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# Assessment of water quality using principal component analysis: a case study of the açude da Macela – Sergipe – Brazil

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## INTRODUÇÃO

The quality of surface water is a very sensitive issue and it is a great environmental concern worldwide. It is critical for long-term economic development, social welfare, and environmental sustainability. A variety of water quality indices have been designed to judge out the overall water quality within a particular area promptly and efficiently. Some examples of these are the US National Sanitation Foundation Water Quality Index (NSFWQI). the Environmental Institute of Paraná (RWQI), Oregon Water Quality Index (OWQI) to evaluate the general water quality of Oregon's stream; and the Central Pollution Control Board of India (CPCB-WQI). These indices measure the quality of water from its reservoirs due to the factors that influence them and, therefore, the parameters adopted for each assume weights and different importance levels in the evaluation of water quality. In this context. the aim of this study is to evaluate the water quality of the Açude da Macela using the Principal Component Analysis to assist interpretation and extraction of the most important parameters for the assessment of variations in water quality of this reservoir.

## MATERIALS AND METHODS

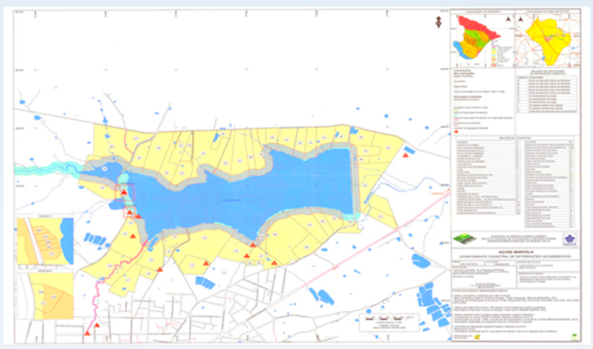

Figure 1- Açude da Macela reservoir
Source: DNOCS

### Study Areas

The reservoir, Açude Macela, has a storage capacity of 2.710.000 m³ and was designed to provide irrigation water for 156 hectares and be an area used for the production of vegetables that supplies the markets of Itabaiana City and the surrounding region, Figure 1.

### Sampling

Samplings were done on selected sites for two years (2010–2012) across in the reservoir width with a view to monitor changes caused by anthropogenic sources. Sampling, preservation and transportation of the samples to the laboratory were done in concordance with standard methods (APHA. 2012). Eleven physico-chemical parameters have been determined by prescribed standard methods. Principal component analysis (PCA) aims to find combinations for certain variables to determine indices which describe the variation in the data with minimal loss of information. From the physical, chemical and biological parameters obtained, it was possible to calculate the water quality indexes, described in Table 1 for the Açude da Macela.

In Table 2, from the principal component analysis, new weights were assigned to the variables considered critical according to their contributions to the determination of each principal component. Then, it was performed the arithmetic mean calculation of percentage contribution of each variable and the result was an approximate figure for assigning new weights used in calculating the WQIR-m.

*Table 1 – Indexes used to assess the water quality of Açude da Macela.*

| Index | Parameters | wi | Equação | Classification |
|---|---|---|---|---|
| O-WQI (Dunnette. 1979; Cude. 2001) | Temperature<br>DO<br>pH<br>Ammonia + nitrate<br>Total phosphorus<br>total solids<br>chlorophyll a | | $\sqrt{\frac{N}{\sum_{i=2}^{n}\frac{1}{q_i^2}}}$ | 0-25 = very bad<br>26-50 = bad<br>51-70 = reasonable<br>71-90 = good<br>91-100 = excellent |
| WQIR (IAP. 2014) | DO Deficit<br>Total P<br>total inorganic N<br>chlorophyll a<br>Secchi depth<br>COD<br>Cyanobacteria<br>Time residences<br>Depth | 17<br>12<br>8<br>15<br>12<br>12<br>8<br>10<br>6 | $IQAR=\frac{\sum(q_i w_i)}{\sum w_i}$ | 0 - 1.50 = Not Impacted<br>1.51 - 2.50 = bit run down<br>2.51 - 3.50 = moderately degraded<br>3.51 - 4.50 = polluted<br>4.51 – 5.50 = very polluted<br>> 5.51= extremely polluted |
| CPCB-IQA (Sarkar & Abbasi. 2006) | DO<br>pH<br>chlorophyll a | 0.31<br>0.22<br>0.28 | $\sum_{i=1}^{n} q_i w_i$ | 0-38 = very bad<br>38-50 = bad<br>50-63 = reasonable/good<br>63-100 = good/excellent |

*Table 2 – Weights obtained through the contribution (%) of each parameter for PCs.*

| Parameters | wi |
|---|---|
| Chlorophyll a | 14.0 |
| Colour | 8.0 |
| $N\text{-}NO_3$ | 6.0 |
| $N\text{-}NO_2$ | 12.0 |
| $N\text{-}NH_4$ | 10.0 |
| DO | 5.0 |
| P-PO4 | 4.0 |
| pH | 10.0 |
| Conductivity | 7.0 |
| SS | 11.0 |
| Total solids | 7.0 |
| Water temperature | 6.0 |

## RESULTADOS E DISCUSSÃO

Through an analysis of the correlation matrix shown in Table 3, it was possible to verify the association between the environmental variables, we were able to obtain an overview of the data set, thus enabling us to identify the variables which have greater significance to this study. In Table 4, the basic descriptive statistics are presented.

