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Hydrobiological evaluation of the sources of the Fès-Taza corridor region: source Atrous and source Louali (Morocco)

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ABSTRACT

As part of our investigation, particular attention is paid to water resources and especially to freshwater sources. The aim of this work is to monitor the spatiotemporal variation of the physicochemical and bacteriological characteristics of the waters of the Atr and LO sources in the Fez-Taza corridor region. The waters of these two Freshwater ecosystems are alkaline with a calcium and magnesium bicarbonate facies, fairly well oxygenated with a minimum of 9.1 (mg / l) at the LO source and a maximum of 12.38 mg / l at the Atr source. The hydrogen potential oscillates between a minimum of 7.2 at Atr and a maximum of 7.9 at LO. The chloride values range from a minimum of 24.85 (mg / l) at Atr to a maximum of 79.87 (mg / l) at the LO source. The sulphate values range from a minimum of 28.51 (mg / l) at LO and a maximum of 56.38 (mg / l) at Atr. The electrical conductivity values range from a minimum of 743 (µs / cm) at Atr and a maximum of 958 (µs / cm) at LO. Permanganate Index values range from a minimum of 0.29 (mg / l) at Atr to a maximum of 5.25 (mg / l) at LO. The temperature recorded averages of 20.55 ° C and 20.66 ° C respectively at the Atr and LO sources. Concerning the orthophosphates, the values recorded at the two resurgences are very small and approach the 0.This on the one hand. On the other hand, the statistical tool revealed the involvement of the season factor in the temporal distribution of physicochemical parameters. In addition, microbiological analysis showed contamination of the aquifer by bacteria of fecal origin which exceeded the thresholds set by Moroccan drinking water standards.

Keywords: quality, physicochemistry, bacteriology, ACP, sources, Morocco, water

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INTRODUCTION

Groundwater constitutes an important reserve in Morocco. It is pure water, normally protected by the grounds that cover them, and by filtration within the aquifer. When pollution penetrates, especially by massive infiltration into a place, it is more or less delayed, and not direct and rapid as in the case of surface water. But, the contamination is much longer to disappear due to the slowness of the circulation of the ground water. In the case of karst lands the characteristics of pollution may be similar to those of surface waters.

The Atrous and Louali sources are among the most sought after resurgences in the Fès-Taza corridor region, their waters being used for irrigation and drinking water supply. These two sources are faced with strong anthropogenic and climatic pressures that threaten the quality of their waters. The aim of this work is to evaluate the influence of anthropogenic activities on the physico-chemical and bacteriological quality of water and to determine the quality of these waters by reference to Potability or irrigation.

MATERIAL AND METHODS

Study area

Atrous (Atr)

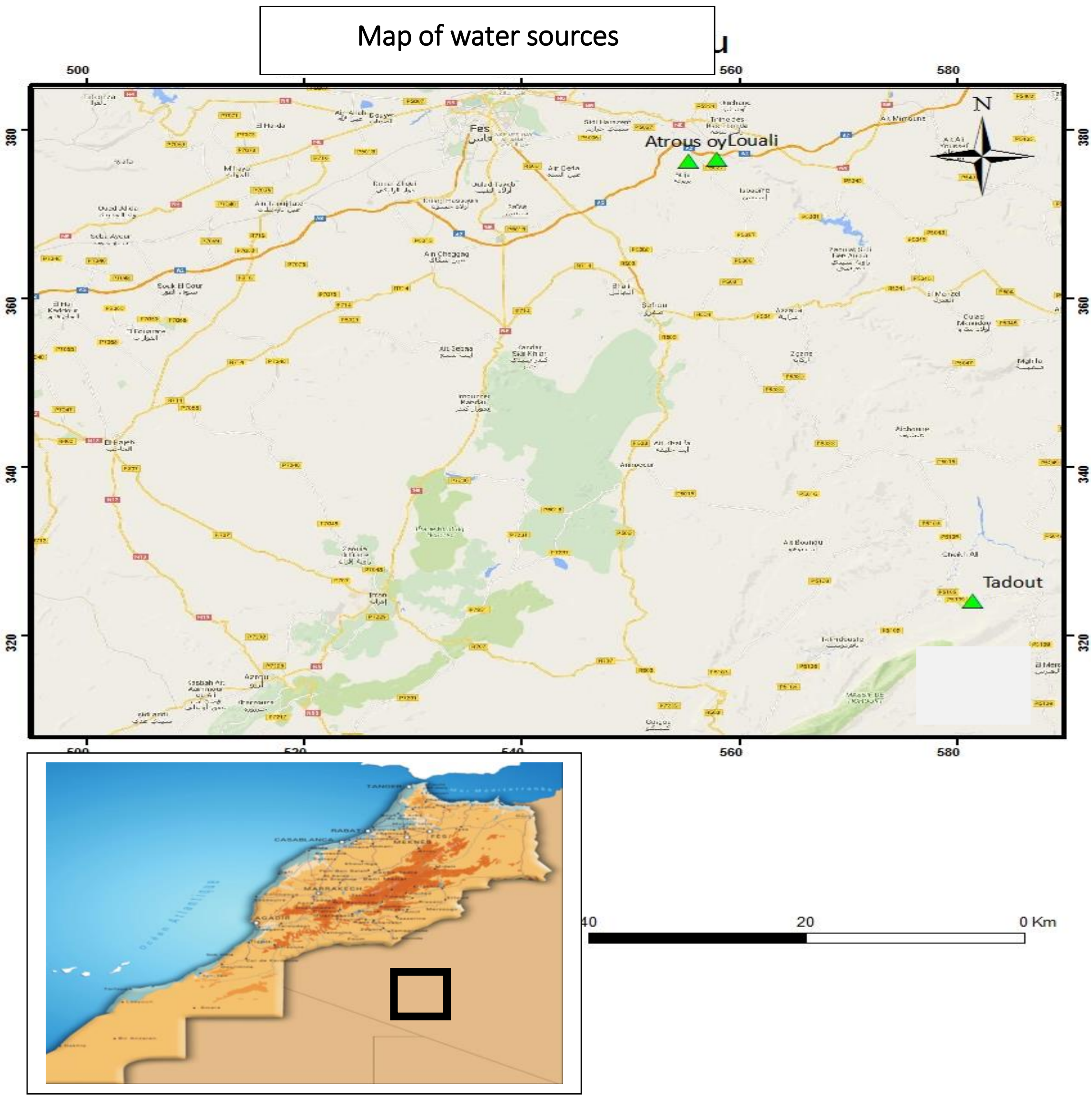

Figure 1: Location of the different study areas

The source Atrous is located about 22km to the southeast of the city of Fez. It is part of the hydroelectric unit of the Fez-Taza corridor. Its average flow is 345 (l / s). This deaf aquatic ecosystem is karstified in the limestone conglomerate sandstones of the Miocene base which cover the dolomitic Lias over a thickness A few meters. The waters of this source are used for the supply of drinking water to neighboring agglomerations and the watering of livestock. Moreover, this source constitutes a seaside resort (Figure 1).

