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# SPATIAL EVOLUTION OF SURFACE WATER QUALTE, WADI KEBIR WATERSHED (North-East ALGERIA)

**Halima BOUDRA[1*], A. DROUICHE[2], F. ZAHI[2], F. BOUAICHA[1], W. MELOUAH[3], M. BOUKHATEM[1]**

*[1]Geology and Environment Laboratory, University of Constantine 1, Road Ain El Bey Zouaghi Slimane Constantine, Algeria*
*[2]Geological Engineering Laboratory (LGG), Mohammed Seddik Benyahia University, BP 98 Ouled Aissa Jijel, Algeria.*
*[3]Laboratory of Underground Oil, Gas and Aquifer Reservoirs, Faculty of Hydrocarbons, Renewable Energies and Earth and Universe Sciences Kasdi Merbah University, Ouargla, Algeria.*
*Corresponding author: halimaboudrahydrogeologie@gmail.com

***Abstract:*** *Wadi Kebir which represents the downstream part of the Kebir-Rhumel watershed, is characterized by a dense hydrographic network, a rainfall varies from more than 600mm/year in upstream (Beni Haroun dam) to more than 1000mm/year at the mouth of wadi Kebir (Ledjnah region). Its waters present a resource for drinking water supply (upstream part), as well as for agricultural development in the downstream plains. The objective of our research work is to determine the quality of the raw water of wadi Kebir and its tributaries. A total of ten samples were taken during the period of high water (April 2017): six samples on the tributaries of the wadi and four samples in the waters of wadi Kebir from upstream to downstream. The physico-chemical parameters of the water (T, pH, EC) were measured in-situ, the major elements ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, K+, $HCO_3^-$, $SO_4^{2-}$, $Cl^-$) and the indicators of pollution ($NH_4^+$, $NO_2^-$, $NO_3^-$, $PO_4^{3-}$) were analyzed at the Geological Engineering Laboratory (LGG). The results obtained show an organic pollution of the waters of Wadi Kebir and its tributaries with levels in the range of 0, 16 to 4, 72 mg/l in ammonium and 0.005 to 3, 67 mg/l in nitrite. The electrical conductivity varies from 1306 to 3460 s/cm indicating charged water. However, it remains below 1080 s/cm for the tributaries. The surface waters of the Wadi Kebir watershed are more or less alkaline (8, 19 - 8, 67). The most dominant hydrochemical facies is bicarbonate calcic-magnesian with minor hydrochemical facies such as sulfate-sodic-magnesian. Its chemistry is controlled by the weathering of the geological formations that characterize the watershed. The Organic Pollution Index (OPI) revealed a degradation of the water quality fromupstream to downstream, especially after the passage of the wadis through the different agglomerations such as those of Elmilia and Djamaa.*

***Keywords:*** *Surface water, Wadi Kebir Watershed, Facies, Pollution, Electrical conductivity, Elmilia.*

## INTRODUCTION

Algeria, like all Mediterranean basin countries, has endured from water stress as a result of climate change and urban and demographic development. The population growth and urban expansion, the development of industrial units and intensive agricultural activities contribute to a rise in the need for water and a degradation of its quality [1]. Earlier studies in different parts of the world [2-5] and Algeria [6-10] have indicated the influence of anthropogenic activities on the surface water quality andits changing scenario

Wadi Kebir is considered an important water resource for the different types of activities along the wadi, particularly urban, agricultural and industrial activities. However, the latter constitute riskfactors through its uncontrolled discharges. The objective of our work is to study the spatial evolution of the physicochemical quality of surface waters of Wadi Kebir and its tributaries. In order to assessthe current status of the physicochemical quality of water, characterize the quality of water tributaries, and define the risks of the impact of anthropogenic activities on these waters.

## MATERIALS AND METHODS

### Study area

Wadi Kébir is considered as the downstream part of the Kebir-Rhumel watershed, occupying 12.78% of the total area. The latter is located in the eastern part of Jijel, with a length of 47.45 km. It is fed by the dam of Bani Haroun. The wadi Kebir crosses several urban, industrial and agricultural areas from its upstream to its mouth in the Mediterranean Sea. The watershed of wadi Kebir is characterized by a dense hydrographic network, in which five wadis flow, the most important of which are wadi Boussiaba and wadi Mechta. The climate in the study area is Mediterranean, with rainfall ranging frommore than 600 mm / year upstream (Bani Haroun Dam) to more than 1000 mm / year at the mouth of the wadi Kebir (Ledjnah region).
From the geological point of view, the Wadi Kebir crosses several geological formations, from south to north (Fig. 1), the Tellian domain in the south, the domain of the Kabyle flysch in the center, and the Kabyle domain and the terrain it supports in the north [11].

