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CARTOGRAPHY OF THE MICROBIOLOGICAL QUALITY INDEX OF SPRING WATERS IN THE KALLE WADI SUB-BASIN IN EL TARF REGION, EXTREME NORTH EAST OF ALGERIA

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Abstract: *Nowaday, water is threatened by pollution due to a similar degradation of hydric resources. The knowledge about water quality is an essentialcondition allowing the establishment of a management system, that will contributeto guarantee water supply in the future. The purpose of this work is to determine the physico-chemical and bacteriological quality of spring water, takenfrom the sub-basin level of the Kallewadi in El Tarf region, located in the extreme north east of Algeria.*

In order to monitor its water quality, we have chosen four sampling sources distributed in the Kallewadi sub-basin. The sampling was carried out during a period of four months extending from February to May 2019. The results show that all physicochemical parameters meet the current standards. As for the bacteriological analyses, they show the absence of all pathogenic germs.The calculation of microbiological contamination index confirms the absence of degradation in water quality inwhich contamination is null.The results are visualized by using GIS via the realization of thematic map, which were elaborated to have an idea about the quality of the studied spring water; these maps show an excellent quality.

Key words: *sub-basin, wadi, Kalle, sources, bacteriological, index, GIS, map, excellent quality.*

1. Introduction

Water is a natural resource that is becoming increasingly scarce. It is part of the patrimony of a nation and also of humanity. The protection, enhancement and development of resources that can be used within the framework of natural balances are of general interest in the world. We must ensure the respect of this noble principle and consider water as an economic and social good, whose access is a right for each person. Water is necessary for the development of all life forms, animal or plant. It is essential to ensure preservation of this vital supply from the qualitative and quantitative viewpoints. In order to do this, we must ensure sustainable management of this resource and preserve the environment, in which water is in continuous interaction.

For several decades, in Algeria, animal, agricultural, industrial and domestic dejections have contributed, more and more to rivers and groundwater pollution than elsewhere.

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In recent years, a lot ofresearches have focused on the study of groundwater and surface water resources quality.
The present work comes in addition to other works and deals with the physico-chemical and bacteriological quality of spring water taken from the Kallewadi sub-basin in El Tarf region. The latter, mainly agricultural region is located in the extreme North-East of Algeria.

1.1. Geographic location of the study area

The study area which is the Kallewadi Coastal sub-basin coded as 03-18 [1 - 2], extends from 8°13′3″ to 8°41′4″ East longitude, and from 36°46′43″ to 36° 56′33″ North latitude. It is limited (fig. 01):