Louali (LO)

Located about 19km northeast of the town of Sefrou.The source of Louali deaf from the sign of Sefrou which is part of the corridor Fes-Taza. This Aquatic ecosystem springs from the dolomitic and calcareous banks located immediately under the Miocene sandstones. It delivers about 223l / s. Their waters serve to supply drinking water to Douar Ain Louali. This resort is an ideal refuge for swimming enthusiasts. (Figure 1).

Sampling

Physicochemical parameters

To better understand the operation of the study sites, with anthropogenic pressures, climatic hazards and also its influence as an abiotic environment, the waters of the two sources were the subject of a physicochemical study following a seasonal periodicity. During each season, two samples have been made, leading a total of 8 companions of sampling covering the year 2015. According to the standardized methods described by [1] (Table 1), 11 variables were the subject of a physico-chemical monitoring. Water samples were collected using own plastic bottles, previously rinsed with water from the station. Measurements of temperature, pH, and conductivity were conducted in situ using a multi-parameter CyberScan PC10 Analyzer. The rest of the evaluations made by metering or spectroscopic assays according to the methods described by [1], in the laboratory of functional ecology and environment of the Faculty of science and technology of Fez.

Table 1: Chemical component analysis method

Parameters	Unit	Measuring equipment and method of analysis
Temperature	° C	Analyzer multi parameters Cyber Scan
Conductivity	µS/cm	Analyzer multi parameters Cyber Scan
pH		Analyzer multi parameters Cyber Scan
Dissolved O_2	mg/l	Winkler method
Calcium hardness	mg/l	EDTA Complexometry of with calcone
Magnesium hardness	mg/l	Difference between total and calcium hardness
Alkalinity	meq/l	Volumetric dosing with sulfuric acid and methyl orange
Permanganate index	mg/l	Oxidizability of hot potassium permanganate
Chlorides	mg/l	Metering,with Mohr method
sulphates	mg/l	absorption spectrometry at 650 nm
Orthophosphates	mg/l	absorption spectrometry at 750 nm

Microbiological analyzes

The microbiological characterization of a water point is part of the analyzes currently practiced. In fact, the purpose of a bacteriological study is to identify the presence or absence of fecal contamination, the microorganisms sought are Total Aerobic Mesophilic Flora (TAMF), fecal coliforms (FC), total coliforms (TC) and faecal streptococci (FS).

Water samples were taken in situ in sterile bottles. Filtrations and seeding, in a petri dish, were carried out the same day. The methods used during this monitoring follow Moroccan drinking water standards. The various culture media recommended for the bacteriological analysis of water are explained in Table 2. After incubation, the Forming Colonies Units (FCU) were enumerated macroscopically in each petri dish.

Table 2: Method of sampling and enumeration of bacteria

	Technique	Sampling volume	Culture medium	Incubation temperature
FMAT	Incorporation in solid medium	1 ml	Yeast extract agar	20°C et 37°C
Total coliforms	Filtration	100ml	Agar lactose to the TTC	37°C
Fecal coliforms	Filtration	100ml	Agar lactose to the TTC	44°C
Faecal streptococci	Filtration	100ml	Agar Slanetz	37°C

RESULTS AND DISCUSSION

Physicochemical parameters

-Water Temperature

Thermal variations are low. The temperature of the waters of the study stations shows a seasonal evolution at a substantially continuous rate (Figure 2). We note a remarkable source heat with an average annual temperature around 20.55 ° C (Atr) and 20.66 ° C (LO). The lowest values mark the winter period. Temperature differences are minimal and are related to the altitude effect. By comparing these results with the potability and irrigation standards recommended by Morocco [2], these waters show acceptable values.

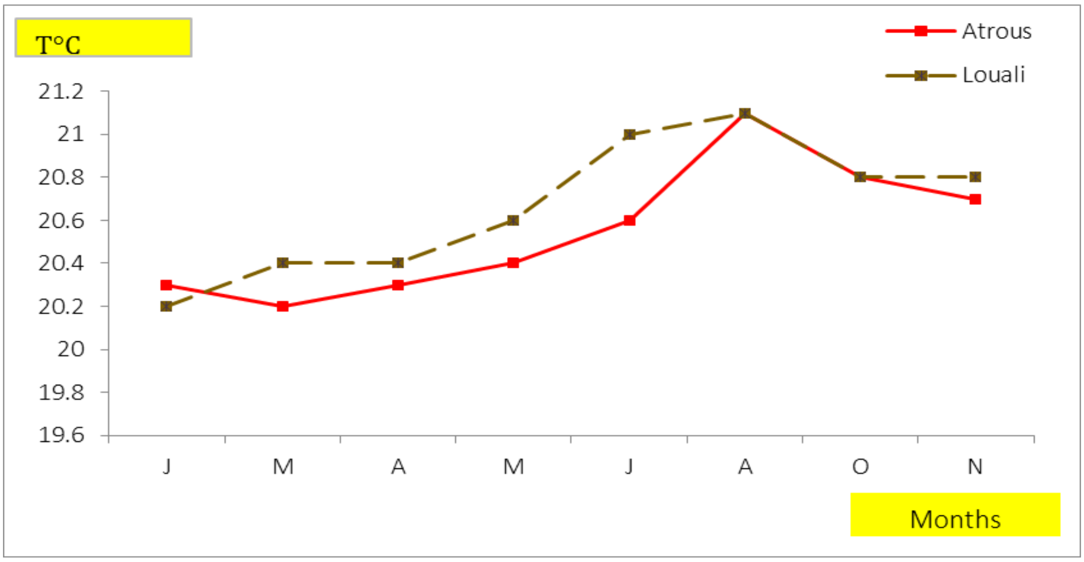

Figure 2: Temporal profile of the temperature variation at the two study sites during the year 2015.

-Hydrogen potential

The pH is important to know because, knowing the values of dissolved CO_2, it indirectly allows the evaluation of the chemical aggressiveness of the waters, in the stations of study, it is slightly neutral to alkaline, In the dry period, its average value is 7.6 (Atr) and 7.7 (LO). The standard deviation of 0.28 (Atr) and 0.29 (LO) shows small variations of this parameter during the year, this low alkalinity is strictly related to the nature of the karstic terrain traversed (Figure 3).

The waters of the studied sources can be considered acceptable by referring to Moroccan standards [2].

