

# Carlson's Index and OECD Classification for the Assessment of Trophic Status of Bab Louta Dam

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**Abstract**— The present work attempts to detect trends in the measurements of some descriptors and to determine the trophic status of the Bab Louta dam. To do this, a spatial and temporal follow-up of the evolution of the environmental variables (total phosphorus, transparency) and the biological descriptor chlorophyll (a), was carried out according to a vertical profile at the deepest point of the reservoir, during a year (May 2016 - April 2017). Two methods were used to determine the trophic status of this dam. The first was set up by the OECD (1982), and the second: the Carlson's Index. The data collected during the study year and according to the OECD (1982) model show that the reservoir is eutrophic, in terms of total phosphorus and transparency, and oligotrophic in terms of chlorophyll (a). While according to the Carlson's Index, the reservoir is mesotrophic during the year 2016-2017.

**Index Terms**— Bab Louta dam, quality, physico-chemical, chlorophyll a, Carlson's Index, OECD

## 1 INTRODUCTION

Eutrophication of lakes and reservoirs ranks among the most polluted water pollution problems. It is one of the serious ecological problems for freshwater around the world [1], [2].

Many of the freshwater lakes, streams, and reservoirs in North Africa suffer from nutrient enrichment resulting in increases in algal growth and in particular organic substances, which may cause water eutrophication particularly in stratified deep reservoirs [3], [4].

Morocco is not excepted; the different forms of pollution to which surface water has been subjected in recent years, associated with the arid to semi-arid climate of our regions, have led to a significant enrichment of these waters in nutrients, with the consequent threat of eutrophication of reservoirs. This phenomenon causes an imbalance of the ecosystem with an anarchic development of algae and an intense consumption of oxygen at the bottom of lakes [5].

The characterization of the trophic state or degree of eutrophication of a lake is an essential tool for monitoring the evolution of water quality. Aquatic systems can be classified by trophic status as oligotrophic, mesotrophic, eutrophic or hypertrophic. To classify the different trophic states of the waters, two main types of trophic indicators are used [6]: biological indicators and physicochemical indicators.

The main objective of this study is to provide a complete evaluation of trophic state of Bab Louta dam by evaluating the performance of classically and commonly used models such as the Carlson's Trophic State Index (CTSI) (1977) [7] and the OECD model (1982) [8].

## 2 MATERIAL AND METHODS

### 2.1 Study Area

The Bab Louta dam is a part of the Sebou drainage basin, the impoundment of the dam was carried out in 1999, the main purpose of the dam is the supply of drinking water. The Bab Louta dam is located on the Oued bousbâa, and controls a watershed of 124 km<sup>2</sup>. It is located in an outcrop of the schisto-quartzitic basement, surrounded by clays of the triassic and marly limestones of the Upper Cretaceous. Average rainfall in the catchment area is estimated at 900 mm / year. With its reservoir of 37 Mm<sup>3</sup>, this dam permits to regulate 8 Mm<sup>3</sup> in order to ensure the supply of drinking water to Taza city and the neighboring centers without deficit until 2020 [9].

### 2.2 Sampling and Analysis

The sampling duration of the Bab Louta dam lasted from May 2016 to April 2017. Water samples were taken monthly to bi-monthly on a vertical profile (from the surface to -30m).

Water samples were collected for analysis of two parameters, total phosphorus and chlorophyll a, using a two-liter Van Dorn bottle. The samples were stored in coolers to maintain the temperature at 4 °C and then they are transported to the laboratory.

The analysis of total phosphorus (TP) was made according to the protocol of the water quality control laboratory of ONEP and the standard standards [10], [11]. For chlorophyll a (Chl a), the extraction was made in boiling ethanol (95%), the optical density of the alcoholic extract was read in a spectrophotometer at wavelengths 665 nm and 750 nm. Calculation of the chlorophyll a concentration is done according to the equation of Marker and al. [12].

Transparency readings were performed in situ with a 20 cm Secchi disc (SD) and the values are expressed in meters.

### 2.3 Data Treatment

Trophic status is the biological response to nutrient additions to an aquatic ecosystem [13]. As a result, the classification of a trophic state of a hydrosystem is often evaluated by measuring several criteria such as nutrient abundance, water transparency,

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phytoplankton growth, .... None of these criteria was a direct measure of trophic state per se [7, 8]. This is why we have tried two different methods to evaluate the degree of eutrophication of the Bab Louta dam.

The Carlson’s Trophic State Index (1977) incorporates three variables: chlorophyll a (Chl a), Secchi disc (SD) and total phosphorus (TP).

The Carlson’s Trophic State Index (CTSI) is calculated according to the following equations [7]:

$$TSI(Chla) = 9.81Ln(Chla(\mu g / L)) + 30.6 \quad (1)$$

$$TSI(TP) = 14.42Ln(TP(\mu g / L)) + 4.15 \quad (2)$$

$$TSI(SD) = 60 - 40.41Ln(SD(m)) \quad (3)$$

Where: TSI (Chl a, TP and SD) and Ln represent the individual Carlson trophic state indices and natural logarithm.