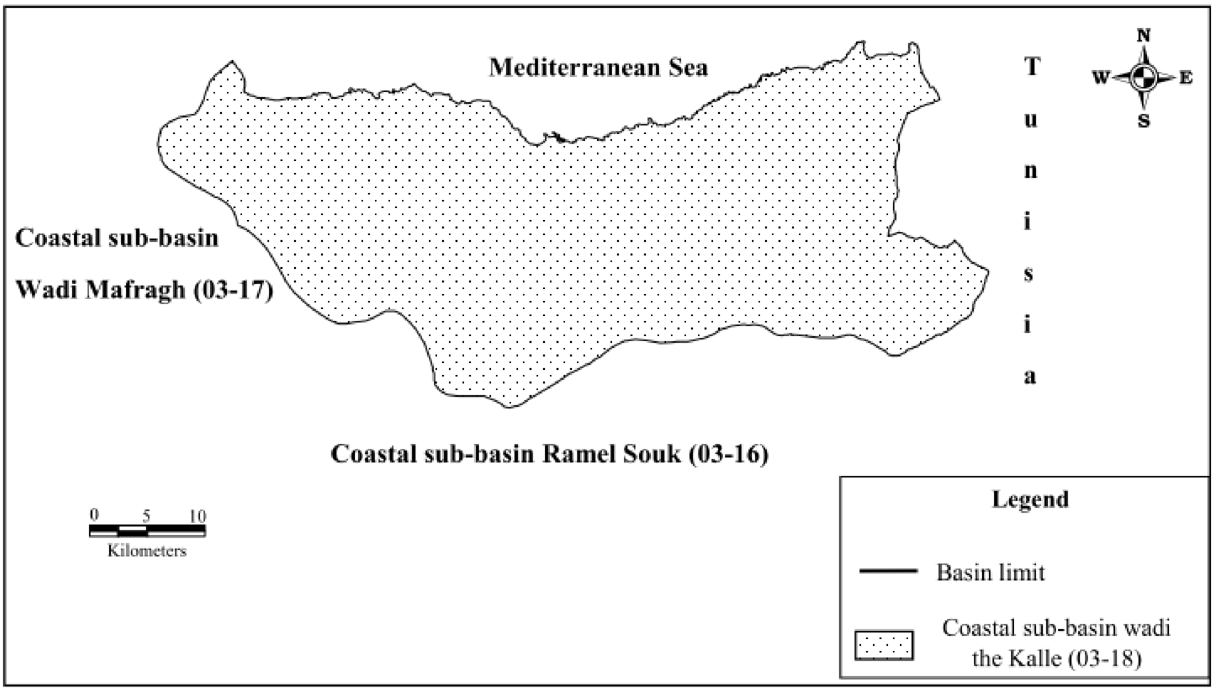

Fig. 1. Map of the Coastal sub-basinof the Kallewadi (03-18).

From North by the Mediterranean Sea;
And from East by the Algerian and Tunisian frontiers;
From the West by OuedMafragh coastal sub-basin 03-17,
andfrom South by Ramel Souk 03-16 coastal sub-basin.It covers an area of 432.2 Km².
The study area covers the eastern part of El Tarfcity, divided into six communes, five of which are partially included in the Kallewadi sub-basin, and one is entirely included.
The available statistics announce 56,487 inhabitants in the whole of KalleWadisub-basin, 2018 estimate according to the 2008 census [3]. This population is strongly concentrated in the most important settlements [4].
The main elements that constitute the relief of the Kallewadisub-basin are [5].
A dune cordon, small eminences of sandstone relief of low altitudes, as well as a set of hills not exceeding 600 m, two alluvial plains swampy, the western slopes of mountains going from north to south and finally, the northern slope of Jebel Kourima with Kef Hammam of 561 m.
The geological study of the Kallewadi sub-basin has allowed to the following results[6], an allochthonous set, which includes two complexes; the Flysch complex with micro breccia (where its lower bedding outcrops only in the

southeastern part of El Aioun), and the Numidian complex, which is characterized by its upper sandstone bedding whose structures have a simple internal layout with a gentle slope (almost horizontal).And an autochthonous post-nape complex, which contains the Miocene water table that develops in its large part in El Aioun sector, covered by quaternary deposits [7].

From the hydrogeological viewpoint, two formations are observed in the region: permeable and low permeable formations. Sandstones, numidian clays, as well as clays and silts belong to the low permeable formations. Their permeability is low [5].

Given the geological structure of the watershed, the supply of aquifers in the The sub-catchment presents two major streams that run all year round (Oued El Haut, 14 km long, and Oued ElEurg, 10 km long) [5].

watershed is from surface water of the northern and southern slopes as well as from wadi El Eurg, wadi El Haut and direct rainfall on slopes that feel the same low-permeability bedrock as that of the aquifers.

The study of sub-catchment soils allows us to determine two soil types, the zonal soils, (which are mainly dependent on the weather), and the azonal soils, (which are independent of weather) [5].

The hydrographic network of the sub-catchment includes all the streams draining the territory of the catchment. It contains all the canals and streams leading to the main stream called in our case Wadi (fig. 2).

The sub-basin is characterized by a Mediterranean climate with abundant rainfall during the wet season and cold months and by a drought during the summer [8].

