world, the Amazon River Basin (FREITAS, 2021).

From this perspective, the large amount of water present in Brazil could be seen as inexhaustible, however, a major problem that affects this abundance is the unrestrained use that generates waste. This unconscious use has also resulted in the amount of waste thrown daily into water bodies in a way that impairs its potability.

The IQA was created in the 1970s, after its creation in the United States by the National Sanitation Foundation - NSF and 5 years later CETESB - Environmental Company of the State of São Paulo started using it. Over the decades, other Brazilian states adopted the IQA, which is now the main water quality index used in the country (ANA, 2020).

For Soares (2001), water quality monitoring is the effort to obtain quantitative information on the physical, chemical and biological characteristics of water through statistical sampling. The type of information sought depends on the objectives of the monitoring network, and these objectives range from detecting violations of water body quality standards to determining temporal trends in water quality

According to ANA (2013) basic monitoring is performed in strategic locations to monitor the evolution of water quality, identify trends, and support the development of diagnostics.

In this study, in particular, the quality of the water available in the lake of the UHE Lajeado in the city of Porto Nacional - TO was investigated. The city has a growing number of inhabitants due to the possibility of employment because of the advancement in agriculture that was leveraged by the expansion of soybean and corn plantations in the central region of the state. However, the available water resources have suffered the impacts of this economic expansion since its waste ends up affecting the waters and compromising water quality.

II. METHODOLOGY

This was carried out through an in loco investigation, where the use and occupation of a specific point of the lake was investigated, which was characterized by the presence of the UHE Lajeado Lake. The water collected was analyzed through physical-chemical and microbiological tests, with the objective of calculating the IQA of the UHE Lajeado Lake in the municipality of Porto Nacional, the water quality was evaluated according to the parameters of the National Sanitation Foundation and Standard Methods (APHA, 2005).

2.1–STUDY AREA

The city of Porto Nacional is located in the central region of the state and is 63 km from the capital Palmas. It has a population of approximately 53,316 (IBGE, 2020) and is one of the largest agricultural centers in the state. The city is bathed by the Tocantins River, the main river of the state and is located in the Araguaia-Tocantins.

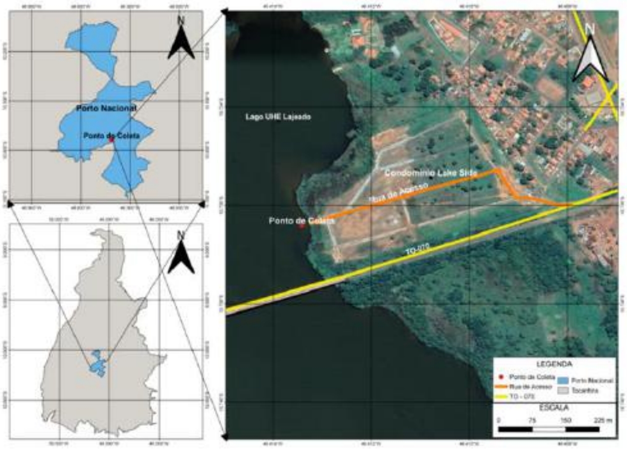

Fig.1 - Lake Side Clubhouse Location Map

Fonte: SEFAZ (2019).

2.2 FIELD METHODOLOGY

The method used for collecting the sample was in accordance with the technical specifications of NBR 9897/87, which deals with planning the sampling of liquid effluents and receiving bodies, and NBR 9898/87 on preservation and sampling techniques for liquid effluents and receiving bodies.

Sample collection and preservation were performed using convenient techniques so that the results would not reflect the conditions at the time the sample was collected. All necessary precautions were taken with the storage, maintenance, and transportation of the collection material. In total, 6 water samples (microbiological and physical-chemical) were collected.

The definition of the water quality index, IQA NSF, was based on monitoring the water on a timeline and for this purpose calculations and adaptation of the index were used for:

2.3 SAMPLE COLLECTION

The collection of water samples from the UHE Lajeado Lake were performed weekly, over a period of six weeks, between the months of August and September 2021. In total, six water samples were collected for each study (microbiological and physical-chemical), using 100 ml containers for microbiological samples and 200 ml for physical-chemical samples.

