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Evolution on the Water Quality in Sergipe Hinterland Reservoirs, Northeast Brazil

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Abstract: Population growth has consequences for intense use of aquatic ecosystems. Samples were taken, between 2013 and 2014, in the reservoirs "Algodoeiro" and "Gloria" in Sergipe, Brazil. TSI (Trophic State Index) and WQI (Water Quality Index) were used. It was determined the parameters such as conductivity, dissolved oxygen, total nitrogen, total phosphorus and chlorophyll. TSI has been applied, in "Algodoeiro", which was classified as mesotrophic. With the increase of rainfall in 2014, this reservoir changed its condition to eutrophic. "Gloria" reservoir was already classified in super-eutrophication. Regarding the WQI, the reservoirs were classified in Class IV, indicating a critically degraded condition.

Key words: Water quality, environmental degradation, limnological studies, TSI (Trophic State Index), RWQI (Reservoir Water Quality Index).

1. Introduction

The study of water is currently associated with the quality and quantity of water since its scarcity has caused environmental and social imbalance. However, the human consumption is the most relevant, so it becomes necessary that it should be monitored and evaluated.

In relation to Brazil, due to the climatic and geomorphological conditions of the northeast region, water resources are scarce, and measures are required to guarantee their supply for most of the year. Water is a strategic and fundamental element for the sustainable rural development of the northeastern semi-arid region, being necessary not only in quantity but also in quality. One of the measures to guarantee the supply of water is the construction of dams or reservoirs. For the management of the water reservoirs, it is essential to monitor their health, through physical, chemical and biological parameters of the water quality, which in turn allow to infer about possible sources of pollutants that could harm the use to which these reservoirs are destined [1-4].

There is a great need for monitoring water quality in a course to ensure the continuous pattern of water to be used. Monitoring of water quality in the most traditional way depends on in situ measurements and frequent laboratory analysis of the samples. This type of point sampling method is the most usual one to allow accurate measurements [5-7].

Water consists of solid wastes in their quality caused by physical processes, mainly by evaporation and chemical operations (growth, death and decomposition). The anthropogenic action on the aquatic environment, highlighted as a contamination

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by pesticides and fertilizers, is mainly responsible for the quality of water in the rural environment due to the agriculture, which is a dominant economic activity in the area [8-10].

With the need of monitoring the reservoirs through the collection and analysis of their physical, chemical and biological parameters, serving to assess the conditions and evolution of water quality over time and to facilitate the studies and interpretation of data collected, many managers choose to use as a tool the water quality indexes which are proposed in order to summarize the analyzed variables [11].

The TSI (Trophic State Index) is responsible for estimating the degree of trophic aquatic systems. It has undergone modifications to suit the limnological conditions of tropical reservoirs, and is now widely used in Brazil. This modification was made by the fact that limnological studies showed that the permissible and excessive critical concentration in relation to chlorophyll a and total phosphorus and the visual disappearance of the secchi disc (water transparency) were different from those found in temperate areas [12].

In this scenario, the present work aims to evaluate the water quality of the Algodoeiro and Nossa Senhora da Gloria reservoirs in Sergipe located in the São Francisco river basin and the Sergipe river basin, respectively, through the RWQI (Reservoir Water Quality Index) and determine the TSI for the referred reservoirs, observing if there was an evolution of the trophic degree and the water quality of these reservoirs over the monitored period, in order to offer information which can help in the actions related to the quality improvement of these lentic environments.

2. Material and Methods

2.1 Study Areas

The São Francisco river basin is the largest and most important in the state. It drains an area of 7,184 km^2, being limited to the south with the basins of the rivers Japaratuba and Sergipe. The most important tributaries of the San Francisco in Sergipe are the rivers Xingó, Jacaré, Capivara, Gararu and Bitumen.

Completely included in the state territory, the Sergipe river basin extends for 3,720 km^2 and is limited to the north with the basins of São Francisco and Japaratuba and, to the south, with the basin of the river Vaza-Barris. The main tributaries of this basin are the rivers Salgada, Jacoca, Jacarecica, Cotinguiba and Riacho Pau Cedro.

Figs. 1 and 2 show the hydrographic basins with the studied reservoirs.

2.2 Methods of Analysis

In this work, the data obtained in the semi-annual campaigns carried out in the period from 2013 to 2014 (Monitoring Report of the Sergipe Reservoirs—CONVENTION N^o. 001/2012-ITPS-SEMARH, Rio São Francisco and Sergipe Hydrographic Basin [13]) will be used. The campaigns were carried out in 2013 (June to August) and (November to December) and in 2014 (June to August) and (November to December).