### Sampling and analysis techniques

The concentration of different physico-chemical parameters was known using 10 water samples taken along the wadi during the month of April 2017. Four samples were collected from Wadi Kebir and two samples from each tributary, one upstream and one downstream. The processing and preservation of the water samples were carried out according to the general guidelines [12]. The choice of sampling stations (Fig. 2) was made according to the level of human and industrial activities.
Parameters such as temperature, electrical conductivity (EC), redox potential (Eh), and hydrogen potential (pH) were determined in situ using a Multi 350i portable meter. The concentrations of Ca2+, Mg2+, Na+, K+, Cl-, HCO3-, NO3-, NO2-, NH4+, and PO43- were determined according to standard methods suggested by Rodier [13]. The error of the ion balance should be less than ±5% for a good measurement. But for surface waters, up to ±10% ion balance error (IBE) is acceptable [14-15].

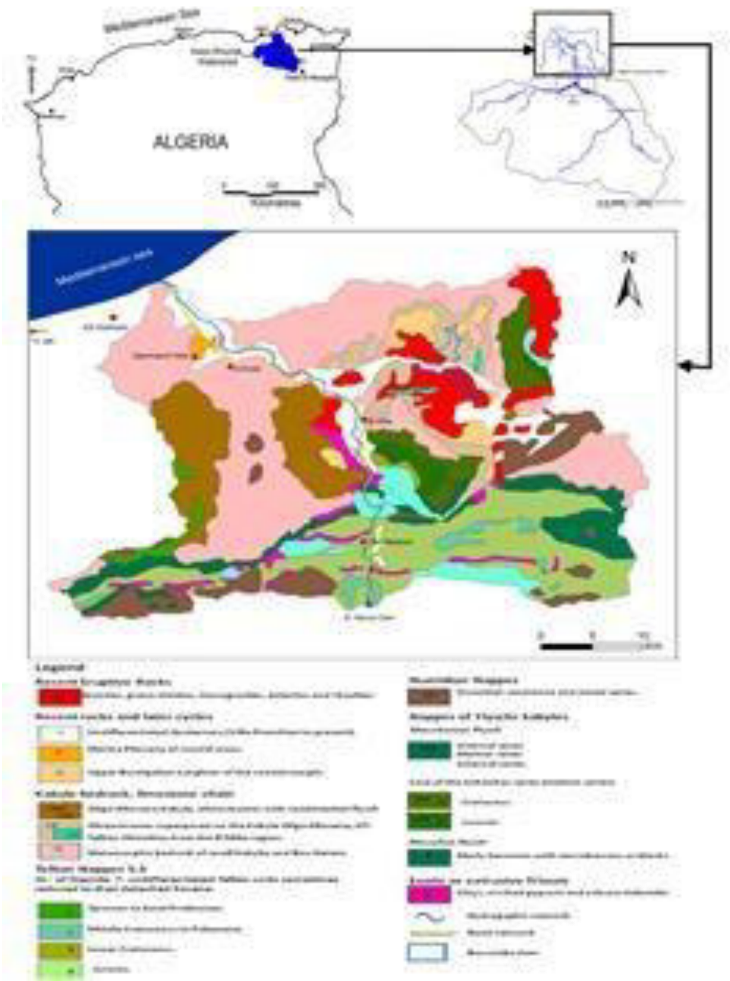


Figure 1. Geographical and geological location of the study area


Figure 2. Inventory map of sampling point

## RESULTS AND DISCUSSION

### General hydrochemistry

The results of the physicochemical analyses of the surface waters of Wadi Kebir and its tributaries (April 2017) in terms of maximum (max), minimum (min), standard deviation (SD) and averagevalues are presented in Table (1).

pH is related to the buffer system developed by carbonate, bicarbonate and carbonic acid, etc. [16]. The water of all Wadis is found to be alkaline, (8.19 - 9.07), this could be explained by the geological nature (limestone, dolomite, marls and flysch) the land crossed, and the domestic discharges of the different agglomerations. The temperature of the different stations varies between 18.96 and 25.5°C, this is due to the time of the temperature measurement and the variation of the air temperature. EC was found varied between 351 and 3410µS/cm (average is 1416.1 µS/cm). The highest values of electrical conductivity were recorded at Kebir wadi are interpreted by the combined effect of the contribution of the Beni Haroun dam [6] and the dissolution of evaporite formations in the upstream part of its watershed [10].

The decreasing order of abundance of the major cations was observed as $Mg^{2+}$ > $Na^{+}$> $Ca^{2+}$ and almost all the samples did not exceed the maximum acceptable concentration of $Mg^{2+}$ for drinking water (50mg/L) except for the waters of Kebir center wadi (S4) which present contents exceeding the standard admissible limit because of the contributions of Boussiaba wadi rich in $Mg^{2+}$.