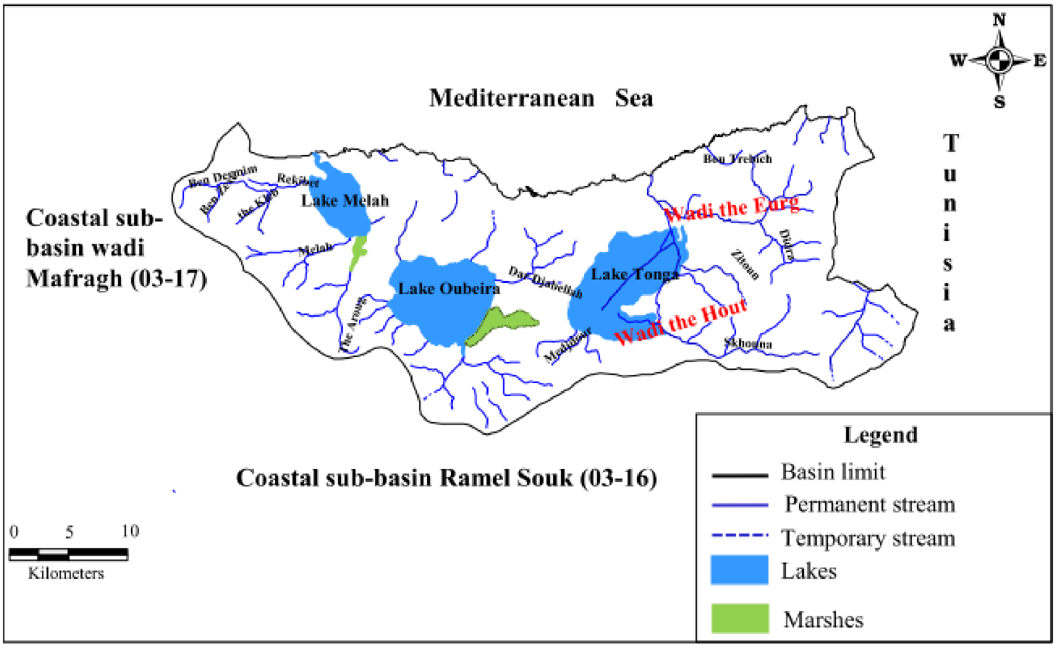

Fig. 2. Map of the hydrographic network of the coastal sub-basin of Kallewadi.

2. Material and methods

2.1. Framework of the study

This study took place at the hygiene laboratory service of prevention and water bacteriological analysis in the public health institution of proximity (Boussebsi Omar), at the public multiservices Clinic (SaidiMousa called Khalifa) in El Kala, El tarf city.

2.2. Period and type of study

This study was carried out on the waters of four sources, located in the sub-basin of Kallewadi. These waters were analyzed in the laboratory of hygiene service of prevention and bacteriological analysis of waters, during the months of February, March, April and May throughout the yearof 2019, at a rate of two sampling per month.

The purpose of this work is to gain insight into the microbiological quality of these spring waters through a microbiological index during 2019.

2.3. Presentation of the sampling stations

For the achievement of this study, four sources have been chosen whose waters are destined for human consumption such as (fig. 3):

The source of Melloul;

The source of Siporex;

The source of AinBargougaya;

The source of Segleb, Their geographical distribution is summarized in tab. 1.

