Impact of Climat Change and Human Activity on Water Quality of Babar Dam, Algeria

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Abstract
The quality of surface water has in recent years, a deterioration largely due to a climate change. The objective of this study was to evaluate the impact of a long drought and human activities on water quality in a dam of eastern Algeria, the Babar. To achieve this, a study of the composition of the waters of the dam using the method of trends was performed. The results show that the water has a calcium-magnesium-sulfated facies. They show that most parameters follow negative trends, with the exception of K (41.56%), NO₂ (5%) and NO₃ (35.62%). The use of potash fertilizers and the discharge spills of village waste directly into the dam basin without any prior treatment leads to an increase in K. The increase in NO₃ is mainly due to fertilizer and nitrification of ammonium (-61%), which was accompanied by a decrease in the levels of dissolved oxygen (-7.5%). The decrease in the orthophosphate content (-80%) is due to its low mobility on the one hand, and to the removal of phosphorus on the other hand by the processes of mechanical erosion from the adsorption of the latter by the soil colloids. This approach has shown that drought and anthropogenic activity have a negative impact on the quality of surface water.

Keywords: Dam; Trend method; Anthropic; Nitrification; Algeria
Abbreviations: ANRH: National Water Resources Agency; DCO: Chemical Oxygen Demand; MES: Suspended Matter; CE: Electrical Conductivity

Introduction
In the face of climatic change that has hit the world in recent years, the quality of surface water has also been a major deterioration due to agricultural, urban and industrial development. Many water quality variables are subject to large fluctuations in space and time and understanding these fluctuations in the environment can be a difficult task [1]. The factors of natural influence may be due to changes in precipitation, erosion, alteration of the materials of the earth’s crust or else they are due to anthropogenic action such as urban, industrial and agricultural activities as well as excessive exploitation of water resources [2]. These factors work together to create a type of water whose chemical composition varies in space and time [3]. In addition, in river monitoring, it is often necessary to determine whether a variable should be attributed to natural or anthropogenic causes [4]. According to Hamzaoui-Azzaa et al. [5], knowledge of the geochemical evolution of water quality could lead to effective management of water resources. Thus, the quality of the water is just as important as the quantity. Several studies around the world [6-17] and in Algeria [18-30] are reported on the effects of agricultural, industrial and urban effluents on the quality of surface water. Wadi El Arab controlled by Babar Dam, was built for the supply of potable water and the supply of industrial water and irrigation. The water stored in the basin of this dam is deteriorating in quality due to different types of pollution, in addition to the natural processes of erosion and leaching of various toxic elements. A physicochemical analysis program which has made it possible to build a data bank, which should be analyzed, and to detect significant trends. This study therefore presents details of the fluctuations in the chemical composition of the water of the Babar dam between January 2013 and March 2016. This work makes it possible to understand the hydro chemical behavior of the surface waters of the dam. The trend analysis applied here is determined by linear regression, using the least squares method following the time series of the water quality parameters, it is a simple and easy method to implement.

Materials and Methods
Study zone
The study area is located in the south-east of Algeria, in the eastern confines of the Saharan Atlas and precisely in the mountain range of Djebel Djehfa belonging to the Nememcha Mountains. Most of the inhabitants (more than 20,000 inhabitants) are concentrated in the city of Babar. The surface of the subwatershed is 567km², the dam of Babar has a capacity of 42Mm³, built to retain the waters of Oued Tamagra in the West and Oued El Htiba in the East. The Babar Dam is located at 35° 10’ 10”N and 7° 01’ 41”E and

Civil Eng Res J 5(4): CERJ.MS.ID.555669 (2018)
the town of Babar is located at 35° 10'4"N and 7° 06'7"E (Figure 1). An increase in the population and inadequate domestic sewer systems have potential to influence the water quality of the dam. The Wadi El Arab provides water for nearby cities and irrigates thousands of hectares of farmland. The increase in water demand at the development stage, including agriculture, could lead to a bleak future for the water quality of the dam.

