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RESEARCH ARTICLE

WATER QUALITY OF THE KEBIR WATERSHED, NORTHEAST OF ALGERIA

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ABSTRACT

Water is a natural resource indispensable not only for the maintenance of human life and health but also for the preservation of all ecosystems and economic activities. At the global level, water is threatened in its quality and quantity by various pollutions such as uncontrolled urban and industrial wastes, excessive use of chemical fertilizers and pesticides in agriculture and the exploitation irrationality of this resource. Water quality in Kebir River has been adversely affected by pollutants usually without any treatment. Chemical and physical degradations are due to agricultural and industrial practices and domestic wastewaters. The aim of the present study is to evaluate water quality of the Kebir and Bougous rivers. The physicochemical parameters are analyzed by using the Titrimetry standard procedure and a Spectrophotometer device. The observed values of different physical and chemical parameters like temperature, pH, electrical conductivity, dissolved oxygen, chloride ions, calcium, magnesium, sulfate, nitrite, nitrate, and ammonium have been also performed. Water is sampled at three study sites with four surveys during 2015 and 2016. The results show the existence of a seasonal variation of the physicochemical element concentrations. Also, there is an eutrophication caused mainly by chemical fertilizers used for agriculture. The present findings alert the inhabitant's sanitation of irrigation water and environmental hygiene, where water quality varies from a moderate pollution state at some sampling stations to a very strong pollution downstream. The used parameters can also be useful when searching deeply for pollution causes and when planning preventive measures for protective purpose.

KEYWORDS

Eutrophication, mineralization, physicochemical analysis, surface water, Kebir watershed

1. INTRODUCTION

The water quality of a hydro-system depends on many environmental factors and processes. It is defined more particularly by the geomorphological (altitude, slope, land use, etc…), pedological and geological (origin and nature of the land) characteristics and anthropogenic watershed (degree of urbanization, industrial activities, agricultural). This constitutes a space delimited by a watershed and having its own hydrographic network. Watersheds collect atmospheric waters and concentrate them on the constituent elements of the network [1,2]. During their transfer to the surface of the soil and/or in depth (runoff, seepage…) and then from their circulation in the hydro-system, the waters are subjected to physicochemical and biological processes which condition their composition [3,4].

The construction and operation of the reservoirs affect the stream habitats, riparian vegetation and aquatic fauna at various scales [5,6]. The impoundments of the rivers can directly affect stream ecosystems through alteration of hydrologic regimes and water quality [7-11]. Changes in water quality could affect the aquatic life by altering the habitats which might decrease the primary productivity [12,13]. Therefore, it is important to identify the changes in water quality upon impoundment on how it would affect the aquatic life [14]. Continuous monitoring of water quality is crucial in order to provide the baseline data needed for future reservoir planning and conservation of the water resource from pollution. Water has become a strategic global issue, the management of which must imperatively integrate itself into a political perspective of sustainable development. Some say that it will be, in the third millennium, an issue of wars as oil has been and still is today [15].

A study of characterization and assessment of the Mexa and Bougous reservoirs, located in the Kebir watershed, for water quality is necessary. The advantages of an index include its ability to single number, its ability to combine various measurements in a variety of different measurement units in a single metric and its effectiveness as a communication tool. A physico-chemical study conducted in order to estimate the water quality along the course of the Kebir Wadi and its main tributaries, and within the dam of Mexa. A follow-up of the spatial evolution of the used variables has been developed, based on a seasonal analytical monitoring of three stations spread along the Kebir Wadi.

A water quality index is a mean to summarize a large amounts of water quality data into simple terms (example: good, poor, very poor, unsuitable for irrigation) for reporting to management and public use in a consistent manner. Measurement surveys are carried out during the two years 2015 and 2016.