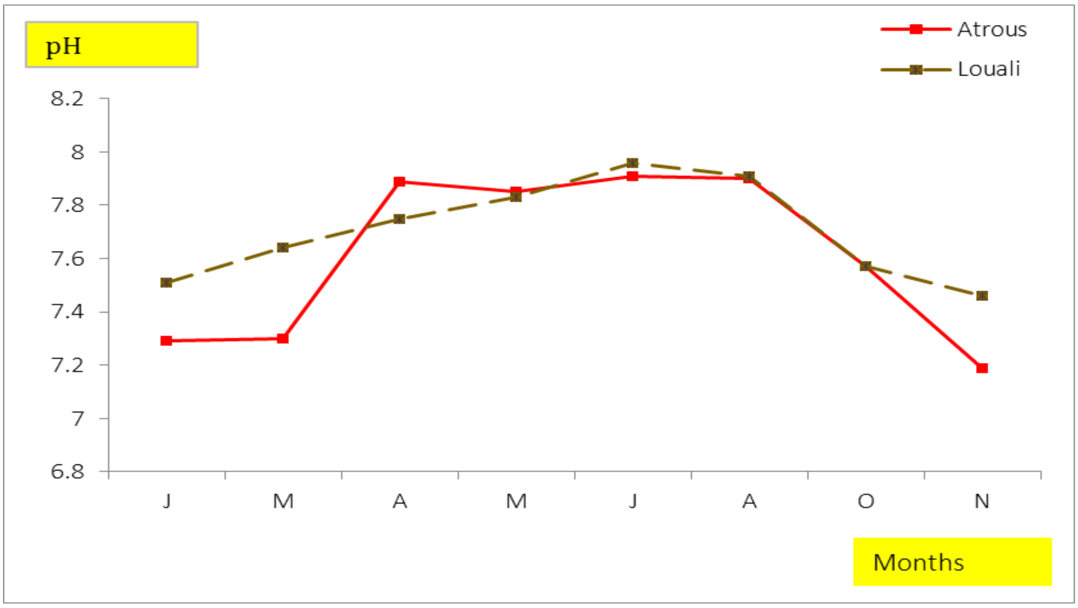

Figure3: Time profile of the pH variation at the two study sites during the year 2015

-Electrical conductivity

The electrical conductivity is directly related to the forms traversed in the hydrogeological basin of the griffins. The measured values range from 743 (µS / cm) to 780 (µS / cm) at Atr and between 875 (µS / cm) and 958 (µS / cm) at LO (Figure 4). These relatively low values are related to the lithology of the terrain traversed. Indeed, the sources Atr and LO belong to the liasic aquifer of the Fès-Taza corridor, resting on a medium Lias dolomite substratum and upper Lias limestones [3]. This predominant facies of the waters of the Fès-Taza corridor is calcium carbonate [4]. Moreover, the comparison of the conductivity in the two resurgences with the Moroccan norm fixed at 2700 (µs / cm) Places these waters in the excellent grid.

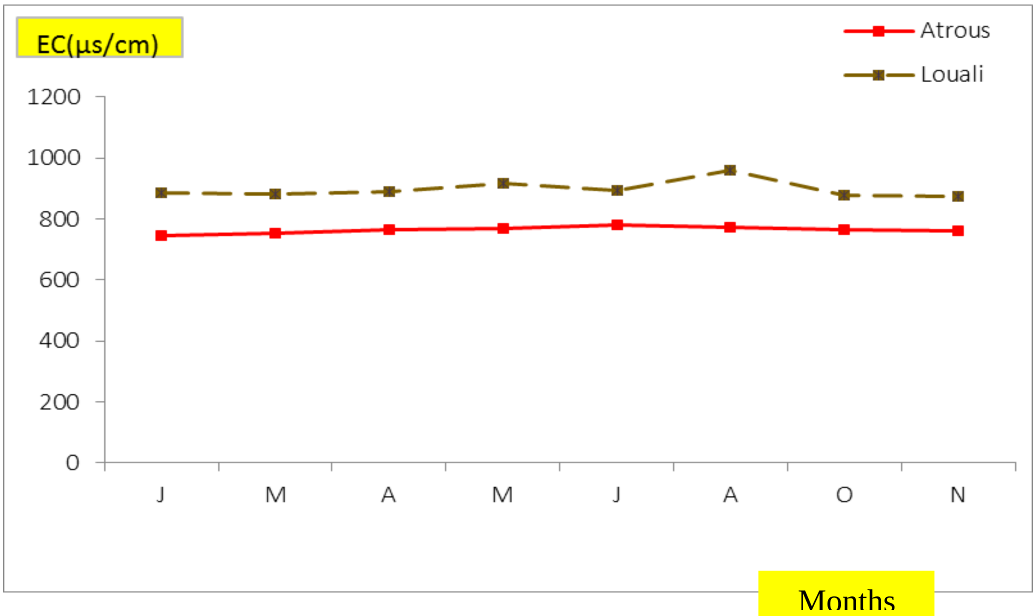

Figure 4: Temporal variation of the electrical conductivity at Atr and LO water during the year 2015.

-Chlorides

Chlorides are widely distributed in nature, usually in the form of sodium (NaCl) and potassium (KCl) salts. They represent about 0.05% of the lithosphere, are naturally occurring in groundwater due to meteoric alteration and leaching of sedimentary rocks and soils, as well as the dissolution of salt deposits. They are often used as a pollution index. For both measuring points, the average values of chlorides evolve in the same way as those of the conductivity. (Figure 5), concentrations ranged from 24.85 (mg / l) to 47.9 (mg / l) at Atr and between 79.8 (mg / l) and 110.05 (mg / l) at LO. The lowest values indicate the winter period, which could be due to dilution by precipitation, while the highest values mark the summer period. This could be linked to the increase in anthropogenic activity. Moreover, the results found remain well below the Moroccan norm set at 750 mg / l [5].

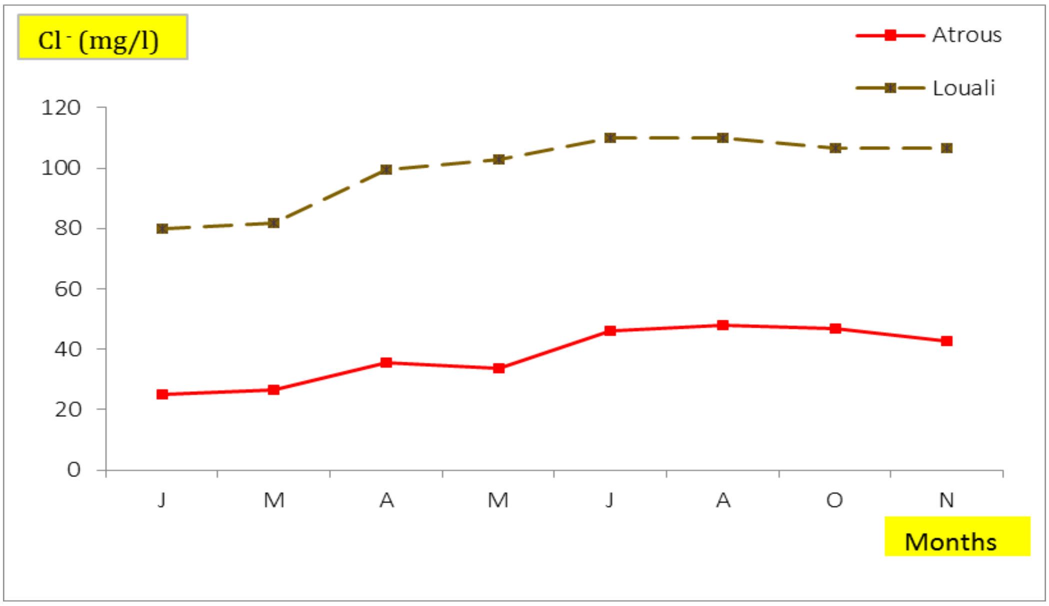

Figure5: Temporal variation of chloride content in Atr and LO sources during 2015.