Analytical methods

The trend method was applied to the physicochemical data of the surface waters of the Babar dam during the 39-month period from January 2013 to March 2016. This method allows to acquire representative data on the spatial and temporal variability of the surface water quality of the Babar Dam on Oued El Arab. For this, we used the data of physico-chemical analyses, carried out by the National Water Resources Agency (ANRH) of Constantine. The measured parameters are determined by the ANRH such as: PH, suspended matter (MES), electrical conductivity of water (CE), surface water temperature of Babar Dam reservoir (T), turbidity (crude), organic matter (MO), calcium (Ca²⁺), magnesium (Mg²⁺), sodium (Na⁺), potassium (K⁺), chlorides (Cl⁻), sulphate (SO₄²⁻), bicarbonate (HCO₃⁻), nitrate (NO₃⁻), nitrite (NO₂⁻), ammonium (NH₄⁺), Orthophosphate (PO₄³⁻), biological oxygen demand in Five days (DBO₅), chemical oxygen demand (DCO), dissolved oxygen (O₂ dis), variation of the water reserve at the deduction level (VR). This technique was applied to the instantaneous monthly physico-chemical data of the Babar Dam, during the period from January 2013 to March 2016 using the Excel 2007. And which constitute a chronological series of 39 analyses and 21 variables (Table 1).

Table 1: Statistical characteristics of chemical data from Babar Dam in the long term.

| Paramètres | y=at+b | T % | Min. | Max. | avg  | σ   | CV  | R   | NA |
|------------|--------|-----|------|------|------|-----|-----|-----|----|
| Vr (Mm3)   | W= 0.0011t+20.06 | 3.41 | 30.222 | 38.005 | 35.29 | 35.12 | 0.276 | /   | /  |
| T °C       | T= 0.000.1t + 1.377 | 2.69 | 7 | 32 | 16.9 | 6.88 | 0 | /   | 25  |
| MES mg/l   | C= -0.344t + 29.46 | -42.81 | 8 | 44 | 22.51 | 10.81 | 0.34 | -0.35 | 25  |
| pH         | pH=-9E-0.5t + 11.4 | -1.24 | 7.17 | 8.08 | 7.78 | 0.175 | 0.17 | -0.001 | 6.5-8.5 |
| CE (µs/cm) | C= -0.202t + 97.04 | -17.54 | 1070 | 1400 | 1222.05 | 86.82 | 0.81 | -0.81 | 2800 |
| O₂ disso mg/l | C= -0.001t + 34.5 | -7.5 | 5.7 | 13.6 | 9.63 | 9.61 | 0.12 | 0.6 | 30  |
| MO mg/l    | C= -0.001t + 66.92 | -24.52 | 3.5 | 9 | 6.28 | 6.29 | 0.37 | -0.21 | /   |
| DCO mg/l  | C= -0.003t + 199 | -11.84 | 18 | 48 | 35.64 | 35.66 | 0.184 | -0.24 | 30  |
| DBO₅ mg/l | C= -0.001t + 72.49 | -38.33 | 0 | 6 | 2 | 2.08 | 0.22 | -0.41 | 7   |
| PO₄ mg/l  | C= -4E-0.5t + 1.765 | -80 | 0 | 0.13 | 0.036 | 0.036 | 0.41 | -0.2 | 0.5  |
| NH₄ mg/l  | C= -7E-0.5t + 2.903 | -61.91 | 0 | 0.43 | 0.095 | 0.035 | 0.28 | -0.11 | 0.05-0.5 |
| NO₂ mg/l  | C= 1E-0.6t - 0.015 | 5 | 0 | 0.23 | 0.041 | 0.041 | 0 | 0.21 | 0.1  |
| NO₃ mg/l  | C= 0.0001t - 14.79 | 35.62 | 0 | 9 | 1.74 | 1.8 | 0.071 | -0.04 | 50  |
| HCO₃ mg/l | C= -0.024t + 11.56 | -18.95 | 79.3 | 384.3 | 137.47 | 137.9 | 0.184 | 0.13 | /   |
In this study, we will effectively present trends in physicochemical parameters using a linear regression method. It is a model based on linear least squares equations. Whatever the case, three trend classes have been defined: ‘+’ if a positive trend is detected; ‘0’ if no significant trend is detected; and ‘-’ if a negative trend is observed. The use of this technique thus makes it possible to highlight the possible effects of anthropogenic pollution in the long term. [6]. This goal is also achieved using the moving average that allows a smoothing that eliminates seasonality and minimizes background noise [26]. The method consists in calculating the moving averages by choosing as length, the period of seasonal variations, so as to make them disappear.