2. STUDY AREA

The Kebir watershed is located in the northeast of Algeria. This watershed (681 km^2) is distinguished at its outlet by a reservoir called Mexa which has been built in 1999 with a capacity of 47 million cubic meters (Figure 1). The watershed has also two reservoirs constructed upstream from the Mexa dam and which are the Bougous reservoir built in 2012 with a capacity of 27 million cubic meters and Barbara reservoir located in Tunisia with a capacity of 74 million cubic meters. The climate is Mediterranean, with a mean annual rainfall equal to 637 mm. The precipitation data sets have shown that there are rainfall events greater than 30 mm/day during an average of 4 to 5 days/year from November to May during the 20-year period. Local temperatures vary between 28°C and 31°C with a mean annual temperature of 18°C [16].

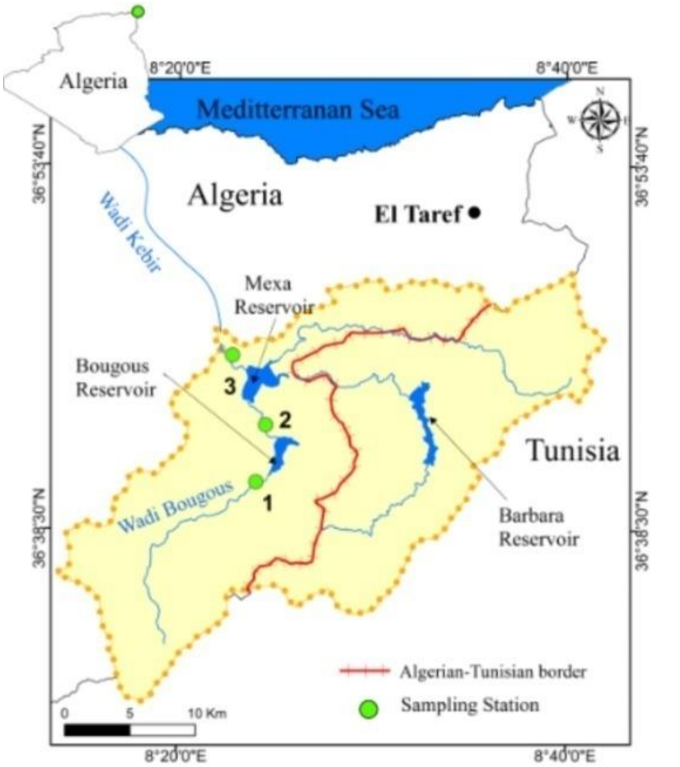

Figure 1: Location map of the water sampling sites in the Kebir watershed.

For the most part, the watershed is composed of weathered Oligocene sandstone and clay rocks that represent as much as 45% of Kebir basin area. The rest of the lithologic formations are constituted of Mio-Pliocene conglomerate and clay, Cretaceous marl and marly limestone [17]. Land use is characterized by intense forest associated with sparse shrubs and grasslands that occupy 43% of the basin area [17]. Dense forests of oak cork and Zeen oak are diffused in the south area of the basin and west of Bougous on poorly developed soils (Figure 1). Shrubs (Oleo-lentiscus and Erica europa) with an open canopy, covering 19% of the Kebir area, are damaged by livestock and fires during the summer season. Most of the agricultural land is cropland and pasture and tends to be especially in the northeast part of the study area.

3. METHODOLOGY

Water samplings have been carried out at sites according to a plan based on the search of the most polluted sources. This is why we have chosen 03 main sites: one site upstream from the basin outlet (site 1) and the two sites are located upstream and downstream of the Bougous reservoir, respectively sites 1 and 2 (Figure 1). The geographic coordinates of the sampling sites are indicated in Table 1.

Table 1: Sampling sites location in the Kebir watershed.

Sites	Latitude	Longitude	Elevation (m)
S1	N 36°39.14'	E 8°22.02'	202
S2	N 36°42.62'	E 8°24.45'	67
S3	N 36°45.96'	E 8°21.99'	31

Water sampling along the Kebir Wadi (Figure 1), on three stations, during the hydrological year (2015/2016) have allowed to make four measurement campaigns on January 2015, April 2015, January 2016 and May 2016.The water samples have been taken and introduced into polyethylene bottles previously rinsed with stream water at each site. They have been then stored at 4°C during transport to the laboratory where they have been analyzed within next 24 hours from sampling [18].