The containers were properly labeled and packed in a thermal box and taken to the IFTO's (Federal Institute of Education, Science and Technology of Tocantins) laboratory in Porto Nacional for processing.

2.4 LABORATORY METHODOLOGY

The samples were analyzed in the laboratory of the IFTO - Federal Institute of Education, Science and Technology of Tocantins, Porto Nacional campus, using the respective materials and application methods.

Table 1: Parameters and techniques used

Parameters	AnalyticalTechnique	Unit
Turbidity	APHA (2005), Direct Measurement	NTU
pH	APHA (2005), Direct Measurement	Escala
BOD	APHA (2005), Differentiation	mg/L
Total Phosphorus	APHA (2005), Spectrophotometry	mg/L
Total Waste	APHA (2005), Spectrophotometry	mg/L
Total Nitrogen	APHA (2005), Spectrophotometry	mg/L
Fecal Coliforms	APHA (2005), Colilert	NMP/100 mL

Fonte: Balduíno, 2019.

2.4.1 TURBIDITY ANALYSIS

To analyze the turbidity, the equipment was calibrated with 0.02 and 110 NTU solutions and 20 mL of the sample was placed in the turbidimeter cuvette to take the turbidity reading

2.4.2 PH ANALYSIS

The pH reading was taken with a pH meter calibrated with pH buffers 4 and 7. Then the sample was placed in the beaker and the electrode inserted to take the pH reading.

2.4.3 TEMPERATURE ANALYSIS

A digital thermometer was introduced directly into the point under study of the UHE Lajeado Lake, where the collection was made, for water temperature measurement.

2.4.4 FECAL COLIFORM ANALYSIS

To analyze the amount of fecal coliforms in the water, the reagent (Colilert) was placed in the sample and then loaded into the incubator for 24 hours at a temperature of 35˚C, and then poured into the Quanti-Tray/2000 (count from 1 to 2,419 per 100 ml), and the result was read:

- Yellow cavities equals total coliforms;
- \- Yellow/fluorescent cavities equals fecal coliforms/ E. coli.

The results of total coliforms and fecal coliforms were obtained simultaneously, by consulting the appropriate table of Hoskin in order to define the MPN of total coliforms and fecal coliforms.

2.4.5 DISSOLVED SOLIDS ANALYSIS

For the analysis of total dissolved solids biochemical oxygen demand, total nitrogen and total phosphorus were performed at LAPEQ - Laboratório de Pesquisa em Química Ambiental, also according to Standard Methods (APHA, 2005).

2.5 WATER QUALITY INDEX - NSF

The AQL was calculated by the weighted product of the water qualities corresponding to the parameters according to the following equation Heller and Padua (2010):

EQUATION 1:

$$IQA = \prod_{i=1}^{n} q_i^{wi}$$

Where:

IQA - Water Quality Index (varies from 0 to 100);

Qi - quality of the i-th parameter, a number between 0 and 100, obtained from the respective average quality change curve (analysis result);

wi: weight corresponding to the i-th parameter or sublevel, a number between 0 and 1, assigned according to its importance for the overall quality conformation;

n - number of parameters (n = 9).

The number "n" will always be equal to nine, because, in the absence of the measurement of any of the parameters that make up the IQA, its calculation is unfeasible

Equation 2:

$$\sum_{i=1}^{n} Wi = 1$$

n: number of parameters that go into the AQL calculation.

The calculation of the IQA will be unfeasible in the case of not having the value of any of the nine variables. From the calculation made, it is possible to determine the quality of the raw water, indicated by the IQA, varying on a scale from 0 to 100, as shown in Table 1.

Table 1 - Water classification according to the IQA-NSF result

LEVEL OF QUALITY	BAND
EXCELLENT	90 <IQA ≤ 100
GOOD	70 < IQA ≤ 90
MEDIUM	50 < IQA ≤ 70
BAD	25 < IQA ≤ 50
VERY BAD	IQA ≤ 25

The evaluation by means of the physicochemical and microbiological parameters of the water quality was established according to the weighting values, whose results fall into a category ranging from excellent to very bad.

III. RESULTS AND DISCUSSION

The monitoring of the water quality was carried out during the rainy season. During the rainy season a dark coloration of the water was observed, which comes from the solids carried to the riverbed. It is important to point out that the darker coloration of the water does not indicate contamination, since colorless water can also be contaminated.