In this work, the data obtained were from the samples collected in the superficial layer, at one point in each reservoir, in two collection campaigns. The determined parameters are shown in Table 1. Adequate and previously cleaned containers were used for each type of analysis. Prior to collection, the containers were washed two to three times with the water to be sampled.

All collection, conservation and analysis procedures followed the methodologies are described in the "Standard Methods for the Examination of Water and Wasterwater", 21st Ed. in 2005 [14] and are also indicated in Table 1. It is important to emphasize that all the analytical determinations were performed at the Water and Dumping Laboratory of the TRIS (Technological and Research Institute of Sergipe).

Standard calibration, blank reagent analysis and duplicate determinations were used to guarantee analytical quality. The laboratory also regularly

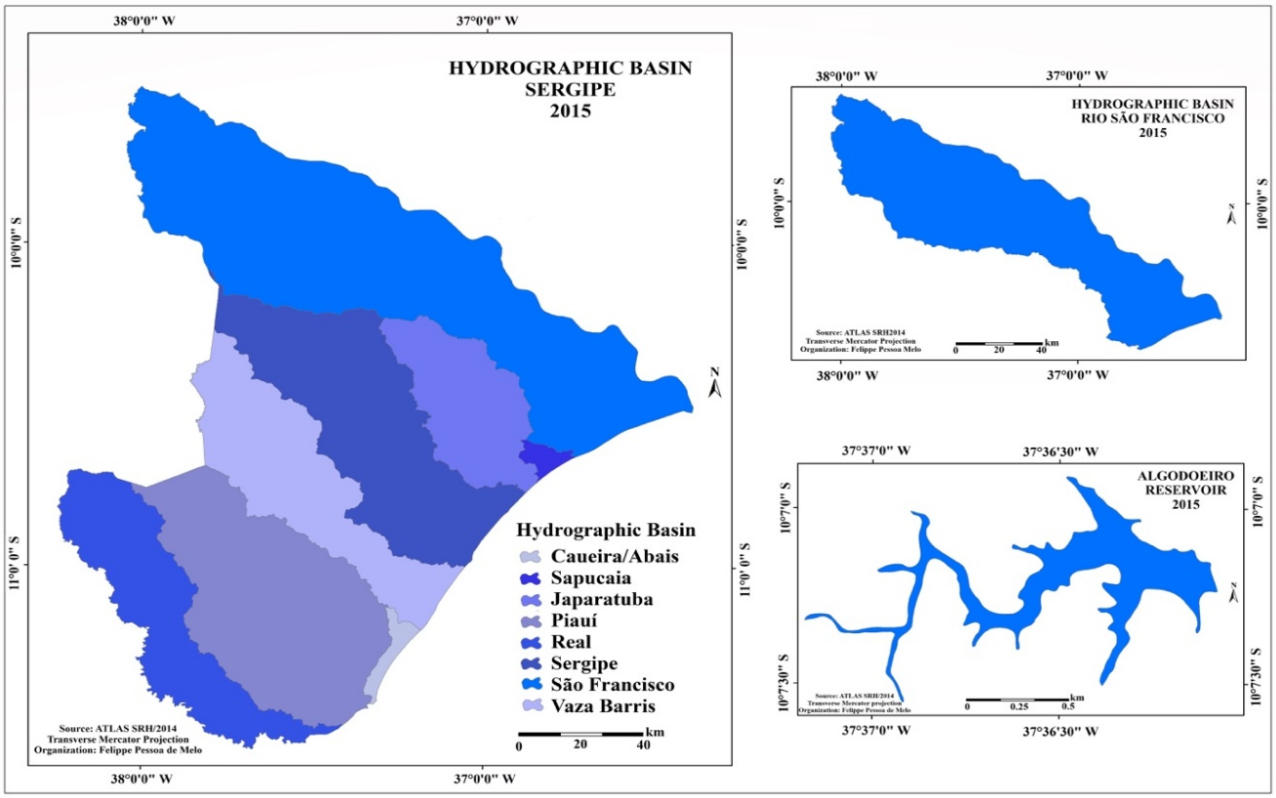

Fig. 1 Reservoirof Algodoeiro in Nossa Senhora da Gloria.