The parameters recorded in situ using a device called a multiparameter (Hanna Instruments HI 9828) are as follow: pH (hydrogen potential), temperature (T), electrical conductivity (EC) and dissolved oxygen (O_2). Moreover, the chloride ions (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), nitrite (NO_2^-), nitrate (NO_3^{-2}), and ammonium (NH_4^+) have been analyzed in the Laboratory of Soils and Sustainable Development, Department of Biology, Badji Mokhtar University-Annaba.

According to standard methods, the different analyzes have been executed using the following methods and devices: a- Chloride ions: using a Titrimetry at the $AgNo_3$; b- Calcium and Magnesium: using an EDTA Titrimetry; c- Sulfate: utilizing a Gravimetric to $Bacl_2$; d- Nitrite: utilizing a Spectrophotometer and the method used for the dosing is that of the Zembelli Reagent; e- Nitrate and Ammonium: using a Spectrophotometer and the method used for the analysis of nitrate is that of the sodium salicylate one [19].

4. RESULTS

Water quality depends on natural factors (soil, subsoil, etc ...) and human activity (domestic and industrial agriculture) producing wastes that are directly or indirectly rejected in the aquatic environment. Water quality is defined according to four quality classes determined from a double-entry table of ANRH (quality class/measured parameters), and which included some parameters that are important, but the latter does not cover all forms of pollution. This is completed by another procedure to reveal the risk of eutrophication using two other elements (nitrogen and phosphorus).

In addition, it is useful to take into account biological criteria such as the global biological index (G.B.I) which are essential for mentioning specific problems in available data and that are determined from the ANRH analysis [20]. Thus, here are the classes for water quality definition (Table 2):

* Class I: Good quality water, used without special requirements.

* Class II: Medium quality water, used after a single treatment.

* Class III: Water of poor quality, can only be used after a very thorough treatment.

* Class IV: Excessive pollution can only be used after specific treatments and it is very expensive.

Table 2: Table representing the norms of water quality.

Parameter / Quality	I	II	III	IV
Mineral Quality				
Ca^{2+} (mg/l)	40-100	100-200	200-300	> 300
Mg^{2+} (mg/l)	< 30	30-100	100-150	> 150
Cl^- (mg/l)	10-150	150-300	300-500	> 500
$SO4^{2-}$ (mg/l)	50-200	200-300	300-400	> 400
Organic Quality				
O_2 (mg/l)	4-6	4-3	3-2	> 2
No_3^{2-} ; No_2^- ; NH_4^+				
NH_4^+ (mg/l)	< 0.01	0.01-0.1	0.1-3	> 3
No_2^- (mg/l)	< 0.01	0.01-0.1	0.1-3	> 3
No_3^{2-} (mg/l)	< 10	10-20	20-40	> 40

Source: National Agency of Hydraulic Resources (ANRH).

The physicochemical analysis of the waters of Kebir Wadi and its tributary (Bougous Wadi) has shown that the levels of the chemical elements and their relation are different from one point to another. The diversity of their composition is directly influenced by the nature and origin of agricultural and urban wastes.

pH is a parameter to measure the acidity, alkalinity or basicity of water [21]. Figure 2a has shown that the pH measured at all sites ranged from 7.16 (site 3) to 7.19 (site 2) with an average of 7.16 during humid periods and between 8.06 (site 1) and 7.40 (site 3) with an average of 7.82 during dry periods, which generally reflects a slightly neutral to basic water character.

The temperature "T°" parameter governs almost all physical, chemical and biological reactions [22]. This temperature acts on the density, viscosity, solubility of gases in water, dissociation of dissolved salts, as well as on chemical and biochemical reactions, development and growth of organisms living in water and particularly Microorganisms [23]. The temporal evolution of water temperature has been distinguished by maximum values in the dry season and minimum ones during wet season. Figure 2b has shown that the temperature varies from 20.04 °c (site 3) to 19.88 °c (site 2) with an average of 19.97 °c during the dry period, but during the wet period it varies from 11.28 °c (site 3) to 8.29 °c (site 2), with an average of 9.98 °c. It is noted that the waters of Kebir Wadi are directly influenced by the air temperature.