3.1 WATER QUALITY PARAMETERS IQA NSF

The term water quality is subjective, since it does not refer to the purity of water, but to its physical, chemical and biological characteristics. In this perspective of IQA evaluation, nine parameters are selected for this study, namely: Water Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Hydrogen Potential (pH), Turbidity, Total Dissolved Solids (TDS), Total Nitrogen, Total Phosphorus and Fecal Coliforms (FC) (ANA, 2020).

CONAMA (BRASIL, 2005) determines the classification of water according to Resolution 357/2005, which states that freshwater is classified into four classes and one special class, and in this study it was examined as being class 2 waters, which are waters that can be indicated for human consumption, after conventional treatment, the protection of aquatic communities, primary contact recreation, such as swimming, water skiing and diving, according to CONAMA Resolution No 274 (BRASIL, 2010), the irrigation of vegetables, fruit plants and parks, gardens, sports and leisure fields, with which the public may come into direct contact, and aquaculture and fishing activity.

3.1.1 TEMPERATURE

Between the period February and March in the studied point was recorded an average temperature of 24.98 °C, the highest value was recorded in the second collection of February and the last collection of March, having been 25.3 °C, while the lowest was in the third and fifth collection of March, having recorded a value of 24.8 °C, in view of the rainy period the values varied little.

According to ANA (2020) the temperature is among the most important parameters, since it directly affects the physical and chemical processes that are made in water sources. Thus, the existing organisms reach limits with upper and lower temperature ranges, since they undergo changes throughout the day and in the changing seasons of the year.

3.1.2 DISSOLVED OXYGEN

Oxygen (O_2) is a gas of great biological importance and participates in numerous chemical reactions in aquatic ecosystems. All heterotrophic organisms depend on oxygen to maintain the metabolic processes of production, energy, and reproduction. The main sources of oxygen for water are the atmosphere and photosynthesis. Otherwise, losses arise from the consumption and decomposition of organic matter (oxidation), by the atmosphere, respiration of aquatic organisms, and oxidation of metal ions, such as iron and manganese (ESTEVES, 2011).

The highest Dissolved Oxygen value occurred in the last collection of March, having a value of 5.11 $mg.l^{-1}$, while the lowest was in the first collection of March, registering 4.98 $mg.l^{-1}$ and with an average value of 5.02 $mg.l^{-1}$.

According to Resolution 357/2005 of the National Council of the Environment (CONAMA), it establishes that the concentration of dissolved oxygen should be equal to or greater than 5 $mg.L^{-1}$ for Class 2 waters, which means that the results obtained are on average within the standard, with some collections having presented values slightly below, a warning sign for the competent bodies.

3.1.3 BIOCHEMICAL OXYGEN DEMAND (DBO)

The highest BOD (Biochemical Oxygen Demand) occurred in the second sample of February, with a result of 1.89 mg/L^{-1}, while the lowest was in the first sample of February with 1.58 mg/L^{-1}, resulting in an average value of 1.74 mg/L^{-1}. The results obtained are within the parameters of CONAMA Resolution 357/2005, where for class 2 waters, the value has to be up to 5 mg/L^{-1} O2.

The existence of high BOD values happens in the decrease of dissolved oxygen values in water, directly influencing the balance of aquatic life. In general, the high values of this parameter in a body of water are caused by the release of organic loads, especially domestic sewage (CETESB, 2009).

3.1.4 HYDROGENICONIC POTENTIAL (PH)

For Vieira (2015) pH is apt to dominate several chemical and biological processes in water bodies, and of procedures associated with water supply and wastewater treatment. It can be influenced by several aspects, such as dissolved solids and gases, hardness and alkalinity, temperature, and biotic factors.

The pH can vary between 0 (very acidic) and 14 (very alkaline), being a factor that interferes in the metabolism of the species CONAMA has determined a limitation for Class 2 waters, through resolution 357/2005 where the values must remain between 6 and 9 (ANA, 2020). The pH of the water in Class 2 waters, obtained an average of 7.03, with the highest value in the first week of March and the lowest value in the last week of March, being within the range stipulated by resolution 357/2005 of CONAMA.

During this period, the pH, went through oscillations, but remained within the range allowed by CONAMA Resolution 357/05, which recommends for springs pH values around 6.0 to 9.0. The maximum value of 7.19 indicated that it is slightly acidic.