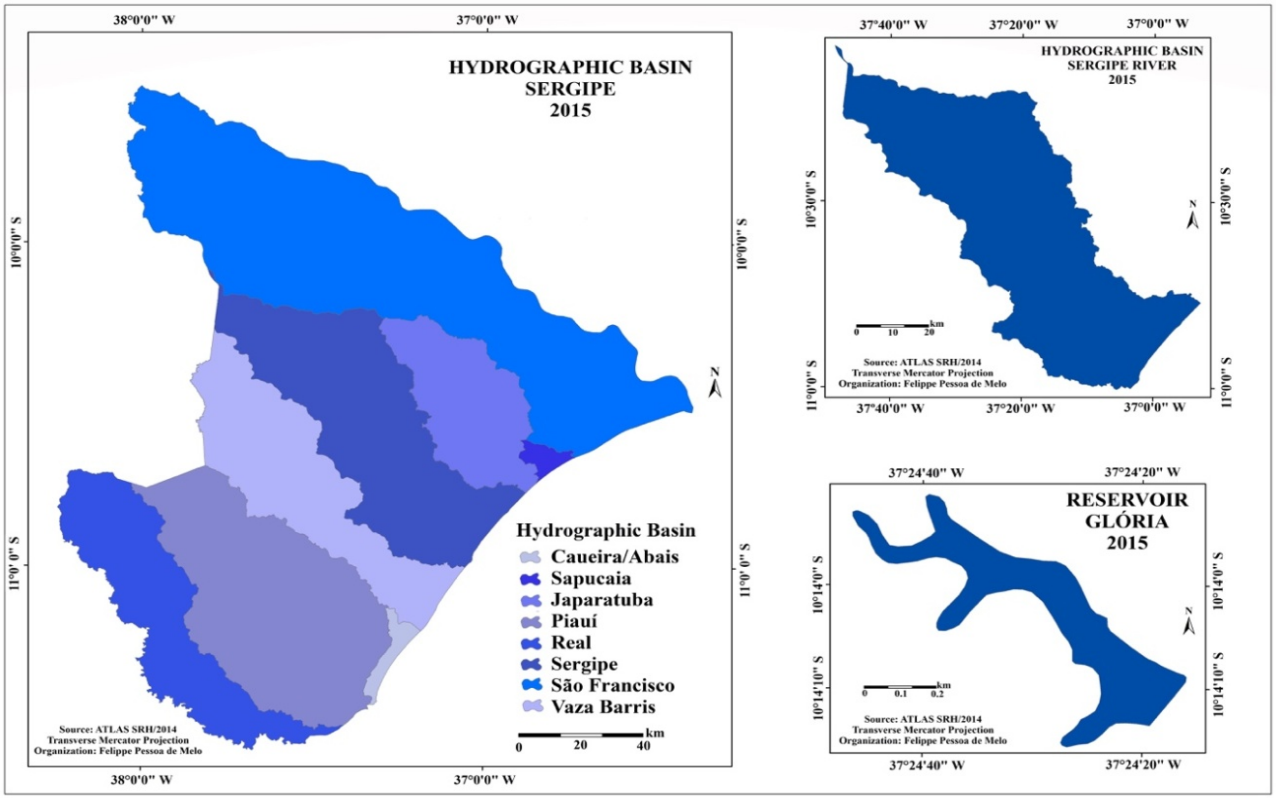

Fig. 2 Reservoirof Gloria in Nossa Senhora da Gloria.

Table 1 Parameters, requirement of sampling, preservation and analysis of samples.

Variables	Preservation	Conservation	Validity	Methods
COD (Chemical Oxygen Demand)	--	Refrigerated	28 days	SMEWW (Standard Methods for the Examination of Water and Wastewater) 2510B
Total phosphorus	H_2SO_4 until pH < 2	Refrigerated between 4 and 5 °C	28 days	SMEWW 4500P
Total nitrogen	H_2SO_4 until pH < 2	Analyze as quickly as possible or refrigerated between 4 to 5 °C	7 days	SMEWW 4500
Inorganic nitrogen total	Filter in membrane 0.45 μm	Analyze as quickly as possible or refrigerated between 4 to 5 °C	24 hours	US-EPA (United States Environmental Protection Agency) 300.0 US-EPA 300.0 SMEWW 4500P
DO (Dissolved Oxygen)	2 mL of manganous sulfate e; 2 mL of alkali iodide + azide	--		SMEWW 2510C
Chlorophyll a	Filter in membrane 0.45 μm	Refrigerated between 4 and 5 °C		ICP OES (Inductively Coupled Plasma-Optical Emission Spectroscopy)

participates in proficiency programs and has accreditation for some parameters.