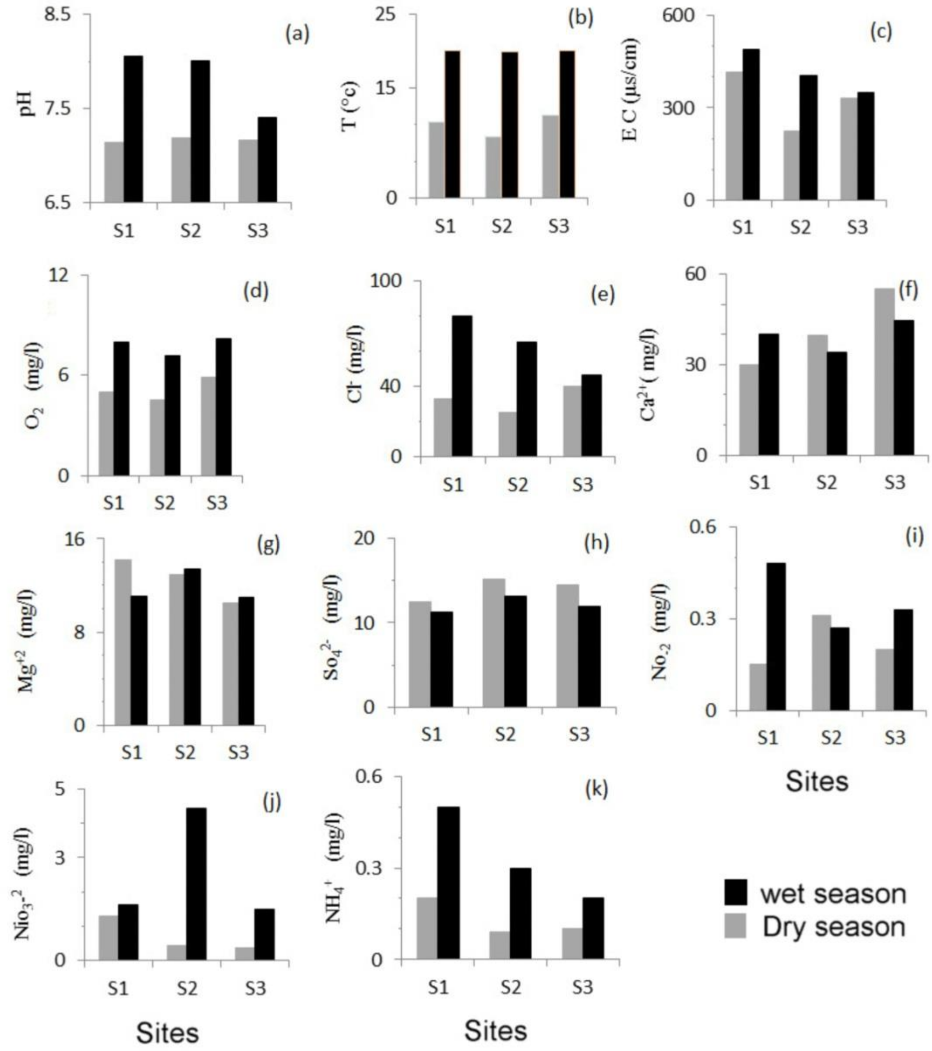

Figure 2: Physicochemical parameters of water in Kebir Wadi at three sites: a) hydrogen potential, b) temperature, c) electrical conductivity, d) dissolved oxygen, e) chloride ions, f) calcium, g) magnesium, h) sulfate, i) nitrite, j) nitrate, k) ammonium.