-Calcium hardness

The graphical representation of calcium ions concentrations did not show significant variations (Figure 6), with relatively high levels ranging from 76.9 (mg / l) to 98.8 (mg / l) at Atr and from 81.1 (mg / L) to 120.6 (mg / l) at LO. The averages obtained are 88.68 (mg / l) and 100.64 (mg / l) respectively at Atr and LO. This would be linked to the importance of the karst reservoir from which the resurgences spring (Figure 6).

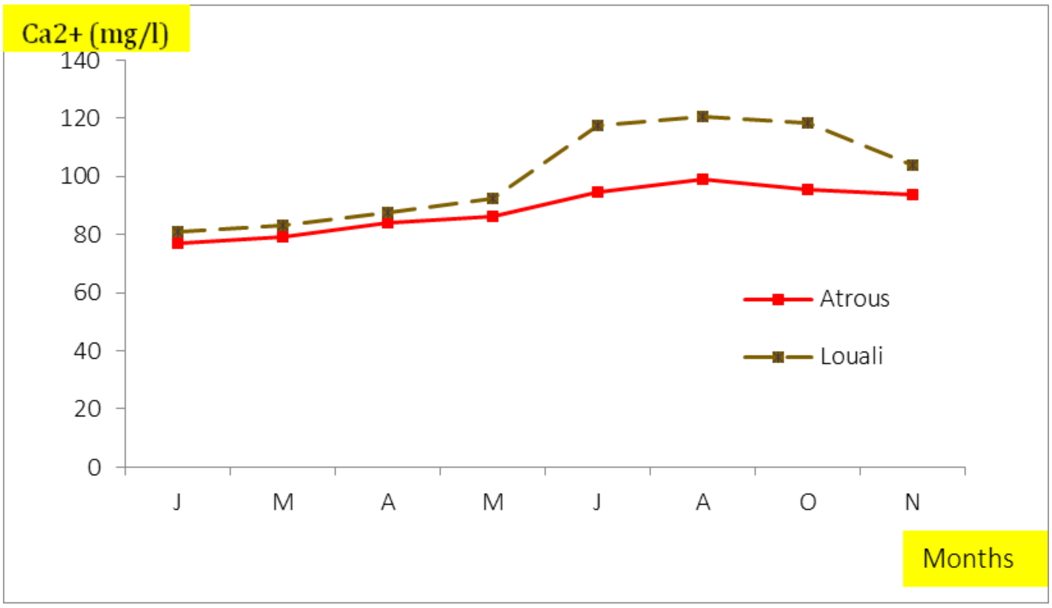

Figure 6: Temporal variation of the Ca2 + content in the Atr and LO sources during the year 2015.

-Magnesium hardness

On the basis of the results of the analyzes carried out for the samples of the waters of these two sources, the magnesium contents show an evolution similar to that of calcium. This is related to the lithology of the carbonate-based region which, after dissolution, produces magnesium and calcium. [3]**.**The averages recorded are 136.92 (mg / l) and 139.52 (mg / l) respectively at the Atr and LO sources (Figure 7).

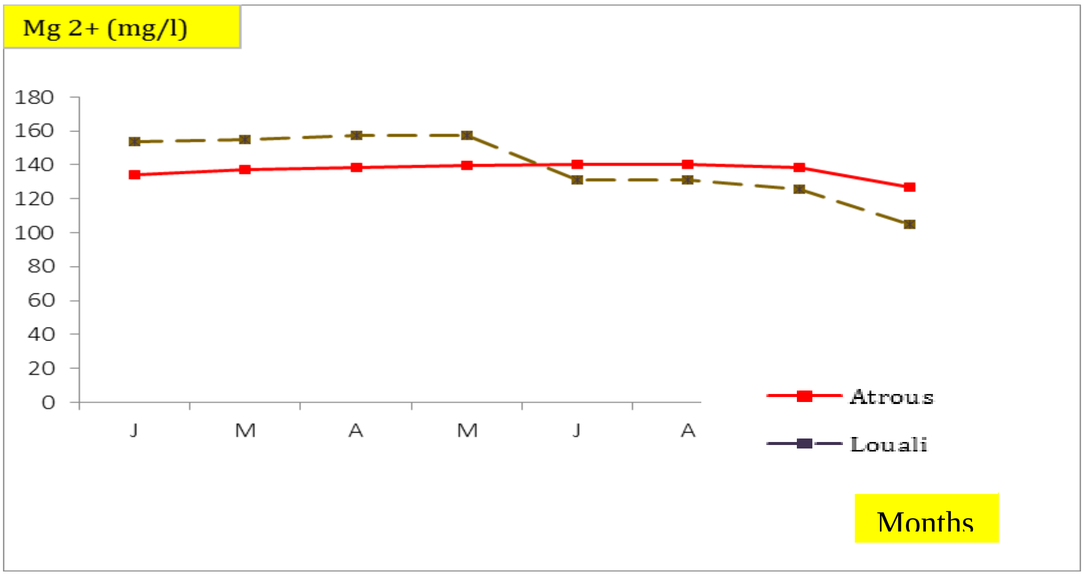

Figure 7: Temporal variation of the Mg 2+ content in the Atr and LO sources during the year 2015.

-Complete Alkalimetric Title (CAT)

The Complete Alkalimetric Title (CAT) is a measure of the alkalinity of water (alkaline carbonates, hydrogencarbonates and total hydroxides). It characterizes the buffering capacity of water, that is to say the ability of an acid or basic product to influence the pH of the water, it is closely related to the hardness, although many species of solutes can contribute. Alkalinity is expressed in an equivalent amount of carbonate. The results relating to the temporal variation of the CAT make it possible to obtain sawtooth curves marked by slight fluctuations in both the rain and dry periods (Figure8). These small variations are proved by standard deviations of 0.134 (meq / l) at Atr and 0.079 (meq / l) at LO.