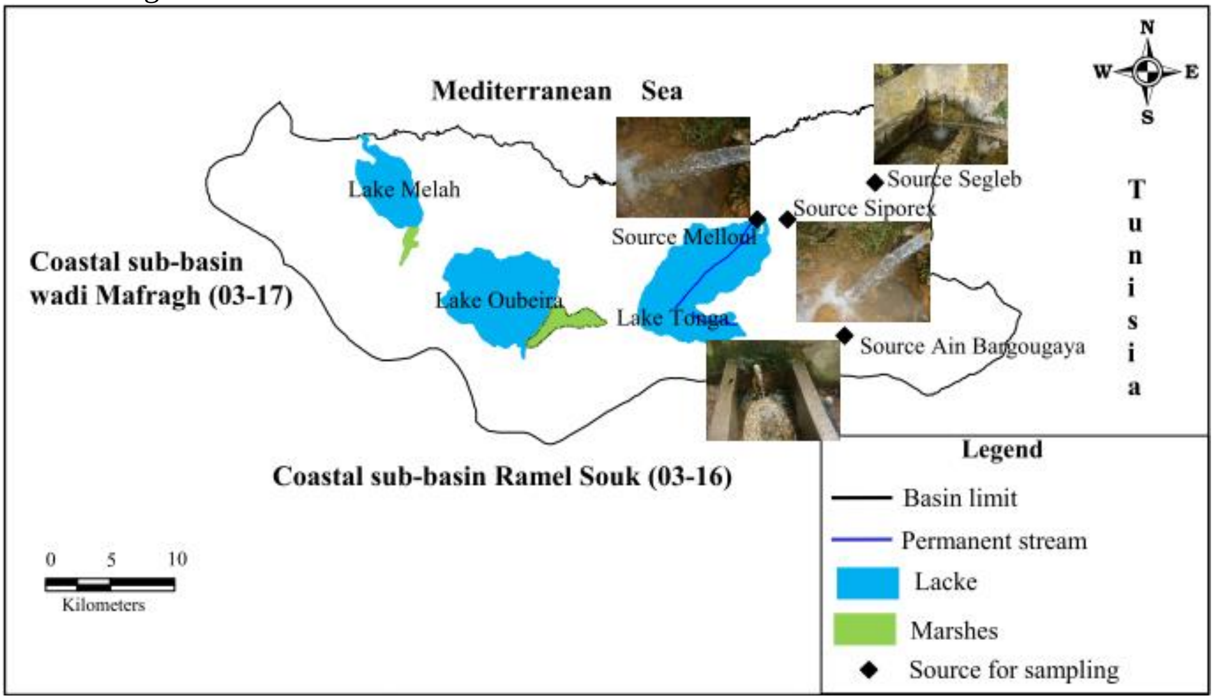

Fig. 3. Map of sampling sources.

2.3.1. The source of Melloul

The Melloul spring, located 2 km north of the Souarekh commune, which is a natural state uncovered and coming from an important phreatic grounwater. Its catchment by drilling gives birth to the wadiMelloul.

It constitutes an important irrigation perimeter of the region. The catchment is connected by a high-pressured pipe which arrives to a 2 x 500 l reservoir, supplying the locality of Melloul with a flow of 250 l/s.

2.3.2. The source of Siporex

Located at 300 m from the Melloul nape, it is a catchment that supplies the Siporex factory and somedwellings.

2.3.3. The source of Segleb

Located 4 km east of Souarekh commune, this spring contains several aquatic plants that can adversely affect water quality and can be exposed to runoff.

2.3.4. The source of AinBargougaya

AinBargougaya is located 7 km from Souarekh, and 3 km north of El Aiounecommune, on the national road 44 towards Tunisia. Its catchment and its adduction include gravitational runoffs from the mountains to a catchment chamber of 100 m length, fitted out in a public fountain of a rectangular shape with an average flow of 100 l/s.

Table 1.

Inventory of sampling sources with names and coordinates.

Source number	Name of sampling source	Coordinates (degree minute)	Altitude (m)
01	Melloul	36°53.784′N08°32.606′E	32
02	Siporex	36°53.576′N08°33.017′E	29
03	Segleb	36°54.621′N08°36.241′E	120
04	AinBargougaya.	36°50.952′N08°35.402′E	308

2.4. Material

The following materials have been used during the field work.

Multiparameteroffield series u-50, HORIBA;

Sterile bottle of 250 ml for water sampling;

A Cooler to transport the samples;

Digital camera Sony DSC-W220;

and a GPS to record the coordinates of each point.

2.4.1. Sampling

Samples are collected in bottles and previously subjected to rigorous cleaning and sterilization to eliminate thebacteria.The sample from each source must be collected in a bottle.

Each sample is accompanied by an information card on which is noted:

The origin of water (water source) ;

the exact address of the sampling site;

and the date of sampling.

2.4.2. Sampling technique

For the water sampling necessary to bacteriological analysis, bottles out of Pyrex glass were preferably used, provided with a broad collar and a stopper with metal screw. The sampling techniques varied according to the purpose and the nature of water to be analyzed**.**

2.4.3. Transportation and storage

In order to prevent that the initial germ content of the water is not likely to be modified in the bottle, all the analyses were carried out as quickly as possible. The evolution is difficult to predict and depends on many factors: temperature, bacterial competition of the presented species, and chemical composition of the water. To this effect, the circular of January 21, 1960, related to the methods of bacteriological analyses of water supply specifies that « if the period of the transportation exceeds 1 hour, and if the outside temperature is higher than 10°C, the samples will be transported in coolers whose temperature must be between 4 and 6°C ». Even in such conditions, bacteriological analysis must begin within a maximum of 8 hours after the sample is collected. If in exceptional cases, the analysis must be postponed, the samples must be stored at 4 °C [9]. This means thateach time the samples are taken; the bottles are clearly labeled, stored in a refrigerated cooler at 4°C and to be transported to the laboratory [10].

2.5. Methods

The analysis of the studied waters and the monitoring of detectable compounds were carried out using the following techniques:

2.5.1. In situ measurement of physical-chemical parameters

The parameters recorded in situ are:potential of hydrogen (pH), temperature (T), electrical conductivity (EC), dissolved oxygen (DO), redox potential(Eh), turbidity and salinity. The measuring apparatus is a multi-parameter field meter series u-50, HORIBA. It is equipped with a probe that simultaneously displays the results of 11 indication parameters such as potential of hydrogen, redox potential, dissolved oxygen, conductivity, salinity, total dissolved solids, seawater specific gravity, temperature, turbidity and depth.