3.1.5 TURBIDITY

Turbidity is the parameter that analyzes the water's ability to disperse solar radiation, being influenced mainly by suspended solids, which reduce the photosynthesis of submerged vegetation and algae. In general, turbidity comes from the erosion of large amounts of solids in the drainage area of the tributaries of the reservoir and the entire watershed (Tavares, 2005).

In the months of February the highest values were registered due to the large amounts of precipitations, presenting values of 6.28 NTU in the second week of February and 6.68 NTU in the second week of March, and the lowest value was registered in the first week of March due to the decrease in rainfall volume, registering a value of 4.13 NTU, with an average of 5.51NTU.

After the analysis it is feasible to check the results with the highest values allowed, according to the Resolution 357/05 of CONAMA, in which the turbidity values are a function of water use, where the allowed value for raw water is up to 100 NTU. The turbidity variant in surface waters is interesting for the relationship with the dissolved oxygen content because the suspended solids hinder the penetration of solar radiation, which causes a decrease in photosynthetic activity (BRASIL, 2005).

Although the average shows a value above 5 NTU, maximum permissible value for the CONAMA Resolution 357/05 for waters at any point of the distribution network, it is important to emphasize the rainy season that may have influenced the values of some collections that are in disagreement.

3.1.6 TOTAL DISSOLVED SOLIDS (TDS)

With the exception of dissolved gases, all impurities in water favor the accumulation of solids in water bodies and are capable of being called residues, since, after evaporation of a sample and drying in the greenhouse, these materials persist. The smaller particles, which are able to pass through a specific filter paper relate to the total dissolved solids (VIEIRA, 2015).

An average of 14.84 $mg.L^{-1}$ was obtained, having recorded in the second week of March the highest recorded value of 19.27 $mg.L^{-1}$, and the lowest in the second reading in February, having recorded 9.84 $mg.L^{-1}$, and averaged in the value of 14.84 $mg.L^{-1}$.

For Resolution 357/2005 the maximum value allowed for Class 2 waters is 500 $mg.L^{-1}$.

3.1.7 TOTAL NITROGEN

According to ANA (2015), water that has high concentrations of organic and ammoniacal nitrogen, and lower concentrations of nitrites and nitrates are unsafe, since they indicate that the site has been contaminated. Eutrophication is the problem factor that is related to high nitrogen concentrations, since they lead to an exacerbated growth of algae, inducing interference with the desirable uses of water (VON SPERLING, 2005).

The highest concentration of Nitrogen occurred in the second analysis in February having registered 2.112 mg/L^{-1}, while the lowest was in the last analysis in March, registering 1.521 mg/L^{-1}.

The element Nitrogen is essential for the life of organisms, since, it integrates the protein molecule, and as a consequence, of the protoplasm. Being equal to phosphorus, it is considered one of the most important and limiting to the life of freshwater organisms (BOLLMANN; CARNEIRO; PERGORINI, 2005).

The highest value of total nitrogen for Class 2 waters, according to CONAMA resolution 357/2005, can vary according to the hydrogenic potential (pH). For $pH \leq 7.5$ the highest allowed value is 3.7 mg/L^{-1}, for $7.5 < pH \leq 8.0$ the maximum allowed limit is 2 mg/L^{-1}, for $8.0 < pH \leq 8.5$ the highest allowed value is 1 mg/L, and for pH greater than 8.5 the highest allowed value is 0.5 mg/L^{-1}. In this study, both the mean pH and the highest pH reading recorded are lower than 7.5, thus the maximum allowed value for Total Nitrogen is 3.7 mg/L^{-1}, thus the analyses of the six collections are within the parameter, and the highest analysis was 2.245 mg/L^{-1}.

3.1.8 TOTAL PHOSPHORUS

According to Vieira (2015), phosphorus is an essential nutrient to maintain the life of living organisms and, in water, it is found in the form of phosphate, either in its dissolved form or as particulate material. Natural sources of phosphate are the chemical weathering of rocks, as well as the decomposition of organic matter. Sewage contributes greatly to the increased accumulation of phosphorus in water, a fact that, in case of high concentration of sewage in the water body, can lead the environment to eutrophication, because phosphorus is a limiting nutrient for the growth of algae.

