



Physicochemical and microbiological study of the Ourika watershed hydrographic network (Marrakech-Morocco region)

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Abstract. The Ourika region is one of the rural areas known for its agricultural, tourism and livestock activities. It is located between 31°00' and 31°20' North and between 7°30' and 7°60' West. Its main course is oriented first to the NE then the NW near the locality of Setti Fadma. With its high altitudes (between 1600 and 3200) and its 1500 km long hydrographic network, an average annual rainfall of 541 mm is recorded. Sustainable management of these water resources is more than necessary because the majority of the population uses the water from wells and natural springs to obtain drinking water. The physicochemical and microbiological studies are part of the tools implemented for the characterization of the water of the region, as well as the realization of a sustainable management of both underground and surface water resources. The physico-chemical analysis has shown reassuring results compared to the quality of the water of the region, where the majority of the parameters do not exceed the norms. With the exception of conductivity and orthophosphate, which increased during the rainy season, with maximum values of 652.6 $\mu\text{s cm}^{-1}$ for conductivity and 0.24 mg L^{-1} for orthophosphate, as well as decrease in dissolved oxygen in summer with values lower than 5 mg L^{-1} . The microbiological study allowed us to identify different bacterial species in spring water such as: *Proteus mirabilis*, *Providencia rettgeri*, *Escherichia coli* and *Klebsiella pneumoniae*.

Key Words: physical chemistry, Oued Ourika, groundwater, surface water, microbiology.

Introduction. The Ourika catchment area is about 503 km^2 wide and has a compactness index of 1.3, located between 31°00' and 31°20' North and between 7°30' and 7°60' West. Its main course is oriented first to the NE then the NW near the locality of Setti Fadma (Saidi et al 2010).

It is characterized by its great spatiotemporal variability and records an annual rainfall of 541 mm on average with a coefficient of variation of 34%. Knowing that the latter increases with altitude and can exceed 700 mm per year on high peaks (Saidi et al 2010). The Ourika valley is known for its high altitude (between 1600 and 3200 m) for the majority of its surfaces. Its hydrographic network reaches a length of 1550 km, with a drainage density of about 3.1 km km^{-2} , facilitating the collection of runoff water from neighboring basins (Saidi et al 2012).

It should be noted that the region of Ourika is one of the rural areas known for its agricultural activities, tourism and livestock. The majority of the population uses the waters of wells and natural springs to obtain drinking water. The quality of this water can be influenced by the different pollutants that generally result from the excessive use of fertilizers, as well as the unregulated releases of various solid wastes, not to mention the lack of awareness of the population (Mullis et al 1997).

Better management of these water resources, improvement of the sanitation system and easier access to drinking water can reduce the risk of contamination, and

avoid a significant percentage of the disease burden (Kahoul et al 2014). This study proposes to evaluate the quality of water intended for domestic consumption, by measuring the different physicochemical and microbiological parameters in order to identify the sources of contamination.

Material and Method

Sampling. The collection of water was carried out at eleven stations taking into account the various activities located in the region, twice a season (noted C1, C1'; C2, C2'; C3, C3'; C4, C4') during 2015/2016, for both groundwater and surface water, in order to establish a diagnosis of the state of pollution of these waters.

The spring water samples, noted S1, S2, S3 and S4, were made at the douars: Amelougui, Aghbalou and Timalizene. While the surface water samples noted O1, O2, O3, O4, O5, O6, and O7, have seen interest all along the Ouad Ourika (more specifically: Setti Fadma, Imi N'tadart, Tazitount, Oualmas and Aghbalou; zones O1 and O2 are located at Setti Fadma, O3 at Imi N'tadart, O4 at Tazitount, O5 and O6 at Oualmas, O7 at Aghbalou. The O2 zone has been added to cover the long distance between Setti Fadma (O1) and Imi N'tadart (O3), as well as O6) (Figure 1).

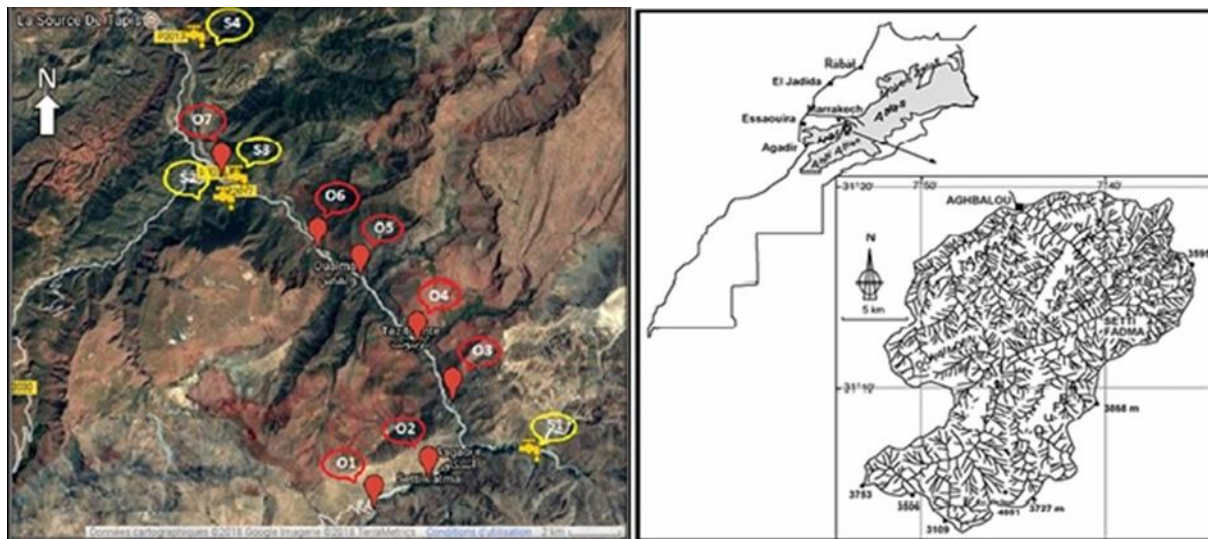


Figure 1. Ground and surface water sampling points (Saidi et al 2010; Google Maps 2018).

Regarding the microbiological study, the water samples were taken at the level of the zones S1, S2, S3 and S4, once per season during the year 2015/2016. Specialized flasks previously rinsed and sterilized by autoclaving at 120° C for 20 minutes were dedicated to this use.

Physicochemical parameters. Water samples were taken from plastic sample bottles, previously cleaned, dried and rinsed with water from the station at the time of sampling.

Water temperature (°C), hydrogen potential (pH), electrical conductivity (EC) and dissolved oxygen were measured in situ using a multisonde (Multi Parameter Water Quality Sensors Mp65). Other parameters: BOD₅, nitrates (NO₃⁻), nitrites (NO₂⁻), orthophosphate (PO₄³⁻), ammonia nitrogen (NH₃-N), hardness or titre hydrotimetric (TH), suspended solids (SS) and sulphate, have been analyzed in the laboratory within 24 hours of transport in a cooler at 4°C. The methods used for the various physico-chemical analyzes are those described by Rodier et al (2009).

Microbiological parameters. In order to highlight any fecal pollution, various tests were carried out, namely: enumeration and search for fecal bacteria such as coliforms and fecal streptococci, Clostridium sulphito-reducers, and isolation and the identification of certain pathogenic bacteria. The methods used for the different bacterial enumeration tests are those described by Rodier et al (2009). For faecal coliforms and streptococci,

the most likely number (MPN) method was used for liquid seeding, whereas for the sulphite-reducing bacteria, the agar-embedding method was used (Rodier et al 2009).

The identification of the bacteria was carried out through various tests: Gram stain, catalase, respiratory type, IMVIC (indole urea, methyl red, Voges-Proskauer), oxidase, coagulase, culture on Simon citrate medium (search for bacterium that uses citrate as the only carbon source), culture on Kligler medium (allows the study of lactose fermentation, glucose, CO₂ production and SH₂ demonstration) and APi 20E gallery (Hammou-Tani 2017).

Statistical. Statistical analysis was performed by principal component analysis on the XLSTAT software.

Results and Discussion

Physicochemical parameters

The water temperature. Considered among the most important ecological factors, water temperature is closely related to a whole set of parameters, its alteration can lead to various ecological consequences (Leynaud 1968). Examples include density, viscosity, solubility of gases, dissociation of dissolved salts, and development of living organisms, particularly microorganisms (WHO 1987). According (Décret n° 2003/464) water is of good quality between when the temperature is lower than 25°C and average between 25 and 30°C. In our study, the water temperature is characterized as being of good quality, with a maximum value of 21°C recorded in summer and a minimum of 8°C in winter for groundwater. While surface water reaches a maximum of 24°C in summer, and a minimum value of 10°C recorded in winter (Figure 2).