2.5.2. Research Method and enumeration of microbiological parameters

In this study, three microbiological parameters have been chosen such as: total germs, faecal coliforms, research and numbering of faecal Streptococci.

During each trip, we had a sample consisting of 4 samples to undergo a bacteriological analysis at the laboratory.The bacteriological analysis aims to highlight the presence of germs, based on the search and counting of these in the samples to be analyzed. The searched germs are: the total germs, the faecal coliforms, the search and the enumeration of the faecal Streptococci. The search and the enumeration of the indicators of contamination are done according to two methods of choice:

- ✓ Either by filtration on 0.45 µm membrane in solid medium by supposing the availability of a filtration ramp,
- ✓ Or in a liquid medium on BCPL by NPP technique (most probable number).

The membrane filtration technique was chosen. To characterize the microbiological contamination at the level of studied spring water, we preceded according to a method the calculation of the IQM [11 - 12].

The Microbiological Contamination Index method is presented below [12]. They include five quality classes corresponding to the generally accepted colors (fig. 4).

Null Contamination
Low contamination
Moderate contamination
Strong Contamination
Very Strong Contamination

Fig. 4. Class of alteration.

The principle is to divide the values of the bacteriological parameters into five classes (tab. 2), then to determine, from one'sown measurements, the corresponding class number for each parameter and then to take the average.

Table. 2.

Quality grid (IMC)

Parameter / Class	Total Coliforms/ml	Faecal Coliforms/ml	Faecal Streptococci/ml
5	<2000	<100	<5
4	2000-9000	100-500	5-10
3	9000-45000	500-2500	10-50
2	45000 - 360000	2500 - 20000	50 - 500
1	>360000	>20000	>500

$$IMC = (Total\ Coliforms + Faecal\ Coliforms + Faecal\ Streptococci)/3$$

IMC of 5.0 to 4.6: Null microbiological contamination;
IMC of 4.5 to 4.0: Low microbiological contamination;
IMC of 3.9 to 3.0: Moderate microbiological contamination;
IMC of 2.9 to 2.0: Strong microbiological contamination;
IMC of 1.9 to 1.0: Very strong microbiological contamination.

3. Results and discussion

3.1. Physico - chemical parameters (in situ measurement)

The physic - chemical parameters measurement resultsof the studied spring water are reported in Tab. 3. They are compared to the Algerian standards relating to water quality used for water production meant for human consumption.

Table. 3.
Averages Results of the of physico-chemical parameters of spring water during the year 2019

Parameter / Source	T (°C)	pH	Eh (mV)	Turbidity (NTU)	DO (mg/l)	Salinity (g/l)	Conductivity (µs/cm)
AinBargougaya	17.83	5.7	50	1	9.92	0.144	220
Segleb	18.72	6.63	-4	0	9.22	0.473	739
Melloul	20.53	7.07	-30	0	9.82	0.008	150
Siporex	19.42	7.02	-28	0	9.7	0.010	180

3.1.1. Temperature

He curve shape shows that the temperature is particularly high in Melloul spring; this is explained by the shallow waters that are directly influenced by the air temperature. It is noted that the temperatures at the level of all springs do not exceed the Algerian standard which is lower than 25 °C [13]. In Table. 3 we present the obtained results which indicate a water temperature that varies between a minimum of 17.83 °C at the source of AinBargougaya and a maximum of 20.53 °C at the source of Melloul.

3.1.2. Potential of hydrogen

pH values measurements recorded in spring water shows that the measured pH at all springs, ranges between 5.70 at the level of AinBargougaya and 7.07 at the level of Melloul, which generally translates a character of slightly acidic to neutral water. Table. 3 illustrates that AinBargougaya and Segleb waters are marked by an acidic pH, probably due to contamination bynitrogenous compounds.
Acidic water is in effect aggressive (corrosive) and can liberate the constituent metals of the pipes, such as iron, copper, lead, nickel, chrome and zinc.

3.1.3. Turbidity

In Table. 3. We present the values of turbidity fluctuate between 0 and 1 NTU. This variation shows that the studied source water have clear water [14], therefore they meet the standards to be drinkable.