The Carlson’s Trophic State is the mean of the three elementary indices previously mentioned.

The system developed by the OECD (1982), widely used internationally, was also chosen to characterize the trophic status of the reservoir. It defines limits for the annual means of total phosphorus, chlorophyll a, transparency (measured by Secchi disc), chlorophyll a peak and Secchi transparency (SD) minimum [8] (Table 1).

**TABLE 1.** Limit values of the water trophic classification system according to the OECD (1982).

	Total Phosphorus <sup>m</sup> (μg/L)	Chl a <sub>m</sub> (μg/L)	Chl a <sub>max</sub> (μg/L)	SD <sub>m</sub> (m)	SD <sub>min</sub> (m)
Ultra-oligotrophic	< 4	< 1	≤ 2.5	> 12	≥ 6.0
Oligotrophic	< 10	< 2.5	≤ 8.0	> 6	≥ 3.0
Mesotrophic	10-35	2.5-8	8-25	6-3	3-1.5
Eutrophic	35-100	8-25	25-75	3-1.5	1.5-0.7
Hypertrophic	> 100	> 25	≥ 75	< 1.5	≤ 0.7

### 3 RESULTS AND DISCUSSION

#### 3.1 Chlorophyll a, Total phosphorus, Transparency

The Chl a concentrations range from 1.15 to 4.42 μg /L, with an annual mean of 2.26 μg /L (Fig. 1), which classifies these waters as excellent quality waters [14].

The Chl a shows significant seasonal fluctuations, the maximum values were observed in summer during the period from June to September, while the lowest values were observed in winter. This could be explained by the conditions that prevail during these two contrasting periods, such as: the stability of the water column, the availability of nutrients, the light and temperature conditions....

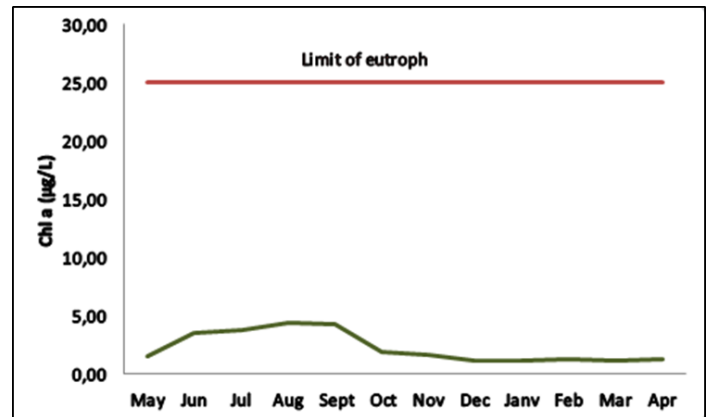


Fig. 1. Monthly variations of Chlorophyll a during the year 2016-2017.

Total phosphorus (TP) levels are well below 100 μg /L, classifying the waters of this reservoir as being of excellent quality [14]. They vary between 42 and 72 μg /L, with an average of 57 μg /L (Fig. 2). The winter period has the highest concentrations of TP occurring throughout the water column, as opposed to the summer period which has lower levels, with a hypolimnion richer in TP (Fig. 2). Indeed, in winter and spring conditions, the sediment behaves like a reservoir by trapping phosphorus. While, in summer and autumn conditions it acts as a source by releasing the fixed phosphates thus stimulating the primary production [15].

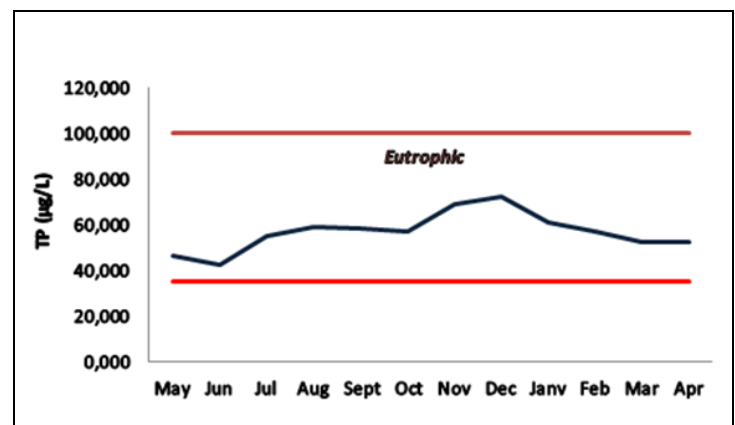


Fig. 2. Monthly variations of total phosphorus during the year 2016-2017.

The values of transparency vary between 2 and 3.8 m, with an average of 2.9 m indicating slightly transparent waters. The most important values were recorded in autumn (October, November) and then fall to record the lowest values in winter (January, February) (Fig. 3), due to the mixing of water during this period, as well as the soil erosion of the basin.