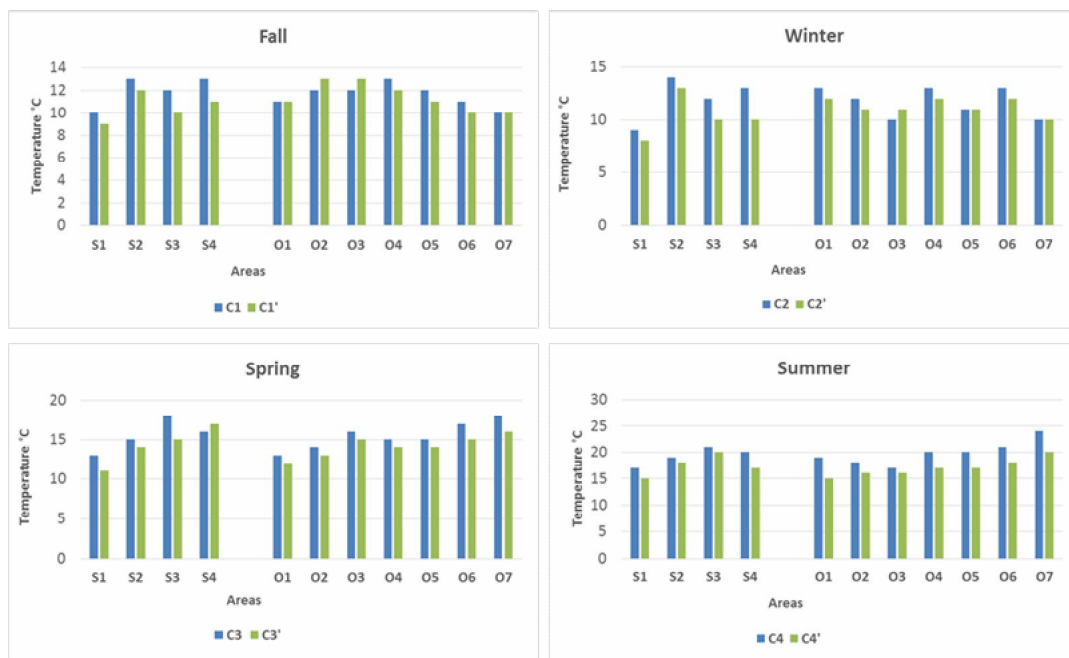


Figure 2. Temperature variation of ground waters and surface waters (C1(1')-C4(4') correspond to the two sampling campaigns which are carried out per season).

The potential of hydrogen (pH). The given pH of a solution is the concentration of hydrogen ions present therein. For natural waters, it is related to the nature of the lands crossed, with values ranging between 6 and 8.5 (Chapman & Kimstach 1996). According to Khaldoun (2015) and Ait Boughrou (2007), pH variations in groundwater follow those of surface waters, with lower values. This is also the case in our study, with values that do not exceed the standards described in MDDEFP (2013), knowing that the acceptable concentration defined for drinking water is 6.5 to 8.5 (Figure 3).

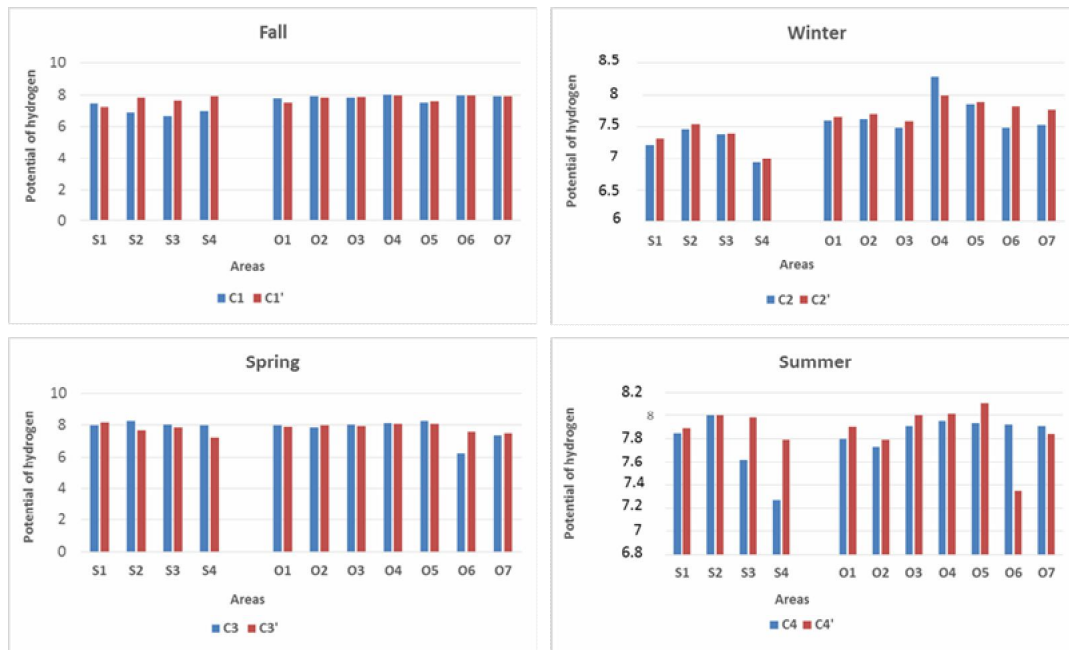


Figure 3. Potential hydrogen variation of ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Electrical conductivity. The measurement of the conductivity is a good appreciation of the degree of mineralization of water where each ion acts by its concentration and its specific conductivity (El Morhit et al 2008). For groundwater, there is strong mineralization with grades that generally exceed the guideline value set by Decree No. 2003/464 of 15/04/03, which is $200 \mu\text{s cm}^{-1}$. Maximum values of 511.8 and $652.6 \mu\text{s cm}^{-1}$ were recorded successively in zones S2 and S4 during winter season. While at the surface water level the conductivity levels are generally low and do not exceed the guide value, with a slight increase in the O6 zone which shows a conductivity of $326.2 \mu\text{s cm}^{-1}$, during summer (Figure 4).

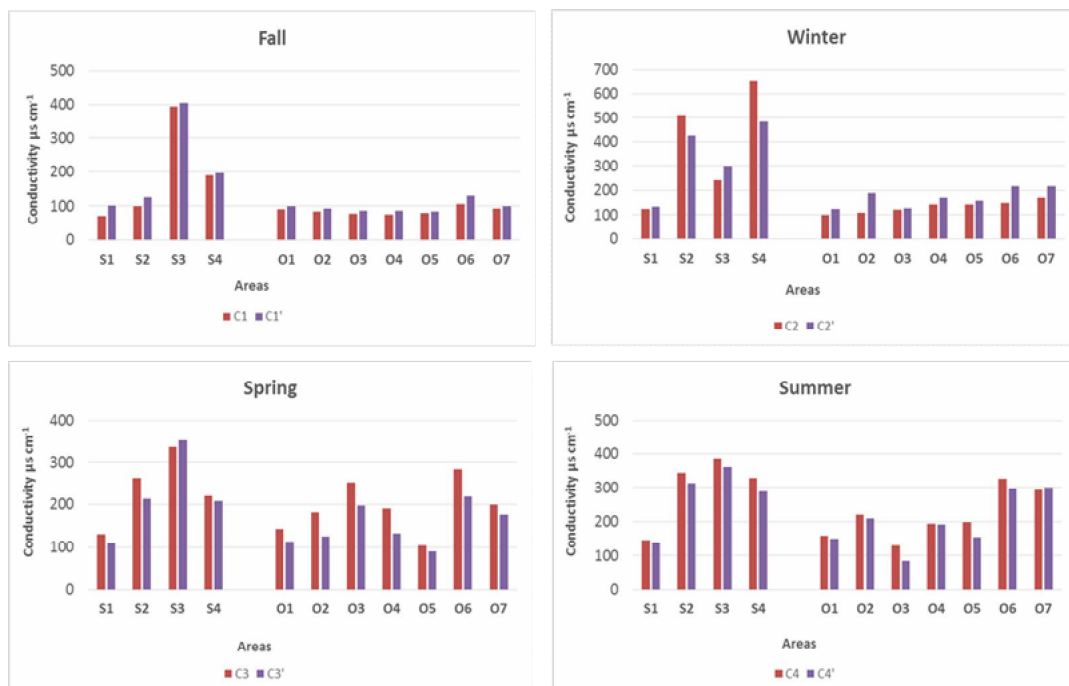


Figure 4. Variation in electrical conductivity of ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Dissolved oxygen. It is one of the most useful parameters for water and is an excellent indicator of its quality. It is one of the most sensitive parameters to pollution. Its value gives us information on the degree of pollution and consequently on the degree of self-purification of a watercourse (Makhoukh et al 2011).

Seasonal evolution shows higher levels during winter compared to summer. This is due to the increase of the temperature in the dry period, knowing that hot water contains less oxygen than cold water (Hébert & Légaré 2000), without forgetting also the factor "flow" which plays an important role in air exchange between the atmosphere and water, which is relatively weak during this season. According to the standards described in the MDDEFP (2013), for the protection of aquatic life, dissolved oxygen concentrations should not be below 5-6 mg L⁻¹ for temperatures between 10 and 25°C.

In our study only the areas S1 and O1 of the summer companion, have values lower than 5 mg L⁻¹. This could be explained by the activity of bacteria that break down the organic matter present in the medium and subsequently cause a decrease in dissolved oxygen (Fekhaoui & Pattee 1993) (Figure 5).