3.1.4. Electrical conductivity

The measurement of the conductivity allowed us to appreciate very quickly, but very approximately the mineralization. In Table. 3 , we present the data analysis that shows a minimum value of 150 µs/cm recorded at the level of Melloul, and a maximum of 739 µs/cm marked at the level of Segleb spring, probably due to water runoff.

3.1.5. Dissolved oxygen

Through the obtained results, we have seen that the studied sources present a good oxygenation.
Table. 3 shows that the values oscillate between a minimum of 9.22 mg /l in Segleb source and maximum of 9.92 mg /l at the source of AinBargougaya, so the spring waters of the sub-basin in Kallewadi have a good oxygenation and of an excellent quality.

3.1.6. Redox potential
Among the values of Eh measured in source water and according to table. 3, we note aMaximum of 50 mv recorded at AinBargogaya and a minimum of -30 mv recorded at Melloul. The Eh-Hp diagram in Figure. 5 shows that for most sources, the environment is reducing and stable except for AinBargougaya source, where the environment is always stable but oxidizing. This is explained by the high contribution of dissolved oxygen.

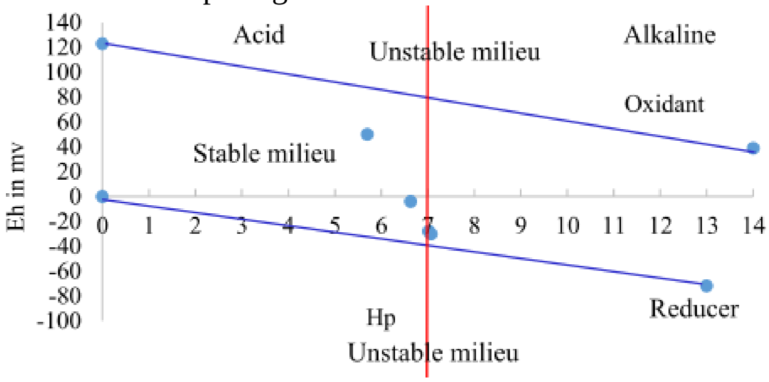

Fig. 5. Evolution of the different sources from Eh to pH.

3.1.7 Salinity
The measurements of salinity in source water showed values between 8 mg/l at the level of Melloul and 473 mg/l at the level of Segleb (tab. 3). This high value is mainly due to erosion of the lithospheric rocks, produced by runoff and groundwater. All along their path, salts are carried away by water and accumulate.

This does not translate a danger but rather a water to be watched.

3.2 Bacteriological parameters

3.2.1. Application of the microbiological contamination index method
For a more significant interpretation, we have chosen two results from the different bacteriological parameters of each month for all sources [15] (tab. 4).
According to table. 4 and the results of 13/02/2019 during the month of February. Wehave noticed that at the level of all the sources, the microbiological contamination is null.According to the results of 28/02/2019, we noticed a null contamination but with an early more or less high of total coliforms at the level of Siporex and Segleb spring water, with respectively 5 and 6 germs/100 ml, seen the norms of WHO.
During the month of March and following the results of 12/03/2019, the contamination index is null but with anincrease of total coliforms at the Melloul level. The latter is a natural state (not covered). For the 26/03/2019, the contamination is null, with anelevation of total coliforms at Segleb and AinBargougaya level whose early is 9 germs/100ml, respectively, due to runoff and gravity runoff of the mountains.
For the month of April and according to the results of 09/04/2019, we note a null contamination consequently water of good bacteriological quality. The same remark for the results of 24/04/2019.
Finally, during the month of May and according to the results of 16/05/2019 and 30/05/2019. The quality of source water is still excellent following the contamination index, which is null, but the Melloul source presents high early total coliforms with 9 germs/100 ml.The water of this source coming from an important phreatic groundwater.

Table 4.

Bi-Monthly values of indices and classes of contamination for spring waters.