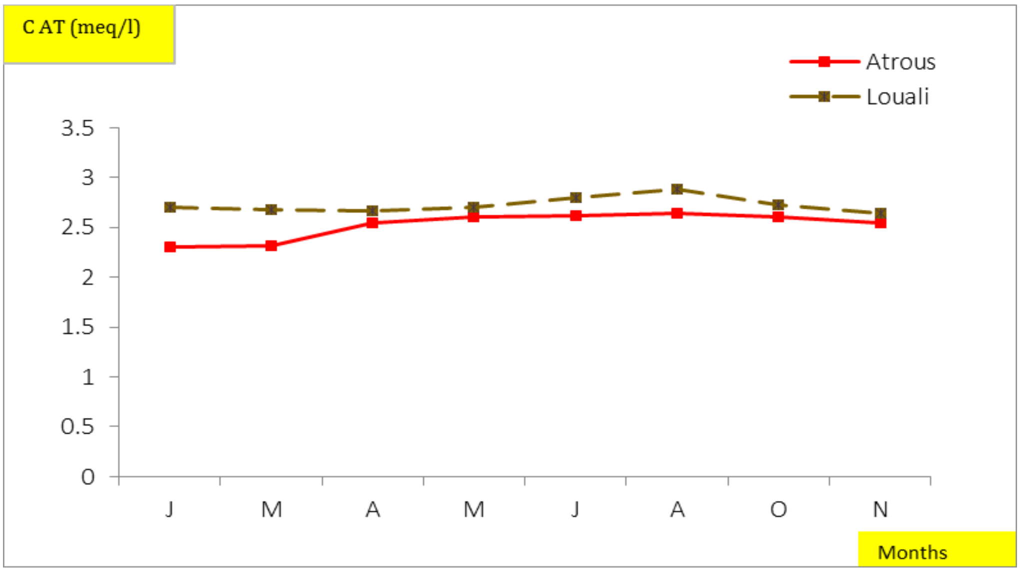

Figure 8: Temporal variation of CAT content in Atr and LO sources duringthe year 2015.

-Sulfates

The concentration of sulphates in surface waters is generally between 2.2 and 58 mg / l [6]. In study stations, sulfate ion contents do not exceed 57 mg / l. This parameter ranges from 38.08 (mg / l) to 56. 38 (mg / l) at Atr and from 28.51 (mg / l) to 32.97 (mg / l) at LO. (Figure 9). These levels remain well below the Moroccan standards [2] set at 200 (mg / l) for drinking water and 250 (mg / l) for irrigation water.

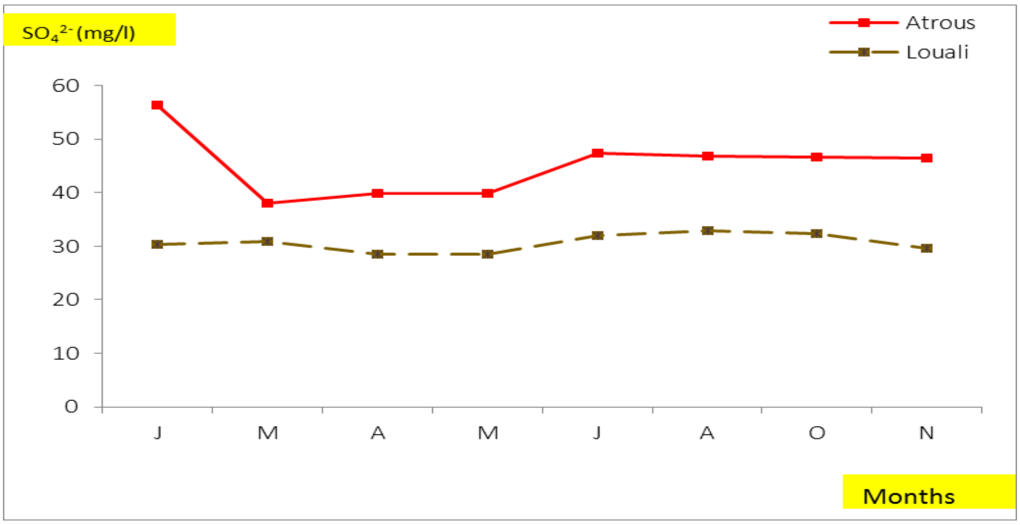

Figure 9: Temporal variation of sulphates content in Atr and LO sources during the year 2015.

-Orthophosphates

This parameter is usually monitored. A high content of orthophosphates may indicate agricultural pollution following leaching of fertilizers. The high contents of this element in surface waters can lead to their eutrophication, since in the absence of human intervention, surface waters contain very little phosphate. [7] estimate that the natural PO_4^{3-}content of watercourses is less than 0.025 µg / l and depends mainly on the nature of the geological substratum.

For the two sources in question, orthophosphate concentrations are well below the tolerable threshold which is:0.4 (µg / l) (Figure 10) Even though these two stations are located near agricultural areas, which justifies the very deep origins of their waters. These results are consistent with those found by [8] in their prospecting for sources in the same study area.

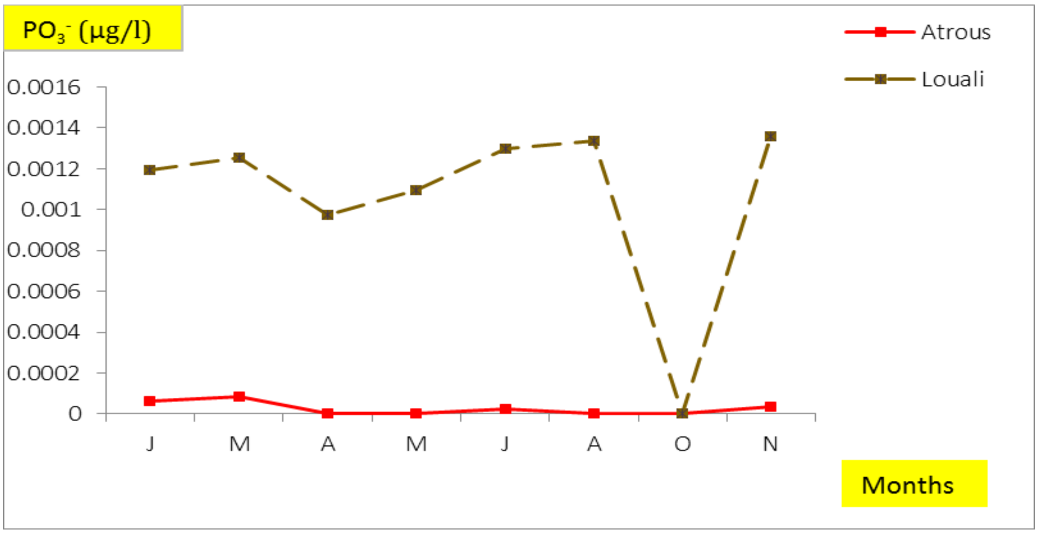

Figure 10: Temporal variation of orthophosphates content in Atr and LO sources during the year 2015.

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-Dissolved Oxygen

Oxygen is a key factor and an excellent indicator of water quality. Its value tells us the degree of pollution and therefore the degree of self-purification of a watercourse. In our study, the seasonal evolution of dissolved oxygen shows higher concentrations in wet periods than in dry periods. Indeed, the levels recorded ranged from 10 (mg / l) to 12.38 (mg / l) at Atr and between (9.1 mg / l) and 10.9 (mg / l) at LO (Figure 11). This is mainly due to the decrease in water temperature; because cold water contains more dissolved oxygen than warm water [9]. Moreover, the high velocities of the winds cause a continuous mixing of the water mass and consequently an enrichment of the dissolved phase in oxygen during the winter season. It should be noted, however, that the Atr station is dominated by an important plant cover of macropphytes and algae, which explains the high availability of dissolved oxygen compared to the other station. It is our responsibility to consider that the year 2015 has experienced a delay in precipitation and that is why we notice a continuous drop in dissolved oxygen even in October.
Overall, the dissolved oxygen regime in the studied sectors is far from being deficient.