Results and Discussion

Characterization of dam water

An examination of the standard deviation and coefficient of variation shows that (Table 1):

- Water, pH, DCO, NO₂, NO₃, HCO₃, Ca and O₂ dis have a small variation (<20%);
- MES, MO, DBO₅, NH₄, SO₄, Cl and Na show a variation around the average oscillated between 20 and 40%;
- The rest of the elements (Turbidity, CE, PO₄, Mg and K) show a strong variation around the average (>40%).

These strong variations resulting from the effluents and the leaching of the grounds following torrential precipitations, badly distributed especially in the time.

The examination of these data also shows that the concentrations of the various elements are below Algerian standards with the exception of:

- SO₄ where 66.6% of the data exceed the standard during the study period;
- NO₂ where 5.12% of the data exceed the standard.
- Turbidity where 36.46% of the data exceed the standard. With maximum values recorded during the year 2013.
- MES where 35.89% of the data exceed the standard. It has a similar evolution as turbidity.

The Piper diagram for these waters shows that the samples have a sulfated-calcium to magnesium facies (Figure 2). The first of the things we noticed between the first campaign (October 2007 to April 2008) and the second campaign (January 2013 to March 2016), no changes were made to the chemical characteristics of the dam’s waters. According to Faurie [31] and Durand [32], calcium can come from inputs of nitrogen fertilizers that participate in the dissolution of carbonates according to the equations 1 and 2 [33].

| parameter | equation | time (m) | 260 | 502 | 407.05 | 407.51 | 0.332 | -0.55 | 400 |
|-----------|----------|----------|-----|-----|--------|--------|------|-------|-----|
| SO₄ mg/l  | C= -0.05t + 2511 | -13.1 | 260 | 502 | 407.05 | 407.51 | 0.332 | -0.55 | 400 |
| Cl mg/l   | C= -0.028t + 1254 | -34.21 | 30 | 205 | 78.33 | 78.58 | 0.373 | -0.07 | 500 |
| Ca mg/l   | C= -0.004t + 334.6 | -4.29 | 81.06 | 169.24 | 137.17 | 138.05 | 0.084 | -0.18 | 200 |
| Mg mg/l   | C= -0.017t + 782.8 | -44.37 | 9.84 | 51.89 | 36.06 | 35.15 | 0.534 | -0.35 | 150 |
| Na mg/l   | C= -0.014t + 674.5 | -22.04 | 19 | 134 | 66.38 | 67.01 | 0.263 | -0.08 | 200 |
| K mg/l    | C= 0.001t - 44.29 | 41.56 | 1 | 5 | 3.86 | 3.87 | 0.437 | 0.51 | 12 |
\[ \text{NH}_4^+ + 2O_2 \rightarrow \text{NO}_3^- + 2H^+ + H_2O \quad (1) \]

\[ \text{CaCO}_3 + H^+ \leftrightarrow \text{Ca}^{2+} + \text{HCO}_3^- \quad (2) \]

The global equation (3) can be written in the following way:

\[ \text{NH}_4^+ + 2O_2 + 2\text{CaCO}_3 \rightarrow 2\text{NO}_3^- + 2\text{Ca}^{2+} + 2\text{HCO}_3^- + H_2O \quad (3) \]

According to the relationship (3), the molar ratio between \( \text{Ca}^{2+} \) and \( \text{HCO}_3^- \) when nitrification is 1. Whereas, according to equation (4), the molar ratio \( \text{Ca}^{2+}/\text{HCO}_3^- \) is equal to 2, when the dissolution of Carbonates is in association with atmospheric \( \text{CO}_2 \).

\[ \text{CaCO}_3 + H_2O + \text{CO}_2 \leftrightarrow 2\text{HCO}_3^- + \text{Ca}^{2+} \quad (4) \]

The surface waters of the Babar dam have a molar ratio \( \text{Ca}^{2+}/\text{HCO}_3^- \) between 1 and 1.5 in 72% of cases and an \( \text{Mg}^{2+}/\text{HCO}_3^- \) ratio are <1 in 100% of cases. This corresponds to the proportion given by equation (3). So the increase of \( \text{Ca}^{2+} \) and \( \text{Mg}^{2+} \) in the water of Babar Dam during the period from January 2013 to March 2016 can be due to the contribution of fertilizers that causes the dissolution of carbonates.