Month	Date	Sources	TC/ml	FC/ml	FS/ml	Index	Contamination
February	13/2/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.00 0.01 0.00 0.01	0.00 0.00 0.00 0.00	0.00 0.00 0,00 0.00	5 5 5 5	Null Null Null Null
	28/2/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.05 0.06 0.02 0.01	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
March	12/03/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.03 0.01 0.01 0.06	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
	26/03/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.01 0.09 0.09 0.05	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
April	09/04/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.03 0.02 0.01 0.02	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
	24/4/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.00 0.01 0.00 0.01	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
May	16/5/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.03 0.03 0.03 0.09	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null
	30/5/2019	- Siporex - Segleb - AinBargougaya - Melloul	0.03 0.03 0.03 0.09	0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00	5 5 5 5	Null Null Null Null

This groundwater probably is contaminated by the waters of wadiMelloulwhich feeds the groundwater in the period of low waters.
In conclusion, this does not translate as a danger but rather a water to be watched.

In addition, bacteriological analyses reveal the total absence of faecalcoliforms and faecal streptococci during our entire study period in all sources.

3.2.2. Establishment of the spring water quality map for 2019

For the establishment of the quality map of source waters, we chose the method of the Microbiological Contamination Index [12]. This method reflects the reality of contamination rates (Fig. 6).In order to have a more meaningful result, the average of different concentrations of the four months for all sources was chosen.

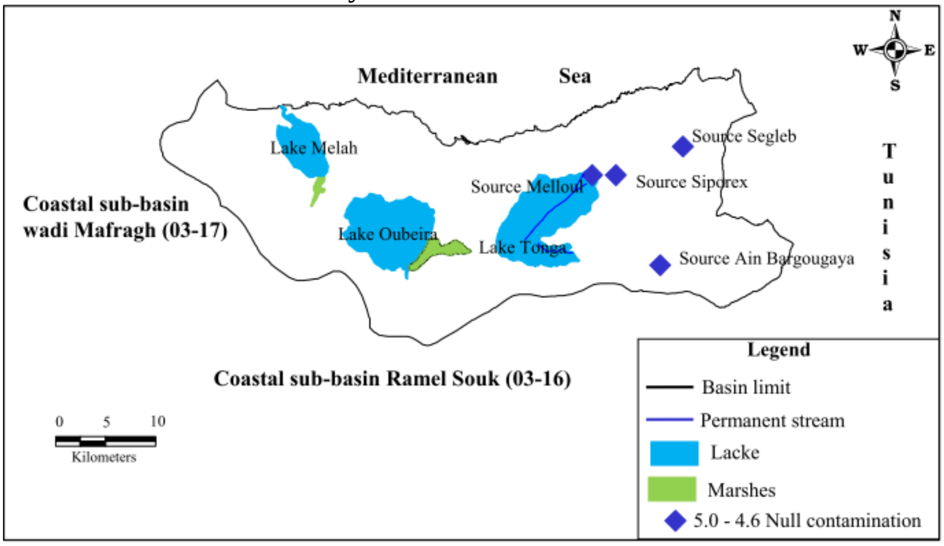

Fig. 6. Source water quality map for 2019

The map clearly indicates an excellent quality of source water in the Kallewadisub-basin, marked by null microbiological contamination.

The low values of this index are explained by a very low total coliform count and the total absence of faecal coliforms and faecal streptococci in the studied sources.

4. Conclusion

The present work was devoted to the study of the physic - chemical and bacteriological quality of source waters at the level of the Kallewadisub-catchment, in the region of El Tarf. According to our analyses and according to the parameter indicators of groundwater quality spring water indicate that:

The temperatures at the level of all sources don't exceed the Algerian standard, which is lower than 25 °C. The values of the pH recorded in the source waters are slightly acidic to neutral. The values of the turbidity show that the studied source waters have clear water. Thedata of analysis show an important conductivity at the level of Segleb source, probably caused by the runoff water. The studied sources present a good oxygenation, the values of Eh measured in the source waters present a maximum of 50 mv translating an oxidizing environment, and a minimum of-30 mv interpreting a reducing location. Finally, the measurements of salinity in the source waters showed a maximum of 473 mg/l.

On the basis of bacteriological results, the analyses reveal the total absence of faecal coliforms and faecal streptococci during the whole study period in all sources. In fact, the results clearly establish the aptitude of all spring waters for drinking water supply and require a monitoring, because of alteration by total coliforms in all sources. According to the microbiological contamination index and during all our period of study, the contamination is null.

It emerges that the studied water sources is of an excellent bacteriological quality. In perspective, it would be judicious to develop and elaborate a strategy of monitoring and protection of the sub-basin source in KalleWadi, based on a permanent follow-up of the physico-chemical and bacteriological parameters to identify the problem of the risk which is in relation with water.

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