The CONAMA Resolution 357/2005 for waters with class 2 lentic environments determines a limit of 0.030 mg.L^{-1} for lotic environments 0.1 mg. L-1. The source of intense ecological interest in phosphorus results from its great need in the metabolism of the biosphere (BRASIL, 2005).

In the six analyses performed in February and March the values found for total phosphorus were all equal to 0, indicating that in the period studied there is no presence of such substance at the point where the collection was made.

3.1.9 FECAL COLIFORMS

According to CONAMA Resolution 375/2005, fecal coliforms, or thermotolerant coliforms, are:

Gram-negative, bacillus-shaped, oxidase-negative bacteria characterized by activity of the enzyme β-galactosidase. They can grow in media containing surfactants and ferment lactose at temperatures of 44-45°C, producing acid, gas, and aldehyde. In addition to being present in human and homeothermic animal feces, they occur in soil, plants, or other environmental matrices that have not been contaminated by fecal material.

The average of the values obtained from the analysis of fecal coliforms was 16.43 MPN/100 Ml, which quantifies the presence of bacteria from the Escherichia coli group. However, in the second collection in February and the fifth collection in March, there was no presence of fecal coliforms. The highest value was obtained in the fourth collection in March, when a value of 70.1 MPN/100 ml was recorded..

3.2 WATER QUALITY INDEX (IQA-NSF)

The results obtained for the months of February and March 2020 served as a basis for calculating the IQA through the physical, chemical and bacteriological parameters of the surface waters of Lake UHE Lajeado in the municipality of Porto Nacional, using as parameters the classification of values by the National Sanitation Foundation. The calculation was performed using Excel as a support tool.

The lowest IQA value recorded was 76.21 in the second week, while the highest was 79.46 in the sixth week, very close values. The period under analysis obtained an average of 77.97, a value classified as good, where the National Sanitation Fundation's standard IQA value for such a category is $70 < IQA \leq 90$. The little variation recorded during all collections shows that the point chosen for collecting water to supply the population of the municipality of Porto Nacional - TO was made in a very satisfactory manner by the company BRK (basic sanitation company operating in the region).

All the results of the parameters analyzed were within the allowed standards when analyzed separately, and were always within the limits established by CONAMA Resolution 274/00, 357/05 and NSF, with little variation in the samples collected during the 6 weeks. This factor contributed to a satisfactory final IQA value.

IV. CONCLUSION

The result obtained from the water quality analysis was of great relevance, in which it was possible to analyze the real state of the water that is being used for public supply. Monitoring the AQL serves mainly to follow the evolution of the local water quality, making it possible to create a history for analysis, serving mainly as an alert to the population and the responsible bodies, so that preventive measures can be taken when necessary.

The results obtained during the study period regarding the alteration of the quality of the water, allowed a good analysis of the place studied and can conclude that the waters of the UHE Lajeado Lake in Porto Nacional - TO met the specifications of the CONAMA Resolution 357/2005 for class two waters, in almost all the 9 water quality parameters, except for turbidity, which was in disagreement. Thus, it was classified as good according to the IQA classification of the National Sanitation Foundation.

Despite the satisfactory result obtained with the study, it is worth pointing out that the care with the waters and soils of the hydrographic basin should be continuous, because even though most of the values were within the parameters, there were still those that came close to or exceeded the limit (Dissolved Oxygen and Turbidity), this shows that monitoring is of great importance and that precautionary measures should be taken so that the current situation does not worsen.

Another factor that may have influenced that made it possible to obtain good results is the fact that the analyzed point is located at the exit of the city in a condominium that has not yet been inhabited, and around it there are few residences. This situation can be changed if there is not a good management of urban expansion in the region, especially with the treatment of sewage and the disposal of solid waste, which are one of the causes that contribute to the pollution of watersheds.

The use of the IQA leads to the conclusion that its use is of fundamental character for the preservation of hydric resources, because with this important tool it will be possible to outline goals and management plans for a better preservation of this resource that is fundamental to life. Therefore, the point used to capture water for urban supply purposes at the UHE Lajeado lake in the municipality of Porto Nacional - TO is in good condition for use.