Concerning the conductivity (Figure 2c), it is higher in sites S1 and S2 during dry periods. On the other hand, it becomes higher in sites S1 and S3 during wet periods. Furthermore, the conductivity values at the three sites and through the two periods do not exceed (500 µs/cm). It is noted that the conductivity is low during wet periods with an average of 323.5 µs/cm and high in dry periods, with a value equal to 415 µs/cm. These values clearly show that the waters of the Kebir and Bougous wadis, and their related reservoirs have a moderate mineralization (Table 3).

Table 3: Mineralization classes based on the conductivity.

Conductivity	Mineralization
Conductivity<100µS/cm	very low
100µS/cm <Conductivity<200µS/cm	low
200µS/cm <Conductivity<333µS/cm	moderate
333µS/cm <Conductivity<666µS/cm	medium accentuated
666µS/cm <Conductivity<1000µS/cm	important
Conductivity>1000µS/cm	high

Source: Rodier et al. [18]

The quantification of the concentration of dissolved oxygen in water from a hydro-system is a fairly important factor in that it participates in the majority of chemical and biological processes in these aquatic environments [24]. Recorded levels range from 4.50 mg/l (site 2) to 5.86 mg/l (site 3) with an average of 5.13 mg/l during humid periods and 7.16 mg/l (site 2) at 8.19 mg/l (site 3) with an average of 7.76 mg/l during dry periods. Indeed, it is site 3 which has the highest concentration. The waters of this wadi can be classified in the category of well oxygenated water.

Chlorides are important inorganic anions contained in varying concentrations in natural waters, usually in the form of sodium (NaCl) and potassium (KCl) salts. They are often used as a pollution index. They have an influence on aquatic flora and fauna and on plant growth [25]. The values obtained range from 80.36 to 46.79 mg/l during the dry periods, and from 40 to 25 mg/l during the wet periods. The maximum values are observed at site 1 and site 2 in dry periods (Fig. 2e). Temporal evolution is marked by a slight lowering of chloride levels during the wet season compared to the dry season.

The calcium concentrations are below the water standard (100 mg/l) in all sites. According to Figure 2f, the Mg^{+2}level during the wet periods is 14.15 mg/l at site S1 and 10.5 mg/l at site 3. During the dry periods, the values range from 11 mg/l at site 3 to 13.11 mg/l at site 2. All these values remain below the standards of potability (50 mg/l) in the three sites (Figure 2g).

In addition, The presence of sulphate ions in water is related to the dissolution of gypsum formations on the one hand, and to pesticides from irrigation waters on the other hand [26]. The sulphate concentrations are ranging from 15.22 mg/l (site 2) to 14.5 mg/l (site 3) during the winter season and from 11.93 mg/l (site 3) to 13,18 mg/l (site 2) during the dry season. Temporal variation of sulphates has shown that all water points are lower than the values reported in table 1 with values of 250 mg/l and the standards of potability (Figure 2h).

Nitrates are naturally present at concentrations of a few milligrams per liter of water, which are highly soluble pollutants and represent the most oxidized form of nitrogen [27]. Analysis of nitrate concentrations has shown that the highest amounts are recorded at site 2 with 4.44 mg/l during the dry periods and at site 1 with 1.62 mg/l during the wet periods (Figure 2j). However, the lowest values are recorded at site 3. Averages range from 0.70 mg/l during the wet season to 2.51 mg/l at the dry season. The values remain below the permissible value by the water standards (10 mg/l). As a result, the studied waters are not subject to punctual pollution by nitrates.

Nitrites are a dangerous poison for aquatic organisms, even at very low concentrations. Its toxicity increases with temperature. They cause degradation of hemoglobin in the blood of fish that can no longer convey oxygen. The result is death by asphyxiation [28]. For the mean concentrations of nitrites, it is shown that they are between 0.15 and 0.48 mg/l at the three sites (Figure 2i).The presence of nitrites is observed with high levels that exceed the water standards (0.01 mg/l) at the Kebir and Bougous wadis for most of the period; this is due to the urban organically wastes from agglomerations such as detergents used in household activities, leaching of soils rich in animal and human feces and the effect of oxidation of the ammonium form. Ammonium ions usually translate an incomplete chemical and micro-biological degradation process of organic matter. It may be considered an excellent indicator of pollution in surface waters by agricultural or domestic waste. Figure 2k shows that the highest values exceeding the water standards are marked in S1 and S2 with values reaching 0.9 mg/l. This can be explained either by the reduction of the nitrogenous forms (nitrate and nitrite) or by the contamination of the wadis water (eg. urban rejection and agricultural leaching).