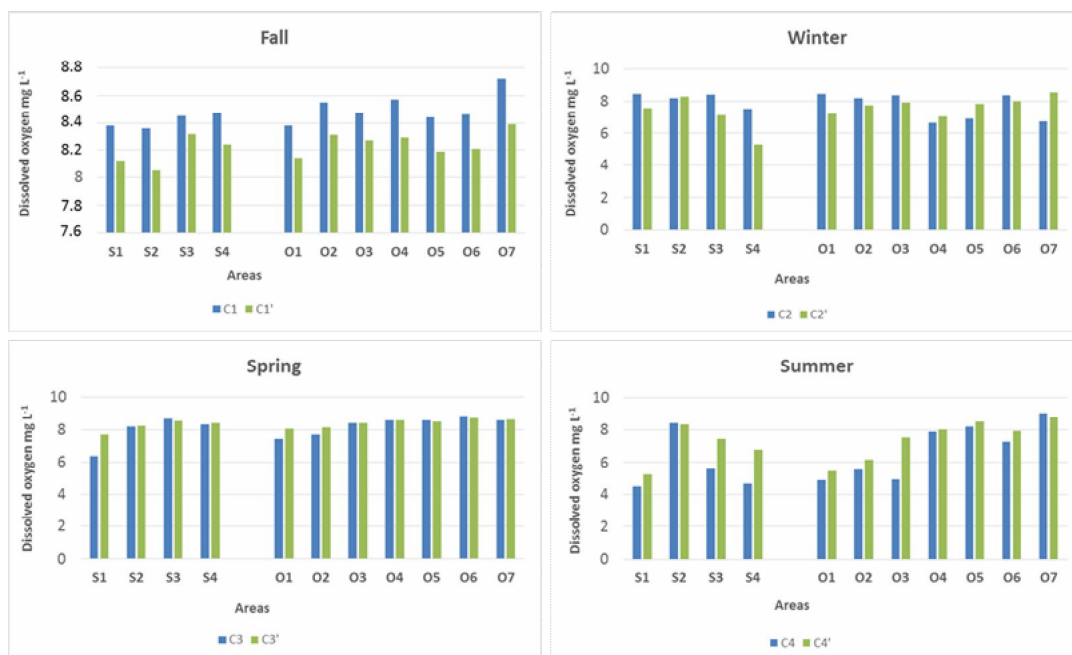


Figure 5. Change in dissolved oxygen levels in ground waters and surface waters (C1(1')-C4(4') correspond to the two sampling levels campaigns which are carried out per season).

BOD₅. Biochemical oxygen demand is the measure of the amount of oxygen required to oxidize the organic or inorganic material in an aqueous sample (Centre d'expertise en analyse environnementale du Québec 2014).

For groundwater, the BOD₅ variations are stable and do not exceed the value of 10. While the surface waters have high values, with a maximum of 70 recorded in the O5 area during the fall season.

According to The decree n° 2003-464 of the 15-04-03, article 1, 2 and 3, concerning surface waters, for a water of average quality with good the concentration in BOD₅ must be lower than 20 mg L⁻¹, which is the case of all areas except O5 and O7 which have high values: 60-70 in fall and 30-40 in spring (Figure 6).

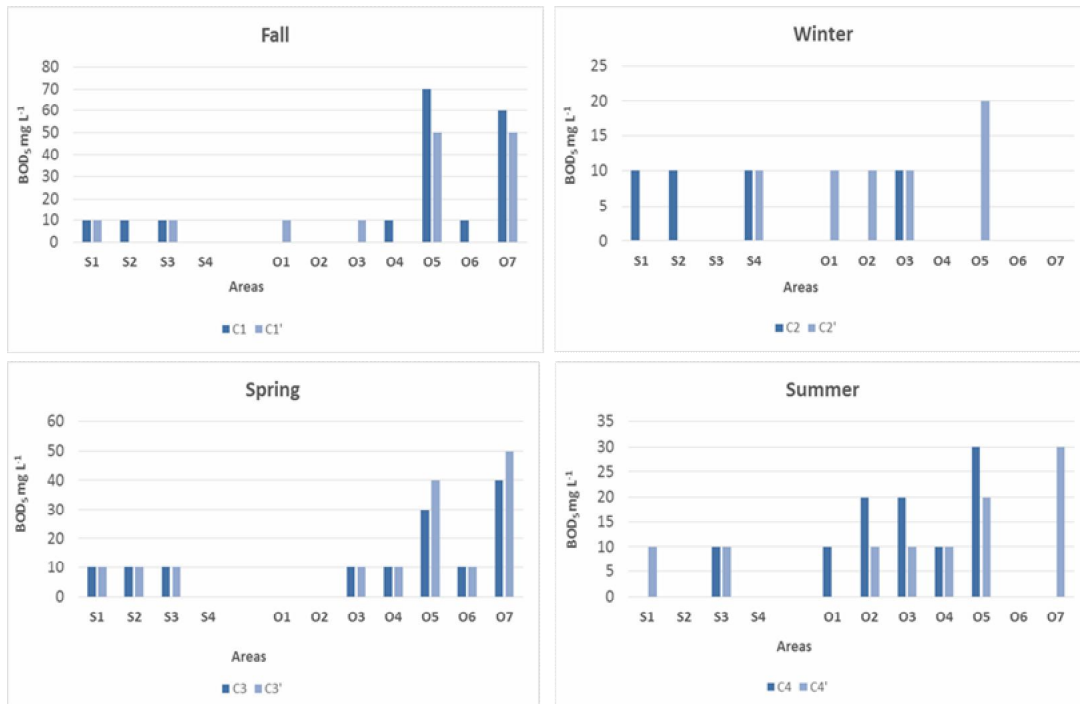


Figure 6. Variation of BOD₅ contents in ground waters and surface waters (C1(1')-C4(4') correspond to the two sampling campaigns which are carried out per season).

Nitrate. It constitutes the final state of the oxidation of nitrogen, its concentration varies between 1 and 10 mg L⁻¹ in natural waters and much less in wastewater (Makhoukh et al 2011). It results from penetration through soil or groundwater but also through the use of fertilizer (Chapman & Kimstach 1996). Our results show relatively low nitrate values, with a slight increase during the summer season compared to winter. The waters of Ourika region show no pollution by nitrates, with concentrations lower than 1 mg L⁻¹. According to the standards described in the MDDEFP (2013), the maximum nitrate concentration should not exceed 10 mg L⁻¹ (Figure 7).

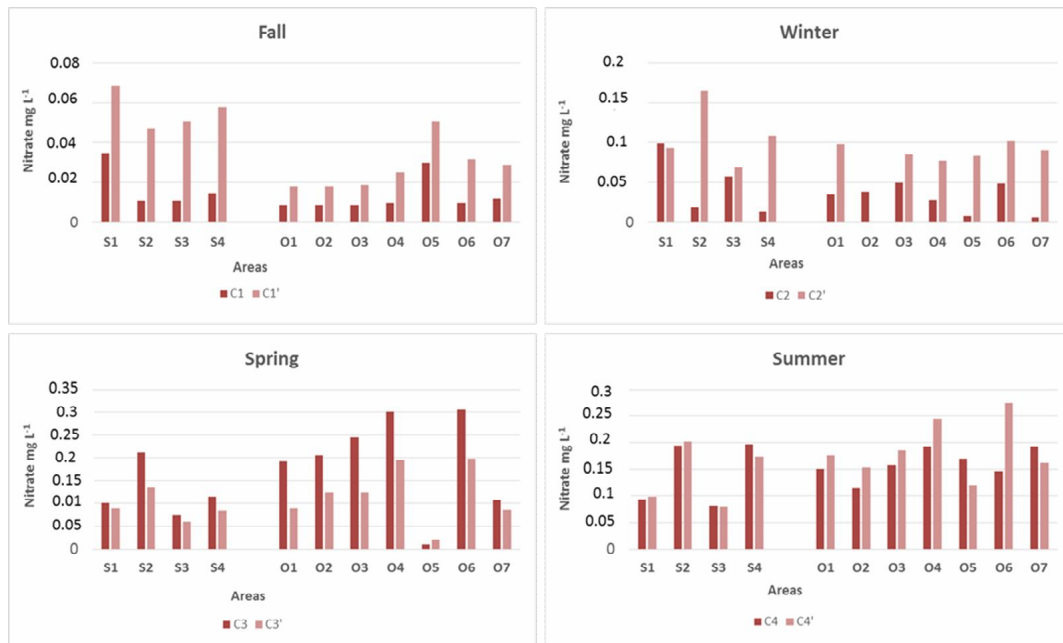


Figure 7. Change in nitrate content in ground waters and surface waters (C1(1')-C4(4') correspond to the two sampling campaigns which are carried out per season).

Nitrite. Nitrites are intermediate forms between nitrates and ammoniacal nitrogen, hence their low concentration in the aquatic environment. Generally, the maximum value accepted for deep water is 0.1 mg L^{-1} (Rodier 1984). According to the standards described in the MDDEP (2013), the maximum acceptable concentration for drinking water is 1 mg L^{-1} . In our study the concentration of nitrite ions is zero for the majority of the zones, and does not exceed 0.1 mg L^{-1} in the rest (Figure 8).