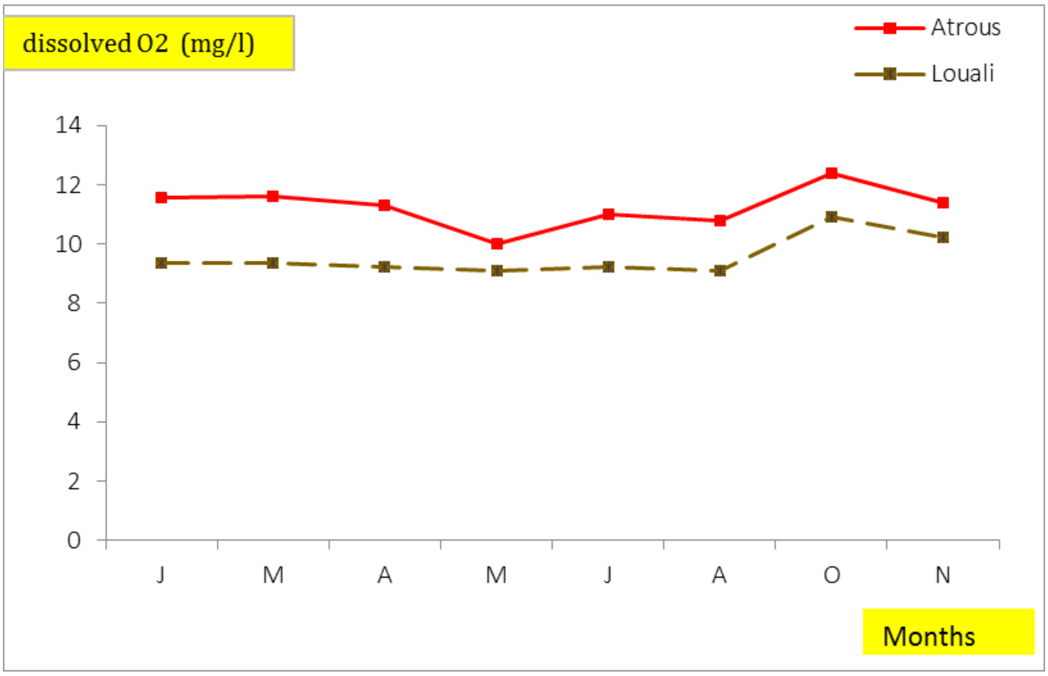

Figure 11: Temporal variation of dissolved oxygen content in Atr and LO sources during the year 2015.

-Permanganate Index

The permanganate index (PI) is an estimate of the concentration of organic matter in surface water and drinking water. It is therefore an important parameter to characterize the overall pollution of a Water by organic compounds. The PI levels in the studied waters range from 0.29mg / l) to 3.4 (mg / l) at Atr while LO is marked by a change from 1.9 (mg / l) to 5.25 (mg / l) (Figure 12). Moisture concentrations are significantly lower than during the dry season. As has been cited previously, both stations are coveted bathing and cooling places, not only by their neighbors, but also by all neighboring agglomerations, the other side of the coin would be an increase in the permanganate index in the summer which appears to be evidence and an immediate consequence of the increase in anthropogenic activity. Finally, it can be stated that in the two study areas the anthropogenic pressure remains, hitherto without significant consequences, but which must be monitored from a perspective of sustainable development. The grid of Moroccan standards then allows to classify these waters in the excellent category.

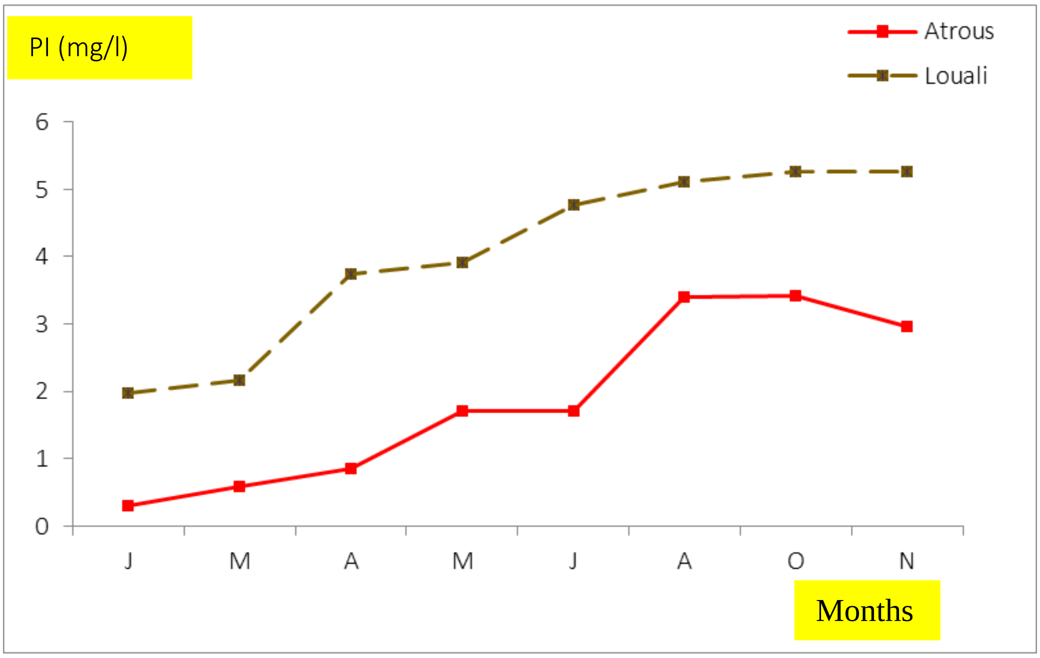

Figure 12: Temporal variation of the permanganate index content in Atr and Lo sources during the year 2015.

Statistical analysis of physicochemical data by PCA

The statistical study by the PCA with the software Unscrumbler 9.2 gives many results presented in Table 3, where the eigenvalues are recorded. The analysis matrix for each source is a table with two inputs, the first containing the parameters to be analyzed, while the second records the different sampling months.

Table 3 : Eigenvalues of the CAP pourcentage cumulé, Pourcentage de variance, Valeur propre

N° composante	Eigenvalue		Percentage of variance		Cumulative percentage	
	Atr	LO	Atr	LO	Atr	LO
1	**5,5751**	**5,42934**	**55,75**	**54,293**	**55,751**	**54,293**
2	**2,40734**	**2,84109**	**24,07**	**28,411**	**79,824**	**82,704**
3	0,860564	**1,09594**	8,606	**10,959**	88,43	**93,664**
4	0,742665	0,354568	7,427	3,546	95,857	97,209
5	0,251285	0,249039	2,513	2,49	98,37	99,7
6	0,113939	0,023435	1,139	0,234	99,509	99,934
7	0,049104	0,0065954	0,491	0,066	100	100
8	1,04E-16	4,49E-16	0	0	100	100
9	0	2,42E-17	0	0	100	100
10	0	0	0	0	100	100

Study of correlations between physicochemical parameters

-The station Atr

The graph of correlations (figure 13) gives us a first idea about the associations existing between the different variables such as Ca2+, Cl-; IP, CE and PO43-. These parameters are relatively well correlated with one another and correlated negatively with the dissolved O2 group and SO42- and T. The elements that define the first group indicate a high mineralization resulting from a long solution time following the water-substrate contact Of the aquifers that shelter the waters of the region.