**Variation of the chemistry of dam water**

The linear trend was determined using instantaneous concentrations and time Table 1. The initial and final average values for the period considered allowed us to calculate these variations. It can be seen that for most parameters, the slope differs significantly from zero with the exception of pH, \( 	ext{O}_2 \) dis, \( T \) °C, Ca and \( \text{NO}_2^- \), where the slope is respectively \(-1.24\), \(-7.5\), \(+2.69\), \(+5\) and \(-4.29\). All other parameters have a positive slope that varies between +10 and +108%.

The trend line of the temperature is stable with a very low slope of 2.96%. This small increase is probably due to climate change. The slope of the pH trend line is slightly negative (-1.24%). This reflects the presence of low concentrations of organic matter, where the increase in \( \text{CO}_2 \) pressure leads to a decrease in pH according to the formula proposed by Kempe [34] (5). The salinity of the water represented by the electrical conductivity, it records a negative trend of (-17.57%), this is due to the increase of the volume of water in the dam during the period of sampling.

\[ \text{CO}_2 + H_2O \leftrightarrow H_2\text{CO}_3 \leftrightarrow H^+ + \text{HCO}_3^- \quad (5) \]

The carbonate elements have a slope that differs significantly from zero. They recorded negative trends ranging from -4.29% for \( \text{Ca}^{2+} \), -18.95% for \( \text{HCO}_3^- \) and -44.37% for \( \text{Mg}^{2+} \). These tendencies are related to the equilibrium state of the various minerals in the water and the increase of the water volume of the dam. These variations in carbonate parameters contributed to the decrease in global salinity (CE) by -17.57% and a drop in pH of -1.24% (Figure 3).

![Figure 3: Variation of carbonated elements in water during the period January 2013-March 2016. Continuous trait: data, discontinuous line: moving average, line: linear trend.](image-url)
Figure 4: Variation of salt elements in water during the period of January 2013-March 2016. Continuous trait: data, discontinuous line: moving average, line: linear trend.

Legend

\[ y = at + b \]: Relation: Concentration/time.

T(\%): Trend (\%).

Min.: Minimum.

Max.: Maximum.

Avg.: Average.

\( \sigma \): Standard deviation.

NA: Algerian standards.

CV: coefficient of variation.

The salinity of water is represented by the electrical conductivity and the variation of this parameter makes it possible to follow the evolution of the global salinity and the chemistry of the water. In the long term, there was a decrease of -17.54%, due to the increase in the volume of water in the dam. Salinity can have two origins, either carbonate or salt. To determine this origin, we established the ratio \( \frac{Ca^{2+} + Mg^{2+} + HCO_3^-}{Na^+ + Cl^- + SO_4^{2-}} \) vs CE. The ratio \( \frac{Ca^{2+} + Mg^{2+} + HCO_3^-}{Na^+ + Cl^- + SO_4^{2-}} < 1 \). This reflects the influence of salt minerals on salinity (Figure 5). The increase in the content of the salt elements allows the increase of the salinity. This resulted in a negative trend in the \( \frac{Ca^{2+} + Mg^{2+} + HCO_3^-}{Na^+ + Cl^- + SO_4^{2-}} \) vs CE relationship.

Figure 5: Origin of surface water salinity of the Babar dam.

The electrical conductivity of the different samples shows a good correlation with the elements (Na, Ca, Mg, SO$_4$, Cl) with a correlation coefficient of (0.34, 0.27, 0.43, 0.68, 0.4). These strong correlations indicate the direct contribution of these elements in the salinity of the surface waters of the dam. By tale, potassium (R = -0.1) and bicarbonates (-0.11) do not seem to influence too much the salinity of the water. The dissolution of the carbonated and evaporated minerals is done according to the reactions (6 to 11). [35].

\[
\begin{align*}
CO_2 + H_2O & \leftrightarrow H_2CO_3 \\
H_2CO_3 & \leftrightarrow HCO_3^- + H_3O^+ & (6)
\end{align*}
\]