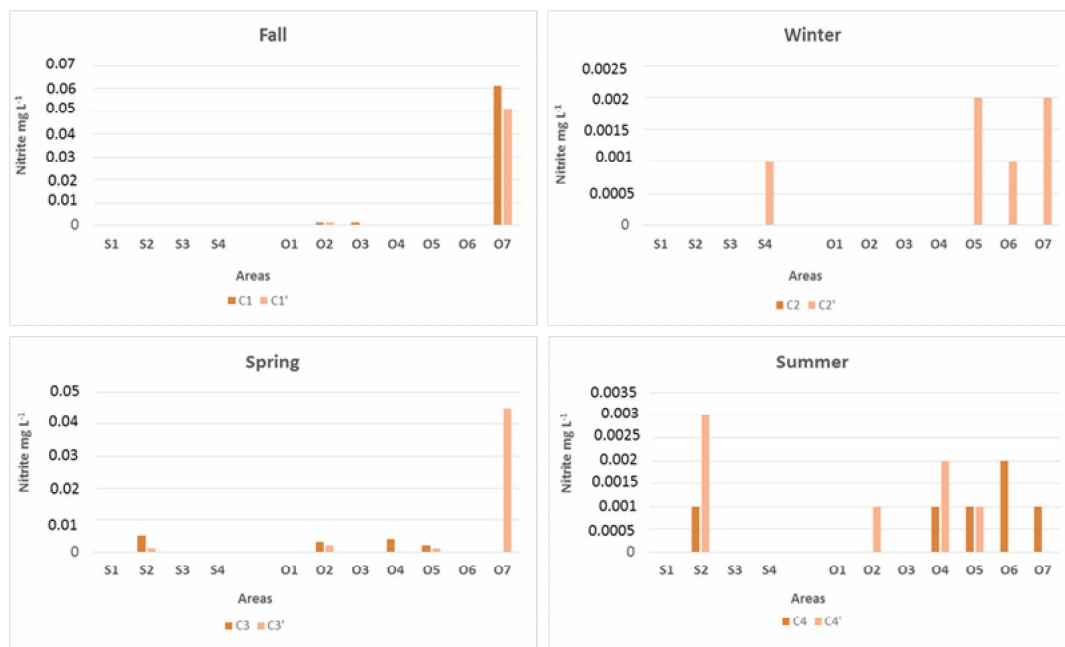


Figure 8. Variation in nitrite content in ground waters and surface waters (C1(1')-C4(4') correspond to the two sampling campaigns which are carried out per season).

Orthophosphate. It is one of the most important nutrients. With its different oxidized forms, it contributes to the distribution of energy in the human body and is one of the basic elements of DNA and RNA nucleic acids (Faurie et al 1998). According to the standard (NF EN ISO 6878), the acceptable limit for orthophosphate is 0.05 mg L^{-1} . This limit value is exceeded in winter with a maximum value of 0.16 mg L^{-1} for source water (S1 to S4) and a value of 0.24 mg L^{-1} recorded in zone O2. In the spring, the orthophosphate concentration reached a maximum of 0.16 mg L^{-1} at zone S4 and 0.26 mg L^{-1} at zone O4. This increase in levels during the winter could be related to the leaching of different fertilizers and pesticides used in agriculture (Figure 9).

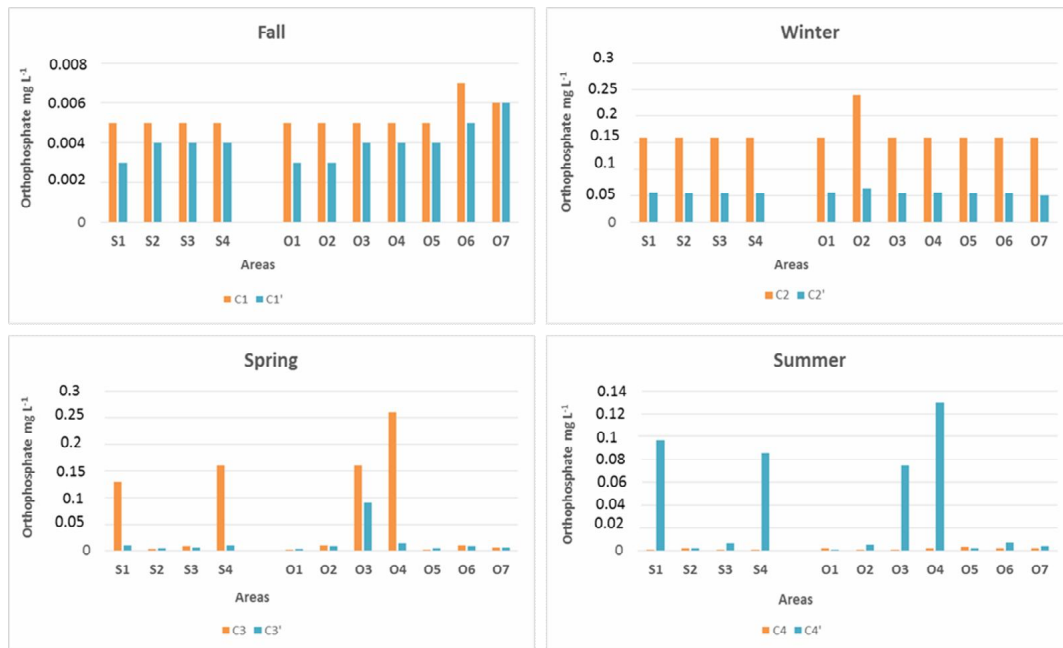


Figure 9. Variation in orthophosphate content in ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Ammonia nitrogen. Ammonia nitrogen is one of the links in the complex nitrogen cycle in its original state. It is a gas soluble in water. There is a small proportion, less than 0.1 mg L⁻¹ of ammonia nitrogen in natural waters. It is a good indicator of the pollution of rivers by urban effluents. In surface waters, it comes from nitrogenous organic matter and gaseous exchanges between water and the atmosphere (Chapman & Kimstach 1996).

In the Ourika region, ammonia nitrogen is absent in all the zones studied, except for O6 which recorded a value of 0.001 mg L⁻¹ in spring and 0.003 mg L⁻¹ in summer and O7 with a value of 0.001 mg L⁻¹. In comparison with the maximum concentration (1.5 mg L⁻¹), described in MDDEF (2013), our results are far below any risk of contamination (Figure 10).

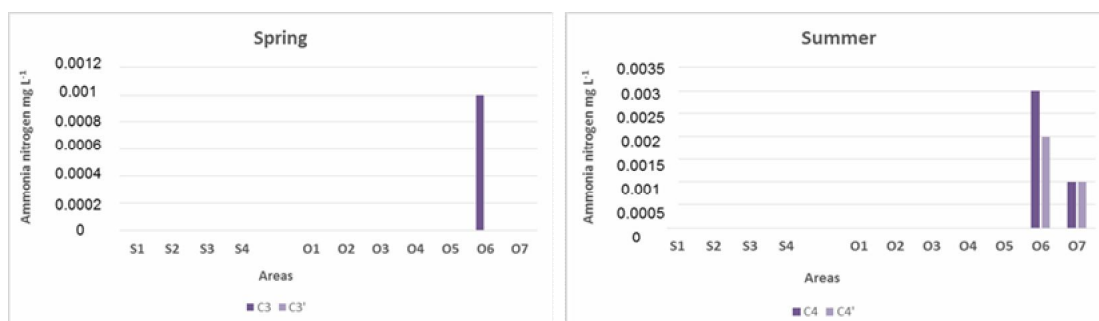


Figure 10. Variation in ammonia nitrogen content in ground waters and surface waters (C3(3')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Oxydability. The oxidability or permanganate index is defined as the oxygen mass concentration in relation to the amount of permanganate ion that is consumed by a water sample under defined conditions. Expressed in mg L⁻¹, this parameter makes it possible to have an approach of the content of organic matter present in water (Rodier 1984).

Our results showed very low values of the permanganate index, with a maximum of 0.072 mg L⁻¹ recorded in the O1 zone during the winter. According to French standards (Directive 98/83/CE, 2009) for water intended for human consumption, the limits for the oxidability rate is 5.0 mg L⁻¹, which makes our values below any risk of contamination (Figure 11).

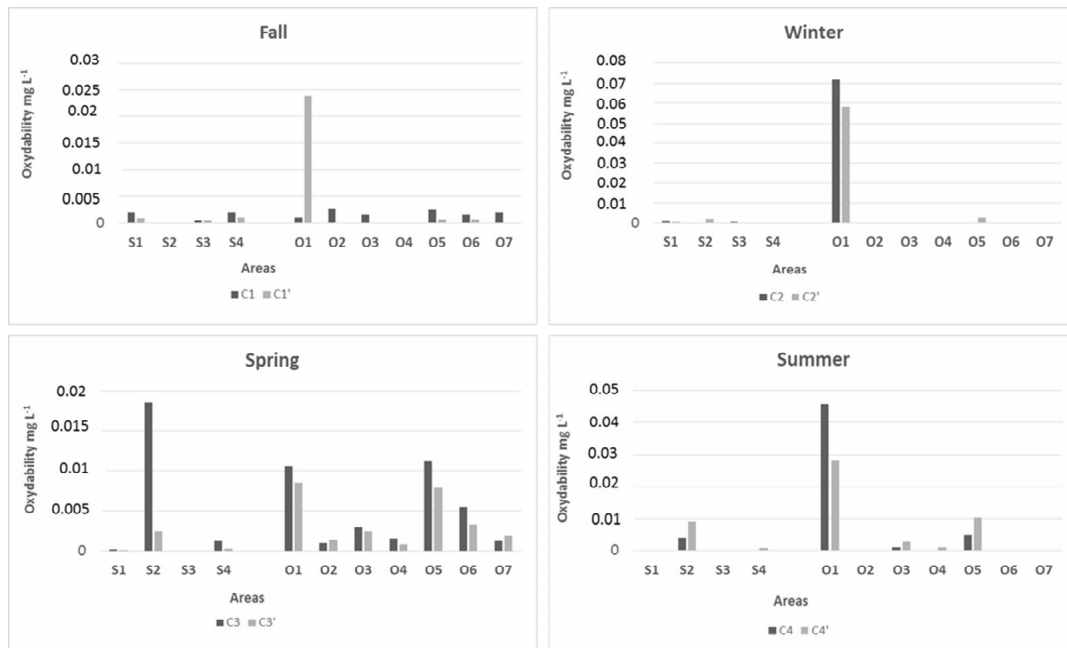


Figure 11. Variation in the oxidability content in ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Chloride. Chlorides contribute to the electrical conductivity of rivers. They are always present but in a very variable proportion, for example, the waters coming from the granitic are poor in chlorides, whereas the waters of the sedimentary regions are much richer. Moreover, the chloride content increases with the degree of mineralization of a water (Hakmi 2006).

