Strategies for water quality reservoir assessment: Water Quality Index, Trophic State Index and Fuzzy Logic

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INTRODUCTION

The phenomenological evaluation of a water system is made through physical, chemical and microbiological environmental parameters which are variables used to obtain quality indexes. Therefore, it is imperative that the data be obtained in a careful and adequate manner, because the water system is constantly altered by environmental factors such as temperature, pressure and anthropological characteristics of the environment under analysis.

The proposed mathematical methods define indexes which group the water classification parameters, numerically translating the phenomenon or process under analysis. However, some of these indexes require a considerable number of parameters which, at times, economic and social factors limit their attainment.

In this context, it is not only necessary to quantitatively assess water resources. This strategy has already been overcome, mainly because of this high population growth near the river banks, of water reservoirs. The need today is to quantitatively and qualitatively assess water resources, as the quality of water is suffering serious consequences of population growth and industrial progress. Thus, this work aims at the application of numerical strategies, including fuzzy logic, to determine water quality indexes and trophic status, which can define the quality of a water body as a consequence of the variation of environmental parameters.

METHODOLOGICAL PROCEDURES

Study area

The Macela reservoir (Figure 1), located in the city of Itabaiana-SE, was evaluated in this work as an important water source for the local population. The experimental data of the water collected in this reservoir were obtained by the Laboratory of Analytical Chemistry Laboratory (LQA), Department of Chemistry, Federal University of Sergipe. Analyzes were performed using the analytical procedure according to APHA (1998).

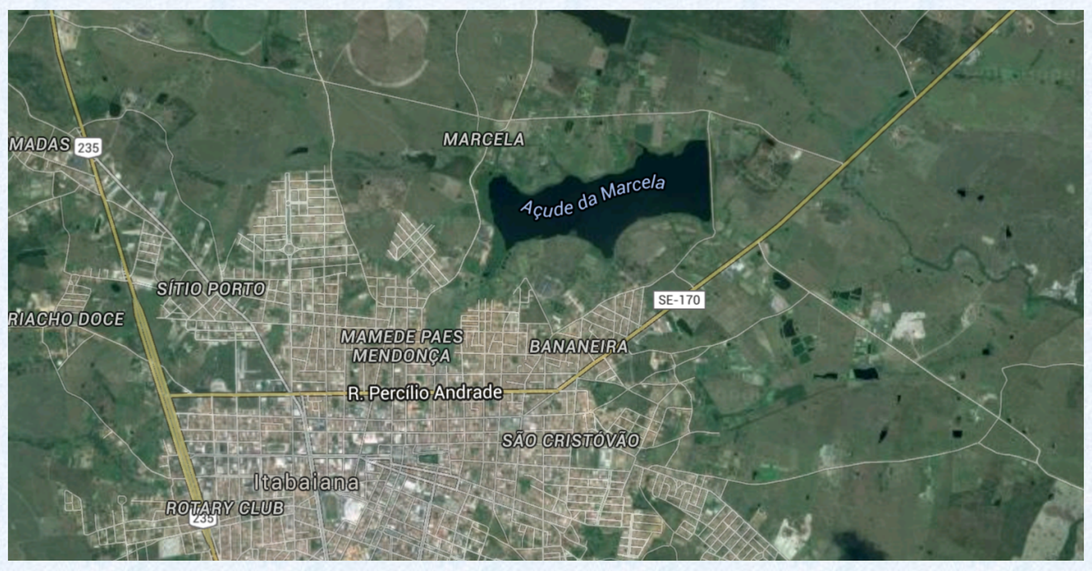

Figure 1. Location of the Macela reservoir, Itabaiana-SE.
Source: Google Earth (2016)

For this work, 10 shallows monitoring wells (up to 8 m deep) were selected to collect, all of them already existing, manually drilled with auger and located in the unconfined aquifer in the North Zone of Aracaju. The sample size was established at the cost of analysis and the twells available for collection. The samplings were carried out in May (rainy season) and in November and December 2015 (dry

RESULTS AND DISCUSSIONS

To obtain the WQI, the mean values of the parameters, Table 1, allow the establishment of a comparison with the WQI calculations obtained for the Macela reservoir using the IQAR (IAP), O-WQI, PW-WQI and CPCB-WQI were equal to 6; 2.16; 9.49, 20.13, respectively. In this way, it was observed that the four indexes present the same conclusion about Macela reservoir which is a high level of eutrophication and is extremely polluted.