3. Results and Discussions

The RWQI calculation was performed by establishing two conditions. The first one was to calculate this index taking into account only the parameters that were measured in this work. It is important to emphasize that the RWQI was calculated with nine parameters, but that in the literature suggests that in the absence of some parameter, this one is not taken into account, as well as its weight. The second condition proposed in this work was to replace the parameters which were not measured, and which are included in the index, by parameters that indicate the reservoir condition phenomenologically/empirically. In this case, the residence time and cyanobacteria concentration parameters were replaced by turbidity and thermotolerant coliforms.

3.1 First Condition: RWQI According to EIP (Environment Institute of Paraná)

Through these results, it was also possible to identify the environmental condition of the reservoir. In this case, the reservoirs presented a condition of lower degradation, but still a very polluted condition, weighing negatively on the general condition of the reservoirs. Observing the results obtained in the reservoirs, there was an increase in the value of the RWQI for the two reservoirs with the change from winter season (rainy season) to summer (dry period).

In these, it was verified that during the monitoring period for the Algodoeiro reservoir, the classification obtained was critically degraded (Class IV with index range between 3.5 and 4.5) for the two periods of the year in which the samples were collected. Class IV water environments have very poor water quality, with bodies with the possibility of fish mortality and high concentrations of nutrients, mainly phosphorus and nitrogen.

The RWQI results for the Gloria reservoir are also shown in Table 2. It is possible to observe that there was an increase in the RWQI value of 4.38 (in winter) and to 4.61 (summer), changing the classification of critically degraded to very polluted, that is, from class IV to class V. For this reservoir, it was observed an increase of chlorophyll a concentration of approximately 20 times, indicating a strongly eutrophicated environment, due to excessive consumption of phosphorus and nitrogen nutrients.

However, in Table 2, it is still possible to visualise a difference in the RWQI for the winter period of 2014, for which the Algodoeiro reservoir in 2013 the RWQI was 4.0 passed in 2014 to 3.51, but the condition remained the same of critically degraded despite the

Table 2 RWQI calculation results.

Reservoir	RWQI (Jun./2013 to Aug./2013)	RWQI (Nov./2013 to Jan./2014)	RWQI (Jun./2014 to Aug./2014)
Algodoeiro	4.00	4.30	3.51
Nossa Senhora da Gloria	4.38	4.61	3.43

improvement in numerical terms. As for the Gloria reservoir, there was an even greater change that previously had an RWQI 4.38 passed to 3.43, leaving the condition from critically degraded to moderately polluted, due to the amount of rainfall in the region of Gloria in the year of 2014 which averaged 810 mm of rain this year. In the winter of 2013, it rained 350 mm and in the winter of 2014, it rained 450 mm, which caused different results. However, when analyzing the results, it was verified that, although the rains have modified the class to which the reservoir belongs, it is noted that some parameters such as phosphorus, DO and chlorophyll a reveal the true condition of the reservoir and that there is a very thin line since the result of 3.43 is very close to the value of 3.51 for which the reservoir would remain as critically degraded.

3.2 Second Condition: Modified RWQI (MRWQI)

In general, in relation to individual parameters, the reservoirs were classified as extremely polluted. On average, the predominant class of reservoirs is Class VI, and this class is characterized by environments with poor water quality, extreme pollution and high concentrations of organic matter and is considered hypereutrophic bodies.

The monitoring of the reservoirs is carried out in three campaigns through the collection and analysis of their physical, chemical and biological parameters in order to evaluate the water quality conditions. It was possible to perceive the reality of the northeast region and the State of Sergipe on the basis of the existing data by modifying the weights empirically and inserting others parameters adapting the RWQI of the EIP.

In the condition for the MRWQI, there was a change to both reservoirs regarding the class they represent, changing the condition from critically degraded to moderately degraded. Although this condition indicates that the reservoirs are in poor condition, the difference between these results may be due to the amount of rain of the month of August 2014, which were greater than the winter of 2013, collaborating for a dilution of the parameters. These results are shown in Table 3.