Knowing that the maximum permissible concentration of chlorides in water intended for human consumption is: 250 mg L⁻¹ (Directive 98/83/CE, 2009), all zones showed low values, with a maximum of 40 mg L⁻¹ in zone S4 during winter (Figure 12).

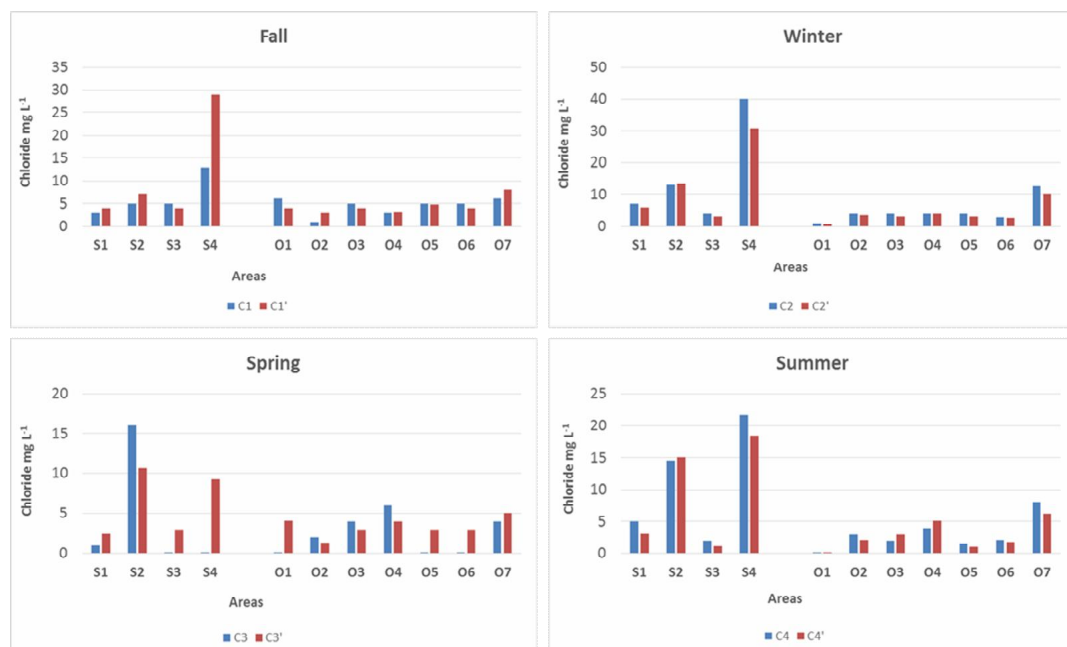


Figure 12. Variation in chloride levels in ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Hardness water hydrotimetric title (TH). The hardness or hydrotimetric title is the sum of the concentrations of the metal cations with the exception of the alkali metals and the

hydrogen ion. Called also calcium and magnesian hardness, it is expressed in milliequivalents of concentration in CaCO_3 (Rodier 1984).

Drinking water is generally considered to have a hardness of between 15 and 25° F. Above 25° F, the water is called hard, below 15° F, the water is said to be soft (Marchal & Rabier 2011).

Based on our results, all areas showed values below 15 ° f, which means that the area is characterized by fresh water for surface and groundwater (Figure 13).

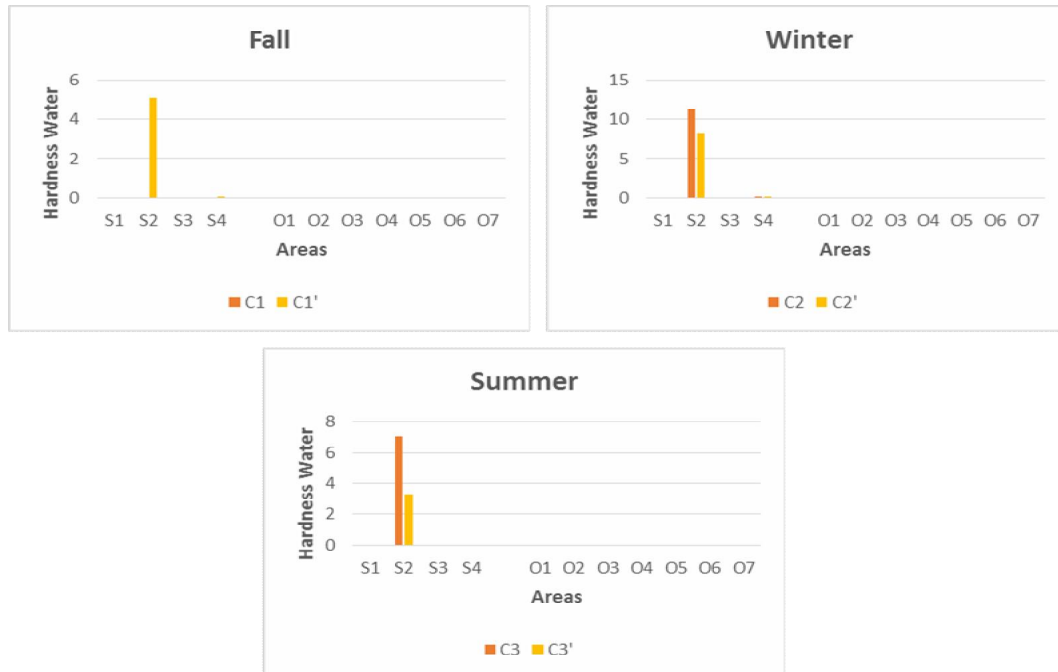


Figure 13. Variation in hardness in ground waters and surface waters (C1(1')-C3(3') correspond to the two sampling campaigns which are carried out per season).

Suspended substances (SS). The suspended substances correspond to the very fine particles in suspension (sand, clay, organic products, particles of pollutants, micro-organisms ...) which give a hazy appearance to the water, and which oppose the penetration of the light necessary for aquatic life. They can constitute a solid pollution of the water, if they are present in too large quantity. In surface water, it is determined by measuring the dry weight of a delimited quantity of filtered water (Laignel 2009).

According to Decree No. 2003-464 of 15-04-03, the concentration of SS must be strictly less than 30 mg L^{-1} for a water to be classified as good quality for multiple use. This is the case for water from the Ourika region in general, whose maximum value in SS is 13.96 mg L^{-1} recorded in zone S1 during the winter (Figure 14).

Sulfate. In general, sulphites in groundwater can reach either the dissolution of minerals such as gypsum and anhydrite, or the invasion of salt water and dewatering of acidic rocks. Sulfate can alter the taste of water at concentrations greater than 500 mg L^{-1} , while it may have a laxative effect at concentrations above 1000 mg L^{-1} . However, drinking water does not contain such concentrations (Nova Scotia Department of the Environment 2008).

The quality limits of a water intended for human consumption for sulfate is set at 250 mg L^{-1} , according to (Décret n° 2003/464).

Compared to the standards, all the zones show sulfate values below the limits, reaching a maximum value of around 120 mg L^{-1} at the S2 zone during the winter, with much lower levels for the sulfate waters, area (Figure 15).

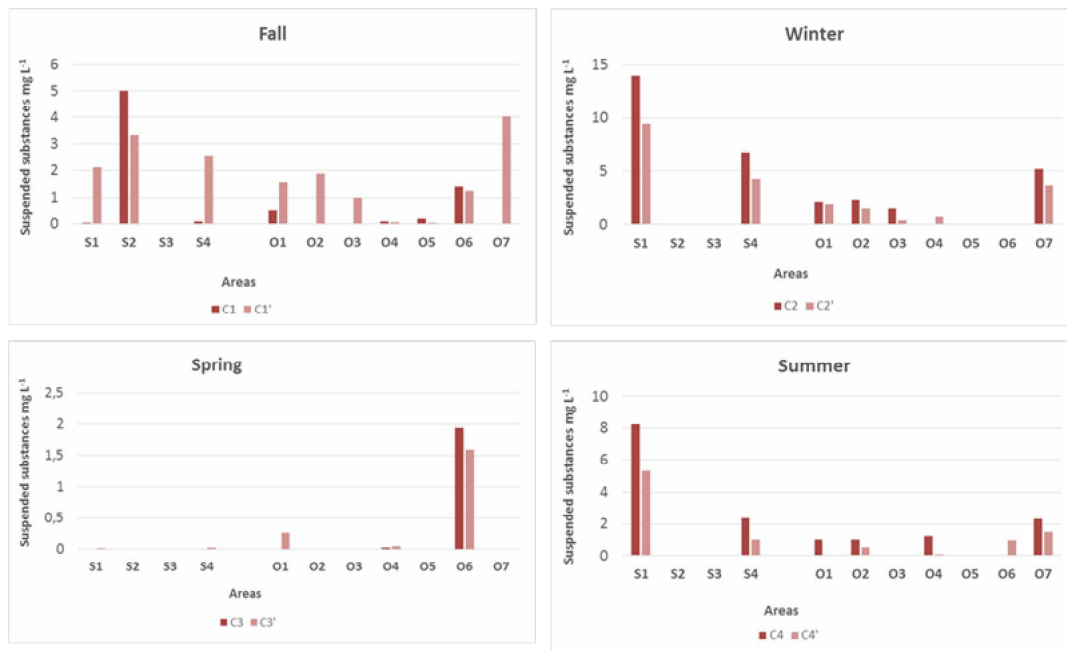


Figure 14. Variation of SS concentrations in ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