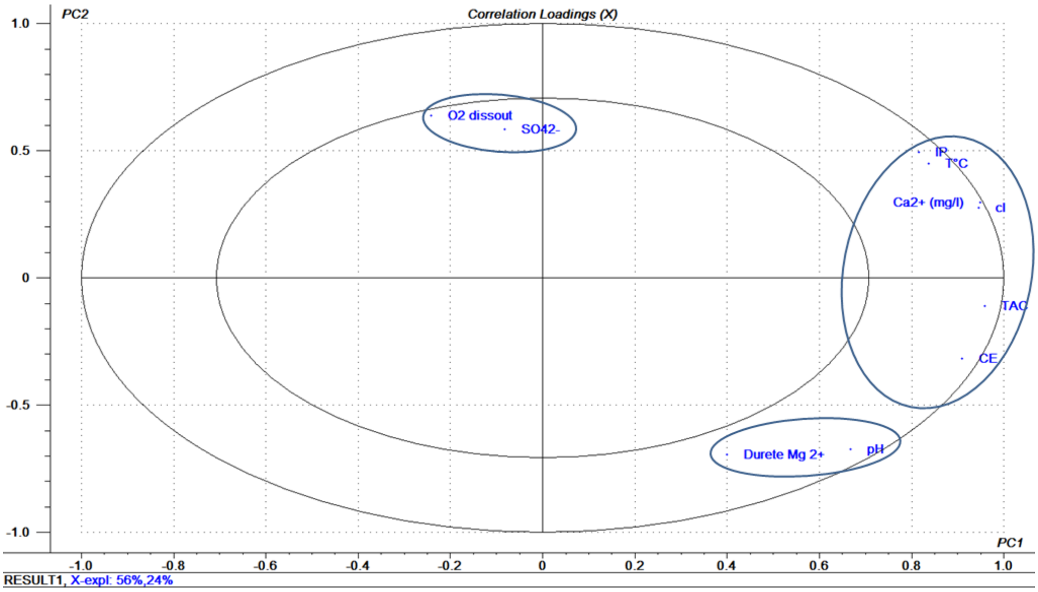

Figure 13: Space variables of the C1 - C2 plan at the station Atr.

-The station OL

The analysis of the variables of the ACP in the plane C1-C2 is presented by (figure 14). This graph shows 3 large groupings of the parameters studied in the water points. The first grouping takes into account Ca 2+, CE, TAC, pH, SO42 + and T and translates highly loaded waters into major elements, which explains the position in the positive part on the C1 axis thus reflecting the lithological nature of the region. The second cluster contains dissolved O2, a very positively correlated group, but in the positive part of the C1 axis and which shows well-oxygenated water, and finally a third constituted Mg2 + in the negative part of the two axes, the depletion in Mg2 + conjugated to an enrichment of Ca2 + is a common phenomenon in a carbonate environment[10].

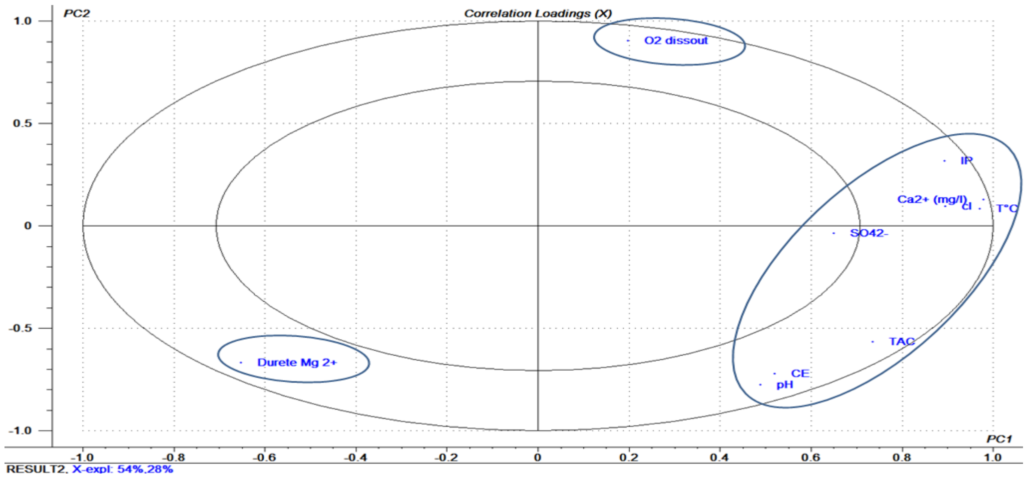

Figure 14: Space variables of the C1 - C2 plan at the station LO.

Influence of the factor "season".

The figures 15 and 16 reflect clearly the implication of the phenomenon of seasonality in the hydrochemical nature of the Atr and LO resurgences although it is commonly known that the chemical composition of well and source waters is mostly acquired during the crossing of the soil and its stay in the reservoir [11].

Four groups of records are differentiated. Each represents a season of the year. The effect of the season factor is therefore clear.

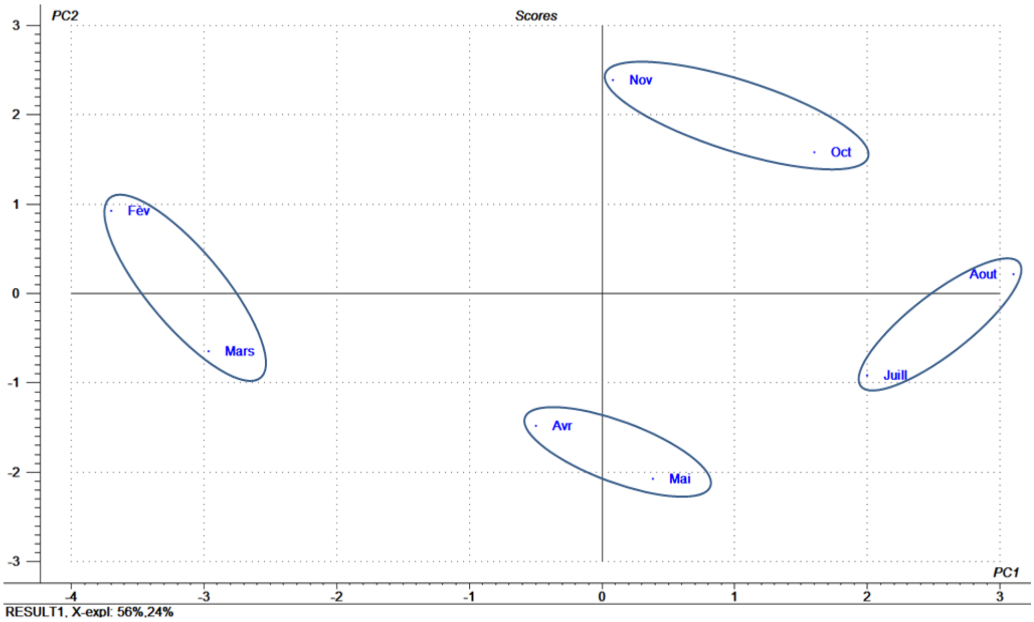

Figure 15: Monthly distribution graph at Atr station.