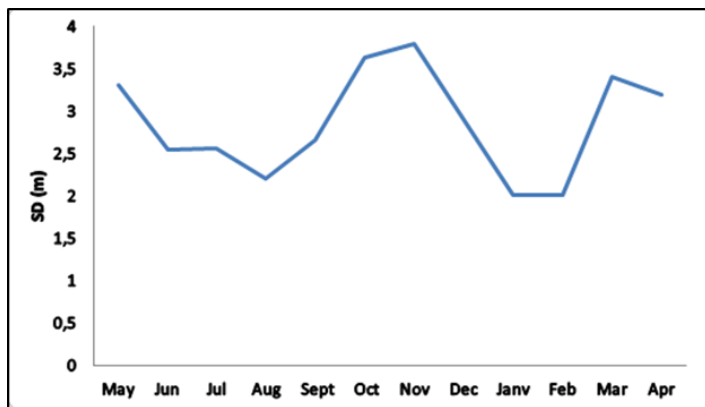


Fig. 3. Monthly variations of transparency during the year 2016-2017.

### 3.2 Trophic Status Assessment

The OECD (1982) [8] model classifies the Bab Louta reservoir, during the year of study, as eutrophic in terms of total phosphorus and transparency, and oligotrophic in terms of chlorophyll (a).

The TP levels evaluate the trophic status of Bab Louta reservoir as eutrophic (Fig. 2), while levels of both Chl *a* entries rank it in the oligotrophic range (Fig. 1). Indeed, [16] suggests that a decrease in TP concentrations indicates an oligotrophic character of a lake. However, several authors have mentioned the role of phosphorus in the eutrophication of aquatic ecosystems and the development of phytoplankton [17], [18].

The annual mean value of transparency (2.9 m) classifies the reservoir as eutrophic, despite its low productivity expressed by Chl *a* entries. This could suggest that the algal development in this reservoir is limited by the transparency of water; this observation has also been mentioned in other works [19].

The Carlson index: The evolution of Carlson's elementary index values (1977), during the study period, shows TSI (Chl *a*) lower than TSI (TP) and TSI (SD) (Table 2).

According to TSI (Chl *a*) values, the Bab Louta reservoir is categorized as mesotrophic in summer (June, July, August, September) and as oligotrophic for the rest of the year. In contrast, the TSI (TP) attribute eutrophic status to the reservoir over the entire study period, whereas TSI (SD) assign mesotrophic status during most of the study period except months January and February (Table 2).

In general, and according to the Carlson index (1977), the Bab Louta dam is mesotrophic during the year 2016-2017.

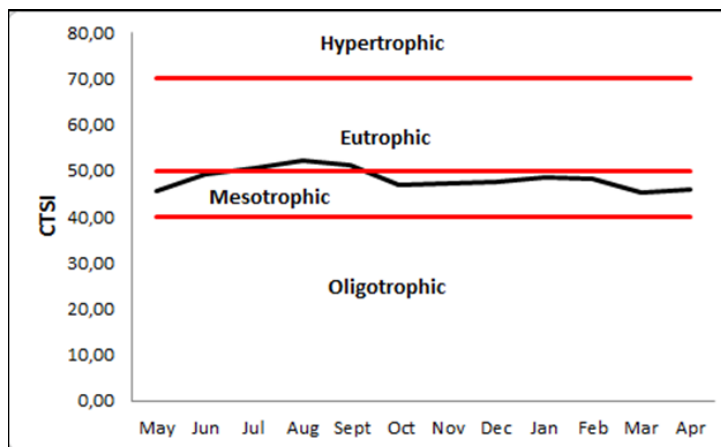


Fig. 4. Monthly variations of CTSI during the year 2016-2017.

### Conclusion

The results obtained during this work show that the waters of the Bab Louta dam have excellent quality in terms of the studied parameters (Chl *a* and TP), with low productivity.

For the two methods used to assess the degree of eutrophication, the transparency and total phosphorus values overestimate the productivity of the reservoir compared with Chlorophyll *a*.

The OECD (1982) model classifies the Bab Louta dam as eutrophic, in terms of total phosphorus and transparency, and oligotrophic in terms of chlorophyll (a). While according to the Carlson Index the reservoir is mesotrophic during the year 2016-2017.

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	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Average
TSI (SD)	42.80	46.51	46.42	48.64	45.88	41.44	40.76	41.66	50.01	50.01	42.37	43.24	45.23
TSI (TP)	59.36	58.05	61.94	62.95	62.70	62.45	65.21	65.02	63.74	60.45	61.13	61.13	62.22
TSI (Chl <i>a</i> )	34.77	42.92	43.69	45.19	44.95	36.61	35.75	31.98	32.10	32.57	32.34	33.01	37.16
CTSI	45.64	49.16	50.68	52.26	51.17	46.83	47.24	47.49	48.51	48.34	45.28	45.79	48.20

The global TSI index, determined by averaging the three elementary indices as stated by Carlson (1977) [7], shows eutrophic water in summer, and mesotrophic during the most part of the study period (Fig. 4).

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