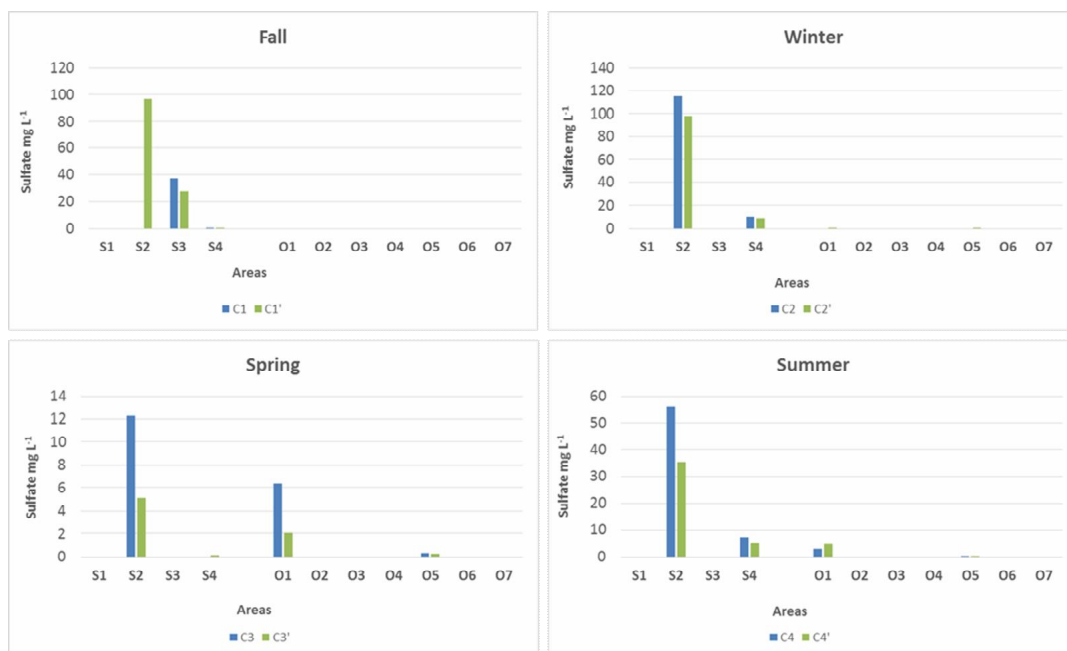


Figure 15. Variation in sulphate levels in ground waters and surface waters (C1(1')-C4(4')) correspond to the two sampling campaigns which are carried out per season).

Bacteriological parameters

Enumeration of total sprouts. The enumeration of total germs that is expressed in CFU (colony-forming unit) mL⁻¹ is often used as an indicator of pollution. Our results show the presence of germs in all zones, ranging from 20 CFU mL⁻¹ recorded in zone S1 during winter, up to 45,000 CFU mL⁻¹ in zone S3 in fall. This contamination may be due to the poor protection of the wells or the infiltration of surface water (Figure 16).

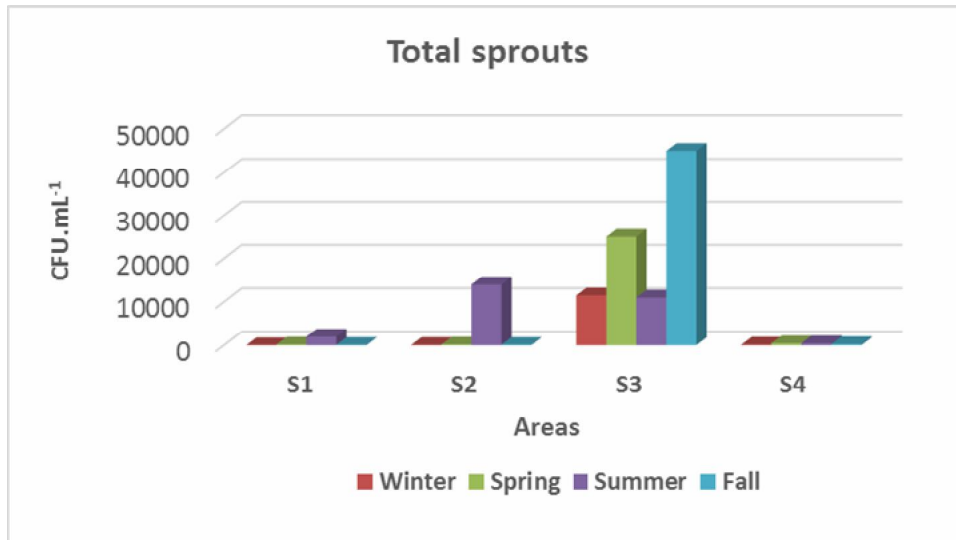


Figure 16. Variation of total sprouts in ground waters.

Enumeration of fecal coliforms. Our results show a minimum value of: 0 CFU.100 mL⁻¹ in winter in zone S1 and S4, and in summer in zone S1 and a maximum value of 25x10⁵ CFU.100 mL⁻¹ in summer at the level of zone S4. These grades far exceed Moroccan standards (2006), (0 CFU.100 mL⁻¹). This contamination is generally due to the infiltration of surface water into the wells, or by the domestic discharges (Figure 17).

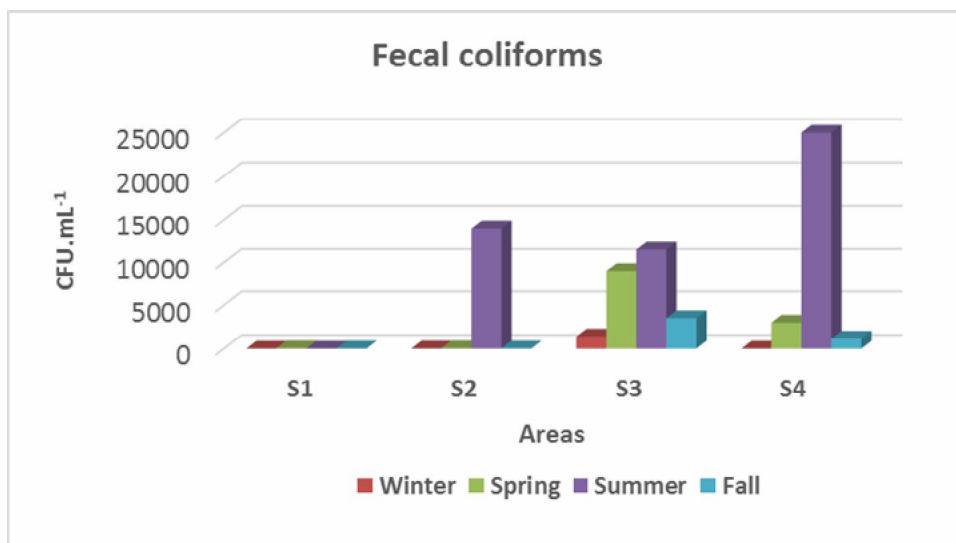


Figure 17. Variation of fecal coliforms in ground waters.

Enumeration of fecal streptococci. No germ must be present in 100 mL of drinking water (Ayad & Kahoul 2016). Our study revealed values up to 7.104 CFU 100 mL⁻¹, which qualifies this water as non-potable. The presence of such a large number of fecal streptococci in the water is reflected in fecal contamination (Ayad & Kahoul 2016) (Figure 18).

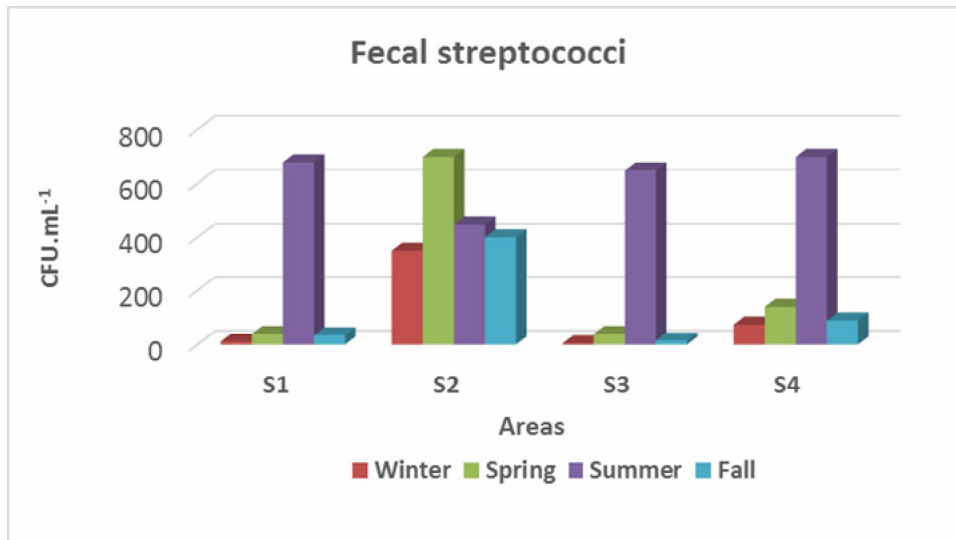


Figure 18. Variation of fecal streptococci in ground waters.