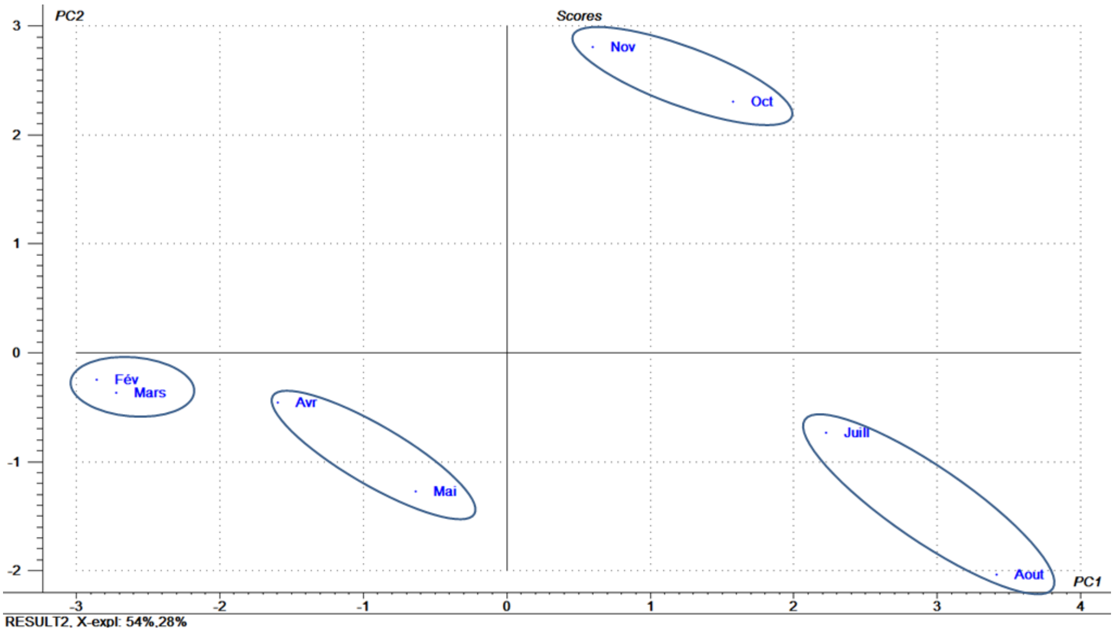

Figure 16: Month distribution graph at LO station.

Microbiological analysis.

The results of the microbiological analyzes are given in Table 4.

Total Coliforms (TC).

Total coliforms are enterobacteria that include bacterial species that live in the intestines of homeothermic animals, but also in the general environment (soil, vegetation and water). This bacterial group is used as an indicator of the microbial quality of water because it contains, in particular, bacteria of fecal origin.

The total coliform counts in water show a concentration of 126 CFU / 100ml at Atr and 137 CFU / 100ml at LO. Such values undoubtedly indicate fecal contamination of these two sources.

Fecal Coliforms (CF)

Fecal coliforms and enterococci are caused by animal or human fecal pollution and demonstrate the potential presence of pathogenic organisms capable of causing enteric diseases. None of these must be present per 100 ml of drinking water so that the water is safe for consumption.

The bacteriological analysis of the water samples of the two study stations indicates the presence of CF at a rate of 7600 CFU / 100 ml at Atr and 8700 CFU / 100 ml at the LO source. This presence of extremely high fecal coliforms indicates that there is a source of fecal matter (manure, septic tank or other).

Fecal Streptococci (FS)

The search for fecal streptococci in the water samples revealed their presence in the LO and Atr sources with respective values: 34 CFU / 100 ml and 29 CFU / 100 ml at the LO and Atr sources. The role of (FS) has recently been recognized as an indicator of fecal contamination in aquifers (groundwater). This interest in enterococci can be explained by the fact that, compared to coliforms, they are more resistant to difficult environmental conditions and persist longer in water; Such conditions are typical of groundwater where the temperature is generally colder and low in nutrients. All this leads us to say that the two sources are prone to a strong fecal contamination remains to prove its origin and it is the report CF / SF which is the appropriate tool that will help us to answer this question.

CF / SF Report

The presence of fecal germs, whether faecal coliforms (CF) or faecal streptococci (FS) does not allow speculation about the origin of fecal pollution. [12] proposed using the CF / SF ratio to determine whether contamination is of human or animal origin. For several decades, the fecal coliform / faecal stuccococci ratio was used as a first-rate informant to determine whether fecal pollution was of animal or human origin. When this CF / SF ratio is greater than 4, the pollution is essentially human (wastewater discharge). When it is less than 0.7 the origin is animal. The origin of the contamination is mixed with predominantly animal if R is between 0.7 and 1. This origin is uncertain if R is between 1 and 2 and the origin is said to be mixed predominantly human if R is between 2 And 4.

During our investigation, the CF / SF ratio was 262.06 at Atr and 255.88 at OL. Such results prove human contamination in both sources and it is the septic tanks that are pointed at. Contaminants from septic systems that can enter groundwater include bacteria, viruses and many other foreign substances. These can create serious contamination problems. Despite the fact that septic tanks and sumps are known sources of contamination, they are poorly monitored and poorly studied.

The use of these results shows that study stations deserve special attention and require extensive disinfection following the abnormally high presence of bacteria indicative of fecal pollution.

Table 4: Results of microbiological analyzes of Atr and LO sources

Microorganisms	Atr	OL
TAMF / ml	286000	295000
Total Coliforms (TC) / 100ml	126	137
Fecal Coliforms (CF) / 100ml	7600	8700
Fecal Streptococci (FS)/100 ml	29	34
CF / SF Report	262,068	255,882

CONCLUSION

The results obtained in this study made it possible to make a diagnosis of the physicochemical and bacteriological quality of the waters of the sources Atr and LO. The results of the physicochemical evaluations revealed that the waters of these two resurgences have normal temperature averages, are weakly alkaline, well oxygenated, have medium mineralization, high calcium hardness and an increase of PI in the summer period (anthropogenic activity). However, the values recorded for all the parameters are well below the Moroccan standards of drinking water and irrigation.
Statistical analysis of the data revealed that the variability of the water quality studied depended on 3 main factors:

- Mineralization resulting from the solubilisation of the underground substratum.
- The season factor.
- The impact of anthropogenic activities.

As for microbiological assessments, examination of the results showed that the waters of the sources in question reveal the enormous presence of bacteria indicative of fecal contamination.
As a result, the establishment of a water quality monitoring program for these two sources is necessary in view of the vulnerability and importance of these two wetlands.

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