5. DISCUSSION

The chemical composition of a water plays an important role in determining its quality, for its attribution to drinking water supply or other uses such as: irrigation, industry... etc. The wet season is characterized by very low temperatures and high precipitations, which explains the phenomenon of dilution of pollution elements in aquatic environments. The dry season is known by the rarity of the rains whose temperatures reach their maximums. Thus, the phenomenon of concentration of pollution elements (such as organic parameters) in aquatic environments should be dominant.

Regarding the parameters of the mineral quality (Ca^{2+}, Mg^{2+}, Cl^{-} and SO_4^{3-}) in both wet and dry periods, the sampling sites have values that do not exceed the norms, and which have been mentioned in the results section. The classification of organic quality towards dissolved oxygen shows that the samples have lower concentrations than the standard of 2 to 3 mg/l and belong to Class III, showing water of poor quality. This can be explained by a decomposition of large quantities of organic matter in this aquatic environment.

With regard to ammonium, the sampling sites (S1, S2 and S3) present a notable classified pollution during the dry periods. In contrary, the wet periods are characterized by two classes of moderate pollution for the sites 2 and 3, which represent the Kebir and Bougous wadis, and notable at site 1 upstream of Bougous Wadi. According to Nisbet and Verneaux, ammoniacal nitrogen exists in waters rich in decomposing organic matter when the oxygen content is insufficient to ensure mineralization [29].

Considered as a toxic element, nitrites are the least stable form in the nitrogen cycle. They come from the reduction of ammonium NH^{+4}. In the study area, the sampling sites (S1, S2, and S3) are characterized by various levels of concentration between 0.1 mg/l and 0.3 mg/l for dry and wet periods. Therefore, the sites are subject to a significant pollution, certainly due to the effect of the oxidation of the ammonium form. Indeed, their origin is linked to pesticides or urban wastes. Meanwhile, the nitrate levels are below the recommended water standards by Algeria (10 mg/l) and therefore the sampling sites have a good quality of water.

6. CONCLUSION

The study of the chemical quality of the Kebir stream water has allowed us to appreciate its chemical quality, which is an essential part of our study. The quality of the surface water of the Kebir Wadi is essentially dependent on external factors knowing that there is not a sewage treatment planning in this region, mainly the spills of urban waters. There is also the intensive use of chemical fertilizer in agricultural activity. Comparison of the contents of the main elements measured in the surface waters of the watershed at the sampling sites and the Mexa dam indicate eutrophication of agricultural origin. Moreover, the various analyzes carried out on the water samples of the Kebir watershed has allowed to identify the behavior of certain physicochemical parameters regarding the quality of water in the two main wadis and reservoirs.

The temporal variation of the mineral pollution at the three sites has shown low concentrations of calcium, magnesium, sulfate, and chloride during both dry and wet periods, with significant organic pollution. In fact, the medium becomes reductive (fall in oxygen levels) due to a significant load of phosphate, nitrite, ammonium leached away by irrigation from the agricultural lands (chemical fertilizer and pesticides) and urban wastes.

A global evolution of pollution origins of surface-waters of the two study during periods of dry and wet weather has been established. Discharges of urban waste water and leaching of agricultural soils in the watershed can be considered as the main sources of nitrogen and organic pollution of the streams. The comparison of the different levels of the main elements taken and analyzed from the surface waters of the Kebir and Bougous wadis at the selected sampling sites indicate a eutrophication of an agricultural origin.

Highest priority should be given to water quality monitoring and indigenous technologies should be adopted to make water fit for irrigation and domestic purposes. The watershed management can be combined with any other sub-indices to determine priority conservation areas.

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