3.3 TSI

The water quality indexes are intended to demonstrate the evolution of water quality over time and the TSI classifies the reservoirs according to their degree of trophia. Analyzing this index for the Algodoeiro and Gloria reservoirs, it was verified that the Algodoeiro one was classified almost all year as mesotrophic, i. e., it was considered a body of water with intermediate productivity, with possible implications on water quality, but acceptable levels in most cases. The Gloria reservoir obtained a supereutrophic trophic degree in the first campaign and in the second campaign, the trophic degree changed to hypereutrophic. The latter indicates a degree of trophy in which water bodies are significantly affected by high concentrations of nutrients and organic matter, compromising their uses. In addition, these reservoirs may exhibit many kelp blooms and fish mortality. Table 4 shows the average results for the three campaigns.

In the work of Mendonca, M. C. S. [15], the reservoirs of Marcela and Jacarecica were evaluated using RWQI proposed by EIP, as well as others commonly used in the literature. Through the results obtained via the analysis of the physical, chemical and biological parameters, the reservoir water quality indices for the Marcela and Jacarecica water were determined.

Table 3 MRWQI.

Reservoir	RWQI (Jun./2013 to Aug./2013)	RWQI (Nov./2013 to Jan./2014)	RWQI (Jun./2014 to Aug./2014)
Algodoeiro	3.59	3.71	3.14
Nossa Senhora da Gloria	3.92	3.97	3.08

Table 4 TSI medium.

Trophic State	Algodoeiro Riacho Alagadiço	N. S. da Gloria Riacho Pau de Cedro
TSI (Phosphorus)	59.22	72.56
TSI (*Chlorophyll a*)	58.38	60.58
TSI	58.89	66.55

Mendonca, M. C. S. [15] also pointed out that all the indices were calculated based on different parameters, but those results were in agreement with the physical-chemical and biological analyzes of water, which presented, in some variables, values well above the maximum allowed for any use of water. Thus, the variables that had the highest analysis results were ammoniacal nitrogen, as well as nitrite and nitrate, and total phosphorus, which are indicative of the eutrophication process, possibly due to effluents from domestic and industrial effluents, as well as the agricultural runoff associated with the application of fertilizers in agriculture.

It is also important to note that phosphorus undergoes continuous transformations in the freshwater environment. Phytoplankton and bacteria consume the available phosphorus in the water medium and transform it into its organic form. These organisms can then be ingested by detritivores or herbivores, which in turn can excrete organic phosphorus in the water, facilitating the assimilation of plants and microbes. Thus, when found in high concentrations, phosphorus can cause eutrophication of the water medium, in addition to, together with nitrogen, influence the proliferation of cyanobacteria. This fact is evidenced by the high concentration of chlorophyll a in the Marcela Water, according to the limit established by CONAMA nº 357/05. The results of Mendonca, M. C. S. [15] can serve to substantiate the results obtained in the present work, considering that the analysis of the indices with different parameters reached the same conclusion about the water quality in the reservoirs.

4. Conclusion

The quality of the reservoirs studied in this work was evaluated through measurements of the physical, chemical and microbiological parameters, by calculating the RWQI and TSI proposed in the literature. These indices serve to assess the condition for a particular use of a water body. These are functions of the parameters normally measured in the laboratory of control and environmental monitoring.

In the case of the studied reservoirs, the problems go beyond a management system. However, it is known that these reservoirs are used as supply for human consumption, animal disintegration and irrigation of vegetables which require monitoring and environmental control measures. After the study of different water quality indices, it can be inferred that the objective of the RWQI and TSI facilitates the interpretation of water quality monitoring data through a number, which represents reduction of a high number of parameters in a simple expression. These indices use various biological and physico-chemical parameters, which assess the vulnerability of water quality, and were the results of research carried out by different government agencies and specialists. Despite all efforts, no index has so far been universally accepted, so that water agencies, users and water managers in different countries have made adjustments in indexes with respect to parameters and the calculation formula of the

Index of Water Quality, proper index for reservoir and the TSI.

This work shows that it is necessary to adopt measures aimed at the control and reduction of nutrients and organic loads in the water, discarded to contain the eutrophication process of these reservoirs. In this context, the monitoring of physicochemical and biological parameters for the evaluation of human impacts on water resources is essential. It is also important to mention that, although the authorities can build treatment plants for adequate nutrient removal, it is necessary for the community to be a partner in the environmental management strategy. The reservoirs of the Algodoeiro and Gloria, according to the results obtained and analyzed in the present work, require type of control, since the water of these reservoirs were classified as unfit for human consumption, according to CONAMA Resolution no. 357/2005.

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