REFERENCES

[1] ANA. National Water Agency (Brazil). Manual de Usos Consuntivos da Água no Brasil / Agência Nacional de Águas. Brasília: ANA, 2019. 75 p.Perfect, T. J., & Schwartz, B. L. (Eds.) (2002). Applied metacognition Retrieved from http://www.questia.com/read/107598848 .

[2] ____In: Water Quality Portal. Quality Indicators - Water Quality Index (IQA). Available at: http://portalpnqa.ana.gov.br/indicadores-indice-aguas.aspx. Accessed on: 17/08/2021.

[3] APHA - American Public Health Association. Standard methods for the examination of water and wastewater. 21 th edition. Washington D. C. American Public Health Association, 2005.

[4] BALDUÍNO, Ângelo Ricardo. ANALYSIS OF THE IMPACTS OF AGRICULTURE ON THE WATER QUALITY OF THE WATER SUPPLY RESERVATORY OF THE MUNICIPALITY OF PORTO NACIONAL - TOCANTINS / Ângelo Ricardo Balduíno. - Palmas, TO, 2019.

[5] BRAZIL. National Council of Environment - Resolution CONAMA 274/2000 of November 29, 2000. Quality of water. Available at < http://www.mma.gov.br/ >, accessed October 18, 2021 at 16:10.

[6] BRAZIL. National Council of Environment - Resolution CONAMA 357, of March 17, 2005. National Council of Environment. Available at < http://www.mma.gov.br/ >, accessed October 18, 2021 at 3:09 pm.

[7] BRAZIL. Federal Law No. 9.433 of January 8, 1997 - Institutes the National Water Resources Policy, creates the National System for Water Resources Management. Diário Oficial da União, Brasília - DF, 1997.

[8] CETESB - Environmental Company of the State of São Paulo, Quality of Inland Waters in the State of São Paulo, Environmental and Sanitary Significance of Water and Sediment Quality Variables and Analytical and Sampling Methodologies, 2008.

[9] CONAMA - National Council of Environment. Resolution 357, 2005.

[10] ESTEVES, F. A. Fundamentals of Limnology. 2. Ed. Publisher Inter ciência, 1998. p. 602.

[11] ESTEVES, Francisco de Assis. Fundamentals of Limnology. 2. ed. Rio de Janeiro: Intercience, 2011. 826 p.

[12] SETTI, Arnaldo Augusto et al. Introduction to water resources management. Brasília: Aneel, 2000. 207 p.

[13] SPERLING, M. Von. Introduction to water quality and sewage treatment. 3º Ed. DESA. UFMG, Belo Horizonte, 2005. p. 243.

[14] VIEIRA, Beatriz Moyses. Evaluation of water quality and its compatibility with uses in rural watersheds with quantitative water deficit. 2015. 122 f. Dissertation (Master's Degree) - Environmental Engineering Course, Technology Center, Federal University of Espirito Santo, Vitória, 2015. Available at: <http://repositorio.ufes.br /bitstream/10/10313/1/tese_9261_Dissertacao_Beatriz_IMPRESS%c3%83OFINAL.pdf>. Accessed on: 28/09/2021.

[15] IBGE, Brazilian Institute of Geography and Statistics. 2020. Available at: https://cidades.ibge.gov.br/brasil/to/porto-nacional/panorama. Accessed on: 16/10/2021 at 19:09.

[16] INEA. State Environmental Institute Water Quality Index (IQA) Rio de Janeiro, 2019. Available at: http://www.inea.rj.gov.br/wp-content/uploads/2019/04/IQA-NSF-Metodologia-Qualidade-de-%C3%81gua.pdf. Accessed on: 16/10/2021.

[17] ANA, National Agency for Water and Sanitation. Available at: https://www.ana.gov.br/as-12-regioes-hidrograficas-brasileiras/tocantins-araguaia. Accessed on 10/17/2021.

[18] FREITAS, Eduardo de. "Tocantins-Araguaia Basin" Brasil Escola. Available at: https://brasilescola.uol.com.br/brasil/bacia-tocantinsaraguaia.htm. Accessed on November 05, 2021.

[19] BRASIL. Resolution CNRH no. 32 of 15/10/03. Brasília, 2003.

[20] Ana National Water Agency (Brazil). Conjuncture of water resources in Brazil: 2013 / National Water Agency. -- Brasília : ANA, 2013. 432 p. : Il.