Table 3 - Correlation matrix

| Variáveis | Chlor. a | Colour | $N\text{-}NO_3$ | $N\text{-}NO_2$ | $N\text{-}NH_4$ | DO | $P\text{-}PO_4$ | pH | Cond | SS | Total solids | W temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chlor. a | 1 | | | | | | | | | | | |
| Colour | **0.770** | 1 | | | | | | | | | | |
| $N\text{-}NO_3$ | **0.527** | 0.006 | 1 | | | | | | | | | |
| $N\text{-}NO_2$ | **-0.526** | **-0.524** | 0.431 | 1 | | | | | | | | |
| N-N $H_4$ | **-0.527** | **-0.565** | **-0.517** | -0.288 | 1 | | | | | | | |
| DO | **0.641** | -0.231 | 0.498 | -0.098 | -0.398 | 1 | | | | | | |
| $P\text{-}PO_4$ | **-0.730** | **-0.770** | -0.475 | **-0.594** | **0.728** | **-0.569** | 1 | | | | | |
| pH | -0.205 | -0.424 | 0.406 | 0.305 | -0.173 | -0.150 | **-0.566** | 1 | | | | |
| Cond | -0.311 | -0.152 | 0.488 | 0.352 | 0.241 | -0.033 | **0.563** | **-0.575** | 1 | | | |
| SS | **0.667** | **-0.607** | 0.392 | -0.307 | -0.203 | 0.374 | -0.406 | -0.194 | **0.652** | 1 | | |
| Total S | -0.203 | -0.395 | -0.205 | -0.209 | -0.043 | -0.137 | 0.135 | 0.179 | **0.505** | -0.395 | 1 | |
| W temp. | -0.189 | -0.123 | 0.156 | -0.005 | 0.083 | -0.236 | 0.131 | 0.063 | 0.229 | -0.196 | -0.034 | 1 |

Table 4 – Descriptive statistics

| Parameters | Mean | Desvio Padrão | Amostras |
|---|---|---|---|
| Conductivity (mS $cm^{-1}$) | 1.67 | 0.63 | 123 |
| Colour (Pt-Co) | 21.48 | 13.28 | 123 |
| pH | 8.56 | 0.39 | 123 |
| Total solids (mg $L^{-1}$) | 1058.02 | 339.64 | 123 |
| Suspended solids (mg $L^{-1}$) | 23.06 | 24.79 | 123 |
| Dissolved oxygen (mg $L^{-1}$) | 5.32 | 2.85 | 123 |
| $N\text{-}NH_4$ (µg $L^{-1}$) | 48.19 | 39.66 | 123 |
| $N\text{-}NO_2$ (µg $L^{-1}$) | 146.92 | 146.31 | 123 |
| $N\text{-}NO_3$ (µg $L^{-1}$) | 1255.96 | 615.88 | 123 |
| $P\text{-}PO_4$ (mg $L^{-1}$) | 415.14 | 200.30 | 123 |
| Chlorophyll a (µg $L^{-1}$) | 59.28 | 63.20 | 123 |
| Water Temperature (ºC) | 28.23 | 1.82 | 123 |

### Application of Water Quality Indexes

Besides being a challenging task, it is necessary to strike a balance between the determined value, the quality of water and the effectiveness of the index by analyzing some water quality parameters. Even when all those pre-selected variables are considered important as quality indicators, some assume different weights because the final destination of the water. Therefore. the Açude da Macela reservoir was evaluated according to the WQIR (IPA), O-WQI, CPCB-WQI and IQAR-m indexes, in order to minimize the subjectivity and improve the credibility of the evaluation of the quality of this water body.

Table 5 – Water Quality Indexes for Açude da Macela

| Indexes | Açude da Macela | Classification |
|---|---|---|
| WQIR (IAP) | 6.00 | extremely polluted |
| O-WQI | 2.16 | very bad |
| CPCB-WQI | 20.13 | very bad |
| WQIR-m | 4.61 | very polluted |

Observing Table 5 and relating the results to the numerical descriptions of the contents found in Table 2, it is possible to notice that the quality of Açude da Macela is classified as extremely polluted, very bad, very bad and very polluted, according to the adjusted indices, with respect to the parameters and calculation formula of WQIR (IAP), O-WQI, CPCB-WQI WQIR-m, respectively.

When comparing the calculation result obtained by WQIR (IAP) and WQIR-m, it is possibe to observe that there was a change on the classification. The reservoir left the extremelly polluted rate to very polluted, this may be attributed to the new weights which were obtained for the environmental variables through principal component analysis, ie, the eclipse effect, which is a result of the easing of the negative behavior of an environmental variable compared to the stable behavior of others, may have been reduced or eliminated.

## CONCLUSION

Regarding the quality of water according to the indicators, it was found that the Açude da Macela reservoir is classified as extremely polluted, very bad, very bad and very polluted according to the water quality indexes RWQI, OWQI, CPCB-WQI, WQI-m, respectively.

The principal component analysis was presented as an important tool to explain the variance of the data set of interrelated variables through a smaller set of independent variables, principal components, and has been instrumental in minimizing the eclipse effect, giving an accurate answer to the assessment of water quality of the Açude da Macela reservoir.

The results of this case study show that it is necessary to adopt measures for the control and reduction of nutrients and organic loads in the water to contain the eutrophication process of this reservoir. In this context, it is essential to monitor the physical, chemical and biological parameters in order to assess the impact of human action on this water resource.

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