Enumeration of *Clostridium sulfito-reducers*. The anaerobic sulphite-reducing bacteria are present in all zones with values up to $14 \cdot 10^4$ CFU mL⁻¹. According to Moroccan standards (NM 03.7.001, 2006), no bacteria should be present in 100 ml of sample. As a result, our values far exceed the norms, and qualify our water as: not drinkable (Figure 19).

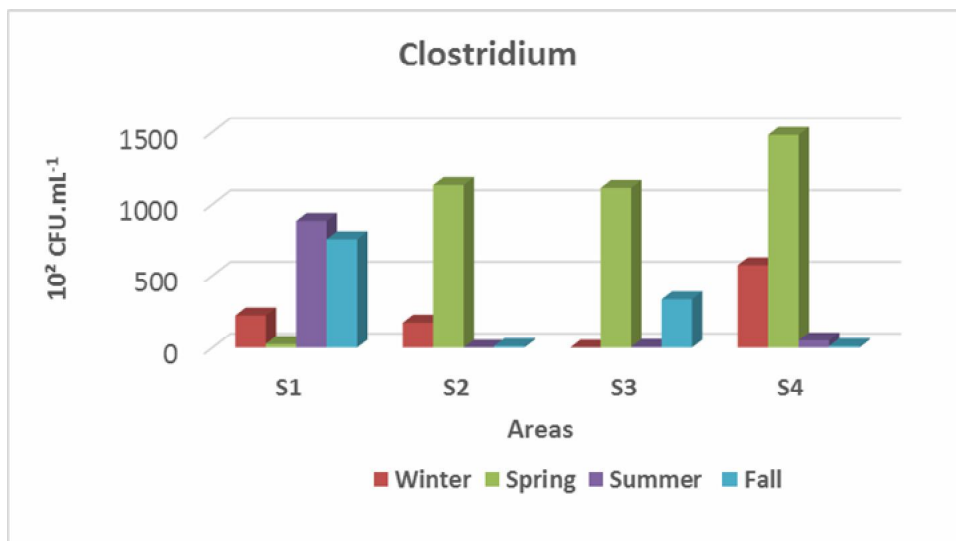


Figure 19. Variation of *Clostridium* sulphito-reducers in ground waters.

Bacteriological identification. The assessment of the microbiological quality of water is based on the concept of so-called "indicators or bacteria indicative of contamination" which do not necessarily have a pathogenic character, but their presence indicates the existence of a contamination by feces (Bouchaala 2017). Bacterial identification is a very important step in the diagnosis of a disease, it consists of recognizing the unknown microorganism, placing it in a known taxon and finally determining the pathogen responsible for this disease (Boukhemis & Boutersa 2015). As a result, bacterial species have been researched and identified in ground water for domestic consumption: *Proteus mirabilis*, *Providencia rettgeri*, *Escherichia coli* and *Klebsiella pneumonia*.

General remarks. According to the results obtained, the organic and mineral charges successively expressed by the electrical conductivity and dissolved oxygen increase slightly from the upstream of the ouad (O1) downstream (O7) (Figures 4 and 5).

This is in line with the results obtained in March 2010 and April 2012 for Ouad Ourika waters, which also reveal an increase in conductivity, ranging from $92 \mu\text{s cm}^{-1}$ to Setti fadma (upstream of the Ouad) to $160 \mu\text{s cm}^{-1}$ at the T'nin Ourika bridge (downstream of the Ouad) (Haddani 2012).

Also the study carried out in 2014 on the Ouad Ourika showed this increase of the degree of mineralization going from upstream to downstream, without forgetting that the lowest contents of dissolved oxygen and in pH were obtained at the O1 station (Setti fadma). The increase downstream could be explained by the discharge of wastewater containing a significant amount of salts (Zuedzang Abessolo 2014).

The low ionic load of the waters of Ourika Ouad could return to the lithological nature of the lands crossed (Badri 1993).

The presence of spores of sulphite-reducing anaerobes with the absence of Coliform bacteria in natural water may reflect old faecal contamination (Guessoum et al 2014). Excluding in our study both families are present in the water of the region, especially in summer.

The highest concentration of bacteria of fecal origin was recorded during summer, which is also the case of the study carried out by Ben Moussa et al (2011).

Principal component analysis for the fall season. The analysis of the results shows that most of the information is explained by the first two factorial axes. In the factorial plane F1 x F2, the Eigen values of the two components F1 and F2 and their contribution to the total inertia are shown in Figures 20, 21, 22 and 23. The mineralization of water is expressed by the conductivity (Rodier 1996). Organic filler is represented by dissolved oxygen (El Morhit 2009; Chaouki et al 2015).

The two axes taken into account to describe the correlations between the variables related to the spatial structures, hold alone 51.67% of the total information with respectively 31.99% for the axis 1 and 19.68% for the axis 2 (Figure 20).

The axis 1 is expressed towards its positive pole by the pH, chloride, nitrite and dissolved oxygen which have good correlations between them. While the axis 2 is defined by the SS and nitrate towards its positive pole and the oxidability towards its negative pole.

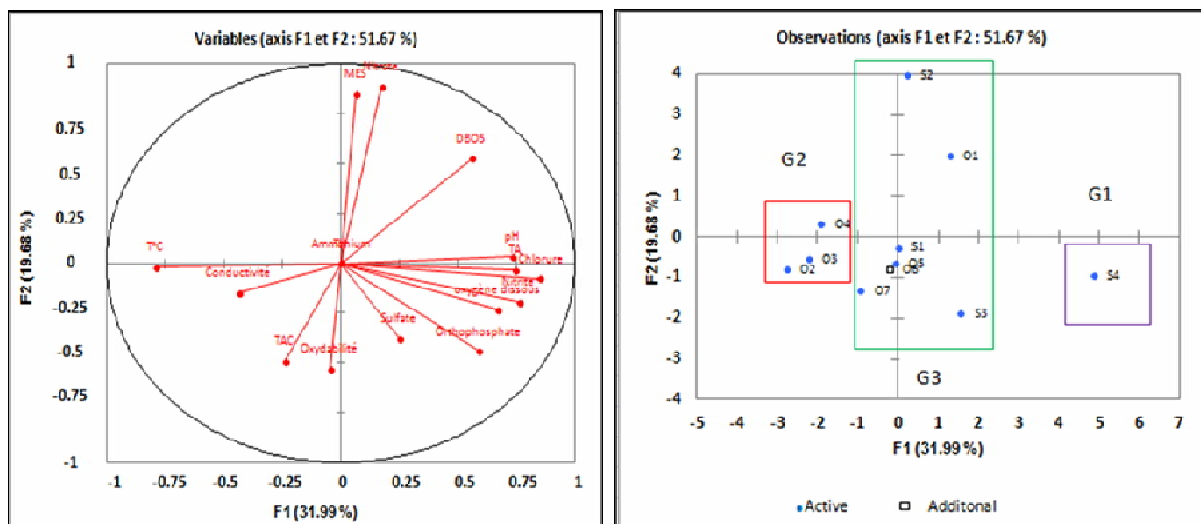


Figure 20. PCA of the physicochemical components according to the zones, in the plane of axes F1 x F2 for the fall season.

The typology released from the F1 x F2 plane (Figure 20; Table 1), shows the classification of three groups according to their hydro-chemical character:

- G1: characterized by high organic load and low mineralization;
- G2: marked by low organic load and strong mineralization;
- G3: moderately achieved by organic and mineral loads.

Table 1

Distribution of the inertia between the two axes (F1 x F2) of the physicochemical parameters for the fall season

	F1	F2
Eigen values	4.479	2.755
Variability %	31.991	19.679
Accrued %	31.991	51.670

Principal component analysis of the winter season. The two axes taken into consideration to describe the correlations between the variables related to spatial structures, alone hold 57.92% of the total information with respectively 36.50% for axis 1 and 21.42% for the axis 2 (Figure 21).

The axis 1 is expressed towards its positive pole by the pH, chloride and sulfate which have good correlations between them. While the axis 2 is defined by the temperature and the conductivity towards its positive pole and oxidability, dissolved oxygen and nitrate towards its negative pole.