For the evaluation of the IQARfuzzy the 4 parameters already mentioned were used, Total Nitrogen, Total Phosphorus, DO and chlorophyll-a. IQARfuzzy was compared to IQAR (IAP) in its classification ranges. The IQARs obtained served to establish, then, the validity of the calculated IQARfuzzy.

Table 1 - Parameters evaluated in Macela reservoir

Parameters	Mean	Stand. Dev.	CONAMA
Condutivity (mS cm^{-1})	1.67	0.63	-
Color (Pt-Co)	21.48	13.28	75 mg Pt-Co
pH	8.56	0.39	Between 6.0 and 9.0
TS (mg L^{-1})	1058.02	339.64	500
TDS (mg L^{-1})	23.06	24.79	-
DO(mg L^{-1})	5.32	2.85	5
$N\text{-}NH_4$ (µg L^{-1})	48.19	39.66	500 µg/L for pH > 8,5 and at most 2000 µg/L for 7,5 < pH ≤ 8,0
$N\text{-}NO_2$ (µg L^{-1})	146.92	146.31	1000
$N\text{-}NO_3$ (µg L^{-1})	1255.96	615.88	10000
N Total (mg L^{-1})	4.52	3.32	1.27
P Total(mg L^{-1})	415.14	200.3	0.05
Clorophyll-a (µg L^{-1})	59.28	63.2	30
Temperature (°C)	28.23	1.82	-

Table 2 presents a comparative analysis between the IQA calculations performed in this work. It should be noted that although the applied fuzzy method took into account only four of the quantified variables, this one is quite representative presenting similar responses to the others with use of other variables in each calculated index, since the chosen parameters, P, N, OD and chlorophyll-a, for the evaluation of a reservoir are the indicators of the eutrophication phenomenon.

Table 2 - Water Quality Indexes for Macela reservoir

INDEXES	Marcela reservoir	Classification
IQAR (IAP)	6.00	Extremely polluted
O-WQI	2.16	Very bad
PW-WQI	9.49	Minimum quality
CPCB-WQI	20.13	Very bad
$IQAR_{fuzzy}$	6.3	Extremely polluted

The trophic state of a reservoir represents, mainly, the entrance of nutrients, through the discharge of domestic sewage. In this item, the TSIs of Carlson and Simpson (1996) and the TSIfuzzy were calculated, to define the trophic conditions of the Macela reservoir..

Table 3 - EIT and percentage for each trophic state - Macela Reservoir

	TSI	Oligotrophic	Mesotrophic	Eutrophic	Hipereutrophic
Clorophyll a	65.77	-	44.54%	21.85%	33.61%
Ptotal	100.09	-	-	-	100.00%
Ntotal	73.43	-	7.02%	21.93%	71.05%
Total TSI	79.76				

Due to the high amount of chlorophyll-a, it can be stated that the presence of cyanobacteria in the reservoir, which leaves this water unfit for consumption, emphasizes that educational measures with the population using this reservoir must exist, since there is the risk of contracting diseases.

Fuzzy logic was used to calculate an TSI using the same parameters used by Carlson and Simpson. The fuzzy inference method was the Mamdani method and for the defuzzification step the center of gravity (Centroid) method was used. Twenty-eight fuzzy rules were implemented according to the degree of importance or pertinence of the system response, in accordance with the definitions of the experts. The output variable was the trophic state index of the water, classifying the system into four trophic levels of the system.

The fuzzy logic for its characteristic of portraying phenomena often complicated to model, obtained in this application coherent results and in agreement with the WQI and STI of other mathematical models. However, it is necessary to observe that the representation of a smaller number of variables will necessarily imply a smaller number of rules and consequently requires that the expert has a great knowledge of the body of water to make the correct selection of the parameters. Thus, the correct definition of the number of variables makes it possible to reduce laboratory tests, as well as to promote a solution proposal for the problem which occurs in the water body under analysis.

CONCLUSION

An evaluation of the Macela reservoir Water Quality Index (WQI) indicates a high level of pollution. IQAR (IAP), O-WQI, PW-WQI, CPCB-WQI and IQARfuzzy converge to values which demonstrate the high level of pollution of these. In addition to the WQI, the Trophic State Index (TSI) was evaluated for the degree of eutrophication. This problem directly interferes with the use of water both for consumption and for human consumption, as well as for recreation.

Through the analysis of the numerical results, it is possible to conclude that the indices are determined in different ways and that the concept of water domain in question. By its perception and practicality, a fuzzy logic can be considered a precise and effective means of determining and evaluating complex environmental phenomena through the determination of environmental classification indexes.

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