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Impact of organic pollution

pH and dissolved oxygen showed a respective negative trend of -1.24 and -7.5% Table 1. The oxidation of the organic material according to the reaction 12 or the increase of the CO₂ pressure lead to a decrease in the pH according to the formula 13 proposed by KEMPE [34].

\[
\text{CH}_4 \cdot _0 + \text{O}_2 \rightleftharpoons \text{CO}_2 + \text{H}_2 \text{O} \tag{12}
\]

\[
\text{CO}_2 + \text{H}_2 \text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \tag{13}
\]

The negative trend of NO (24.52%) is in line with the trend of the MES (-42.81%), DCO (-1.08%) and that of the DBO₃⁻ (-38.33%). This can be explained by the installation of conditions of degradation of organic matter by microorganisms. This degradation was accompanied by a decrease in dissolved oxygen of (-7.5%) and a decrease in pH (-1.24%).

Data analysis shows a positive trend for NO₃⁻ (35.62%), NO₂⁻ (5). This is mainly due to the development of intensive agricultural production upstream of the dam and urban discharges [36] into the main stream without any prior treatment. Moreover, this gradual increase in NO₃⁻ concentration corresponds to the yield of nitrification, in the presence of oxygen aerobically according to the reactions (14) and (15) [37]. This oxidation allowed a decrease of oxygen of -7.5%.

\[
\text{NH}_4^+ + 3/2\text{O}_2 + \text{H}_2 \text{O} \rightarrow \text{NO}_2^- + 2\text{H}_2\text{O}^+ \tag{14}
\]

\[
\text{NO}_2^- + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_3^- \tag{15}
\]

This positive trend is also related to the use of fertilizers on these agricultural soils, this has been evidenced throughout the world by El Achheb [38], Fischer et al. [39], Grenz et al. [40], Travi et al. [41] and in Algeria by several authors like Boudoukha et al. [29]. Indeed the form of nutrient is very toxic for both man and the aquatic world. This explains why the release of nitrogen in this form poses a potential risk to the environment [42].

The phosphorus trend (-80%) does not follow the same trend as nitrates and nitrites, this situation can be explained by the immobility of this element on the one hand, and on the other hand, the elimination of phosphorus by mechanical erosion processes from adsorption of the latter by soil colloids [33,43]. It can also concern the regulation of phosphorus concentrations in Wadi waters by several biogeochemical processes such as apatite precipitation [\(\text{(PO}_4\text{)}_3\text{(F, Cl, OH)} \text{Ca}\)] [44] and consumption by aquatic plants [45-48].

Influence of water volume

Looking at the trend line shows a positive trend (+3.41%), as the inputs represented by precipitation are greater than the outputs represented by evaporation. The analysis of the evolution of the volume of water according to the various hydrochemical parameters shows a very significant linear correlation between the volume of water and the parameters with a stronger negative bond (-0.35 to -0.81) for (MES, EC, DBO₃⁻, DCO, Mg), a weak negative bond (-0.001 to -0.21) for (pH, MO, NO₃⁻, Na, Ca, NH₄⁺, PO₄³⁻, Cl) and for the rest positive bonds were recorded such as HCO₃⁻ (-129), NO₂⁻ (0.22) K (0.51), O (0.06). On this basis, it is noted that most of the bonds are significant at the threshold of 10%, except (pH, NO₃⁻, Na, O₃⁻) which highlights either a phenomenon of dilution or concentration depending on the case.

Conclusion

The temporal evolution of physicochemical parameters was monitored during the 39-month period. The results show that most of the parameters follow negative trends, with the exception of K (41.56%), NO₃⁻ (5%) and NO₂⁻ (35.62%). The use of potash fertilizers and the dumping of village waste directly into the dam basin without any prior treatment leads to an increase in K. The increase in NO₃⁻ is mainly due to fertilizer input and ammonium nitrification (-61%), which was accompanied by a drop in dissolved oxygen levels (-7.5%). The decrease of the orthophosphate content (-80%) is due to its low mobility on the one hand, and the elimination of phosphorus on the other hand by the mechanical erosion processes from adsorption of the latter by the colloids of the soil.

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