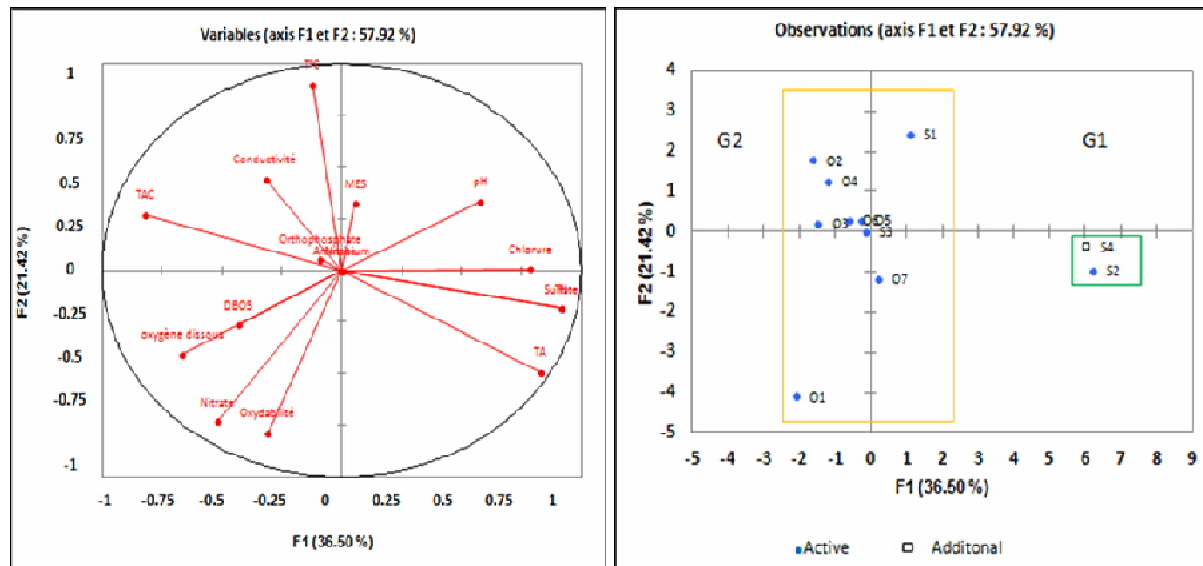


Figure 21. PCA of the physicochemical components according to the zones, in the plane of the axes F1 x F2 for the winter season.

The typology released from the F1 x F2 plane (Figure 21; Table 2), shows the classification of two groups according to their hydro-chemical character:

- G1: characterized by low organic load and low mineralization;
- G2: moderately achieved by organic and mineral loads.

Table 2

Distribution of the inertia between the two axes (F1 x F2) of the physicochemical parameters for the winter season

	F1	F2
Eigen values	5.110	2.998
Variability %	36.499	21.417
Accrued %	36.499	57.916

Principal component analysis of the spring season. The two axes taken into account to describe the correlations between the variables related to the spatial structures, hold alone 48, 34% of the total information with respectively 26, 74% for the axis 1 and 21, 59% for the axis 2 (Figure 22).

The axis 1 is expressed towards its positive pole by the conductivity, dissolved oxygen and temperature and towards its negative pole by the suspended substances (SS) and the pH which have good correlations between them. While the axis 2 is defined by sulphate and nitrites towards its positive pole.

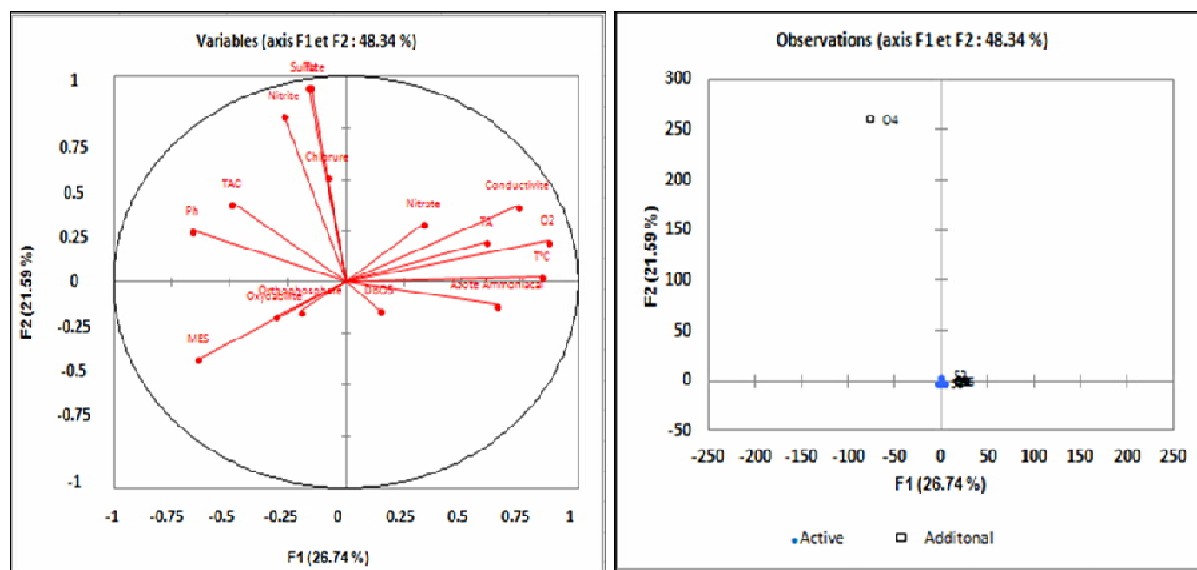


Figure 22. PCA of the physicochemical components according to the zones, in the plane of the axes F1 x F2 for the spring season.

The typology released from the F1 x F2 plane (Figure 22; Table 3) shows the classification of a single group moderately affected by organic and mineral loads.

Table 3

Distribution of the inertia between the two axes (F1 x F2) of the physicochemical parameters for the spring season

	F1	F2
Eigen values	4.279	3.455
Variability %	26.741	21.595
Accrued %	26.741	48.336

Principal component analysis of the summer season. The two axes taken into account to describe the correlations between the variables related to the spatial structures, hold alone 63, 21% of the total information with respectively 33, 52% for the axis 1 and 29, 69% for the axis 2 (Figure 23).

The axis 1, is expressed towards its positive pole by the oxidability and the BOD₅ and towards its negative pole by the conductivity, dissolved oxygen and temperature which have good correlations between them. While axis 2 is defined by orthophosphate towards its positive pole.

The typology released from the F1 x F2 plane (Figure 23; Table 4), shows the classification of two groups according to their hydro-chemical character:

- G1: characterized by low organic load and low mineralization;
- G2: marked by high organic load and strong mineralization.

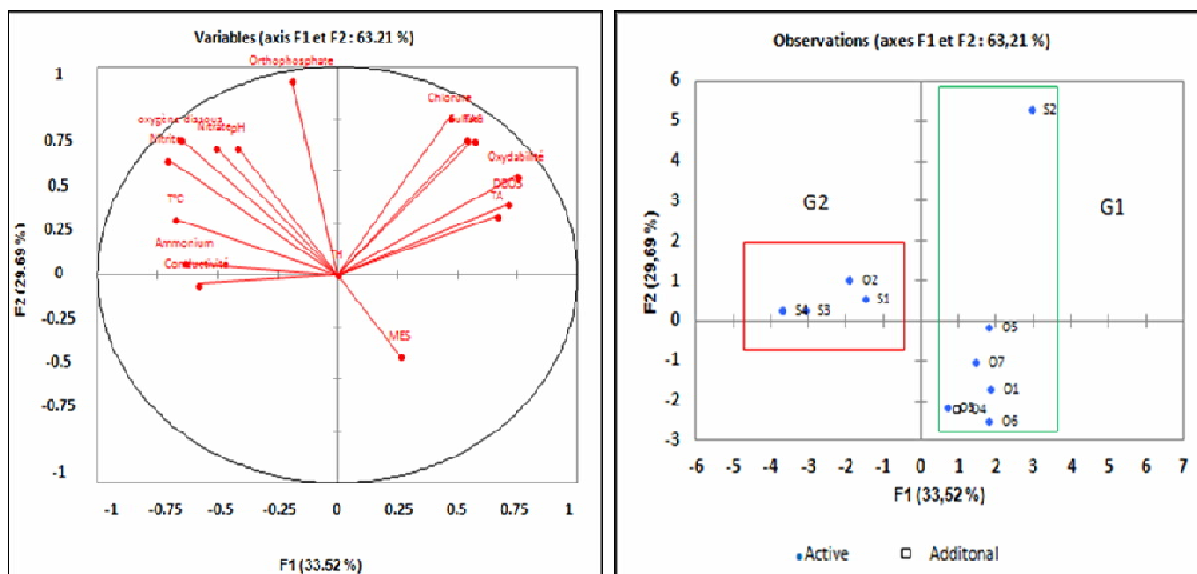


Figure 23. PCA of the physicochemical components according to the zones, in the plane of the axes F1 x F2 for the summer season.

Table 4

Distribution of the inertia between the two axes (F1 x F2) of the physicochemical parameters for the summer season

	F1	F2
Eigen values	5.028	4.454
Variability %	33.517	29.693
Accrued %	33.517	63.211

Conclusions. In general, the water supply of the Ourika region depends on the aquatic ecosystem of the High Atlas. Based mainly on agricultural, tourism and livestock activities, the components of the environment are under increasing pressure and are causing a deterioration of the latter.

The results of the physicochemical study revealed that the whole Ouad is characterized by a middle-class water without exceeding the limits set for the majority of parameters, despite the various activities along its edge (cafes and restaurants) and domestic waste.

The microbiological study has allowed us to identify different bacterial species in spring water such as: *Proteus mirabilis*, *Providencia rettgeri*, *Esherichia coli*, *Klebsiella pneumoniae*, with a much higher bacterial presence in the water during summer, which qualifies the water as non-potable.

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