Table 1. Statistical parameters of the chemical elements in Kebir wadi

| Parameters | Unit | Min. | Max. | Mean | SD |
|---|---|---|---|---|---|
| EC | µS/cm | 351.00 | 3410.00 | 1416.1 | 1060.78 |
| pH | / | 8.19 | 9.07 | 8.501 | 0.23 |
| T | °C | 18.96 | 25.50 | 21.24 | 2.12 |
| Eh | mV | -24 | 282 | 216.60 | 84.73 |
| $NH_4^+$ | mg/L | 0.16 | 4.72 | 1.16 | 1.32 |
| $NO_2^-$ | mg/L | 0.005 | 3.67 | 0.56 | 1.06 |
| $NO_3^-$ | mg/L | 0.33 | 2.92 | 1.16 | 0.80 |
| $PO_4^{3-}$ | mg/L | 0 | 3.63 | 0.47 | 1.06 |
| $Ca^{2+}$ | mg/L | 8.01 | 73.74 | 40.08 | 18.02 |
| $Mg^{2+}$ | mg/L | 15.36 | 57.6 | 32.16 | 14.51 |
| $Na^+$ | mg/L | 19.9 | 104.1 | 56.63 | 32.71 |
| $K^+$ | mg/L | 4.8 | 17.5 | 8.27 | 3.46 |
| $HCO_3^-$ | mg/L | 73.2 | 336.72 | 210.32 | 72.10 |
| $SO_4^{2-}$ | mg/L | 11.83 | 306.05 | 129.53 | 119.84 |
| $Cl^-$ | mg/L | 33.72 | 111.82 | 67.09 | 28.30 |

The decreasing order of abundance of the major anions was determined $HCO_3^-$ > $SO_4^{2-}$ > $Cl^-$. The concentration of anions in all samples did not exceed the maximum acceptable limit as prescribed for the drinking water. The dominant elements give a global facies of bicarbonated magnesium type. This facies reflects the presence of carbonate formations (limestone, marl, cipolin and shale).

The redox potential ranged from -24 to 282 mV which indicates an oxidizing-reducing environment.

High values of ammonium (0.16 - 4.72 mg/L), phosphate (0.00 - 3.63 mg/L), nitrite (0.005 - 3.68 mg/L) and bicarbonates (73.2 – 336.72 mg/L), linked to urban discharges that flow directly into these wadis during their passage by the main agglomerations of the region [7], and to the rejections of the Elmilia tannery (1.46 $mgL^{-1}$ in ammonium and 0.83 $mgL^{-1}$ of nitrite) at the Kebir wadi station before confluence.

The upstream waters of the wadis Ardjanna and Djamaa have similar physicochemical characteristics; an oxidizing medium with an Eh varied between 204-269 mV, whereas the electrical conductivity as (351-479 µS/cm), which is indicating low mineralization. The concentrations of nitrates (0.57 to 4.39 $mgL^{-1}$), nitrites (0.005 to 0.02 mg/L) and ammonium (0.16 to 0.29 mg/L) were found to be low. These nitrogenous compounds are related to the degradation of organic matter (vegetation cover that covers the mountains of its sub-watersheds).

**Organic Pollution Index (OPI)**

This indicator is calculated by integrating the concentrations of four chemical parameters associated with organic pollution: biological oxygen demand ($BOD_5$), ammonium ions ($NH_4^+$), nitrites ($NO_2^-$) and phosphates ($PO_4^{3-}$). The value of the OPI index varies from 1 to 5 (5 corresponds to the best quality). The contents are divided into (05) five categories of organic pollution index. After determining the class of each pollutant, an average is made to characterize the pollution.

After the calculation of the organic pollution index (OPI) for each station (April 2017), we proceeded to the graphical representation of the OPI, in order to facilitate the interpretation

According to the map (fig.3) during the period April 2017 we recorded a moderate OPI at the station S1 (wadi Kébir upstream) due to the influence of the agglomerations that are upstream of the study area, particularly the agglomeration of Sidi Maarouf, this index becomes strong after the passage of the wadi through the industrial area of Bellara and the upstream part of the agglomeration of Elmilia. At the station S4 (wadi Kébir center) the OPI is always strong because of the combined effect of the discharges of agglomeration of Elmilia and the contributions of wadi Boussiaba characterized by a strong OPI.

Figure 3. Map of the spatial evolution of the organic pollution index in April 2017

At station S10 (Oued Kébir downstream) the OPI becomes moderate despite the confluence of Wadi Kebir with Wadi Ardjanna which presents a strong OPI and wadi Djamaa with a very strong OPI this is due to the self-purification power of Wadi Kebir. The wadis Ardjanna and Djamaa are characterized by a low OPI in these upstream parts (virgin areas). Then we note a degradation of water quality after the passage of these wadis by the agglomeration of ElAncer for wadi Ardjanna (high OPI) and the agglomeration of Djamaa for wadi Djamaa (very high OPI).

## CONCLUSIONS AND RECOMMENDATIONS

Wadi Kebir is considered as one of the sources of drinking water supply for the upstream part of its watershed, as well as for the agricultural development in the plains of the downstream part. Thequality of surface water of Wadi Kebir and its tributaries are a function of several factors, physical, chemical, biological and lithological.

The determination of the chemical facies of the waters of the study area, showed the predominance of the facies Bicarbonate calcic-magnesian and sulphate sodium, organic elements. The organic pollution index map shows a strong to very strong OPI downstream of the tributaries. However, it is weak to null upstream of Wadi Kebir and its tributaries, which explains the impact of anthropic activities that cause a risk of alteration of water quality, which draws the alarm bell as to the protection of this resource and the limitation of discharges by the installation of wastewater treatment plants, especially for urban and industrial areas, and to educate farmers in agricultural areas to reduce the excessive use of fertilizers and pesticides.

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