

## **THE USE OF TOTAL ORGANIC CARBON TRACERS TO CHARACTERIZE THE FUNCTIONING OF KARST SYSTEMS IN THE TLEMCE MOUNTAINS, NORTHWEST ALGERIA**

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### **ABSTRACT**

The use of environmental tracing (Total Organic Carbon) is a good means to understand the role of the unsaturated zone in the functioning of karst aquifers. The knowledge of the aquifers located in the unsaturated zone is of prime importance to understand phenomena at the spring outlets of karstic systems. The speed and ease of introduction of water into the system explain the expansion of karstification through the saturated zone. The unsaturated zone is greatly involved in the global flow during the hydrological year. The fluctuation of TOC contents depends on the functioning of karst aquifers. The system with fissured type behavior shows a low average TOC value (3,6 mg/l for Tellout) as well as a relatively restricted fluctuations during the hydrological cycle. High average TOC contents and important variation in time are, however, typical of Taga system (5 mg/l). This system is supplied by surface water. The studies of aquifers structure (Taga and Tellout) to put in evidence an important contribution of water coming from perched aquifers, especially during flood events. The piston flow in the unsaturated zone put in charge the drains and stops drainage in the lower part of the system. The direct participation of infiltration is relatively low for all springs.

**Keywords:** Algeria, Tlemcen Mountains, Karst, Total Organic Carbon, Hydrodynamic functioning.

### **1. INTRODUCTION**

The role of the unsaturated zone is determinant in the karst aquifer hydrodynamic and karstification processes. The effective protection of the karst aquifer requires an understanding of the properties of the unsaturated zone. The water flow and solute transport in the unsaturated zone has been the topic of many investigations during the last decades, however, in the arid region are still approached from a qualitative standpoint

The purpose of this work is to use hydrochemical as a tracer to study the role of the unsaturated zone in a karstic system in arid region.

The present study aims to:

- test the effectiveness of the buffer effect of the unsaturated zone, and thus to obtain information on storage and transit times,
- estimate the effective contribution of recent infiltrations to the rapid flow.

Two types of infiltration can be distinguished in the unsaturated zone of carbonate aquifers: The first of these corresponds to the circulation of water through karst conduits, which ensures the fast flow of water towards deeper zones, with relatively high flow but short-lived. The second type features the slow circulation of water through the matrix bedrock and fissures, with a small flow and a low velocity.

The quantitative and qualitative evaluation of water resource and its necessary protection entered in the list of the major priorities for the South Mediterranean during these last two decades. This is particularly the case in Tlemcen region where the climatic conditions associated with the increasing demand for water recharge, involve an increase in the exploitation of the resource. The objective of

this study is the use of hydrochemical and isotopic parameters of the important springs, (1) to characterize the role of the unsaturated zone in the karst aquifer functioning, (2) to assess the origins of the groundwater in order to determine the recharge areas of the springs.

The studied area is located in Tlemcen Mountains, in the north west of Algeria. It is aligned WSW–ENE, 30–60 km away from the Mediterranean Sea. This area covers approximately 2000 km<sup>2</sup>. The Trara Mountains and the Maghnia plain separate the Tlemcen Mountains from the sea. The southern of Atlas Mountains is limited by the Oranese High Plains (Fig. 1).

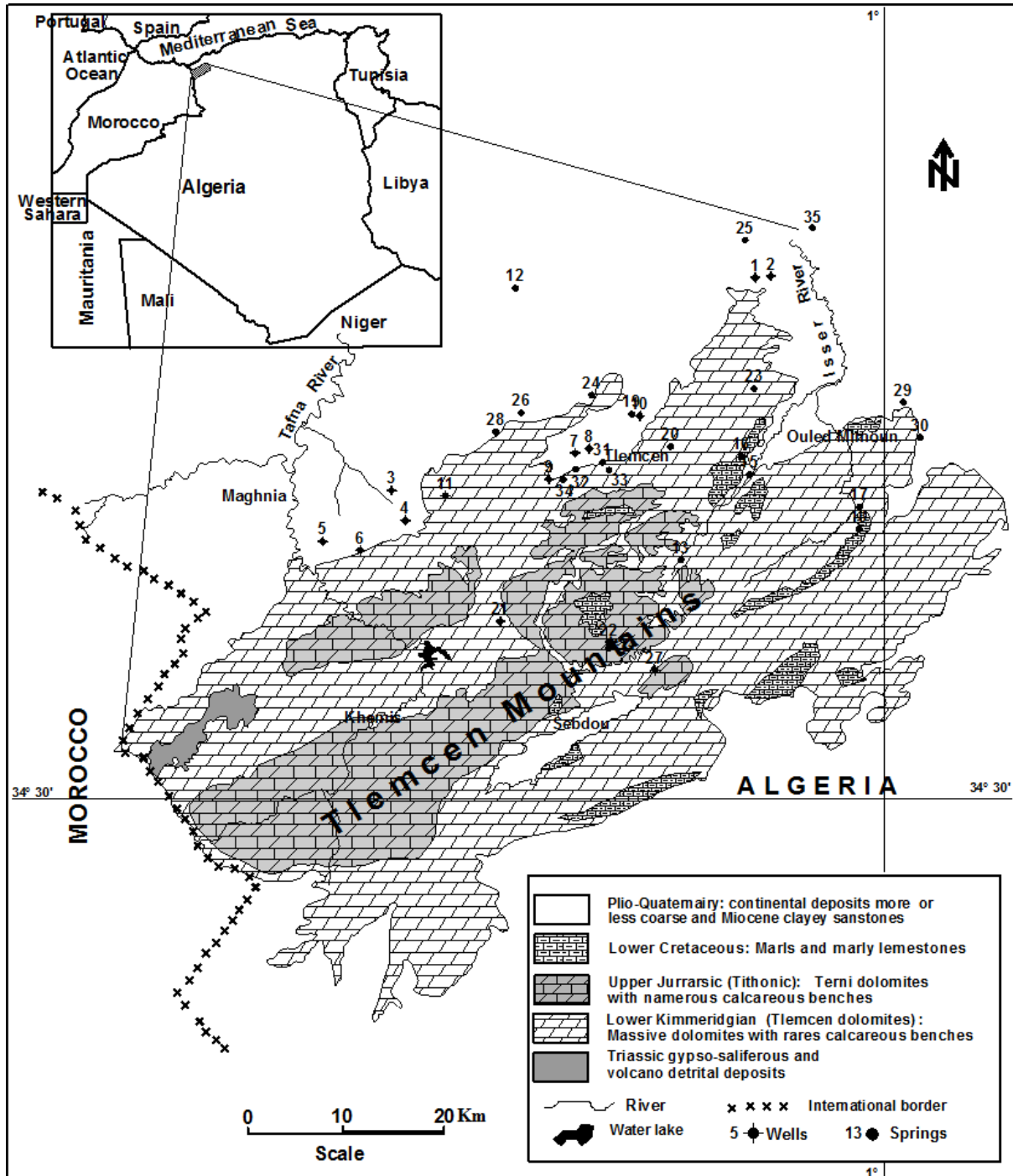


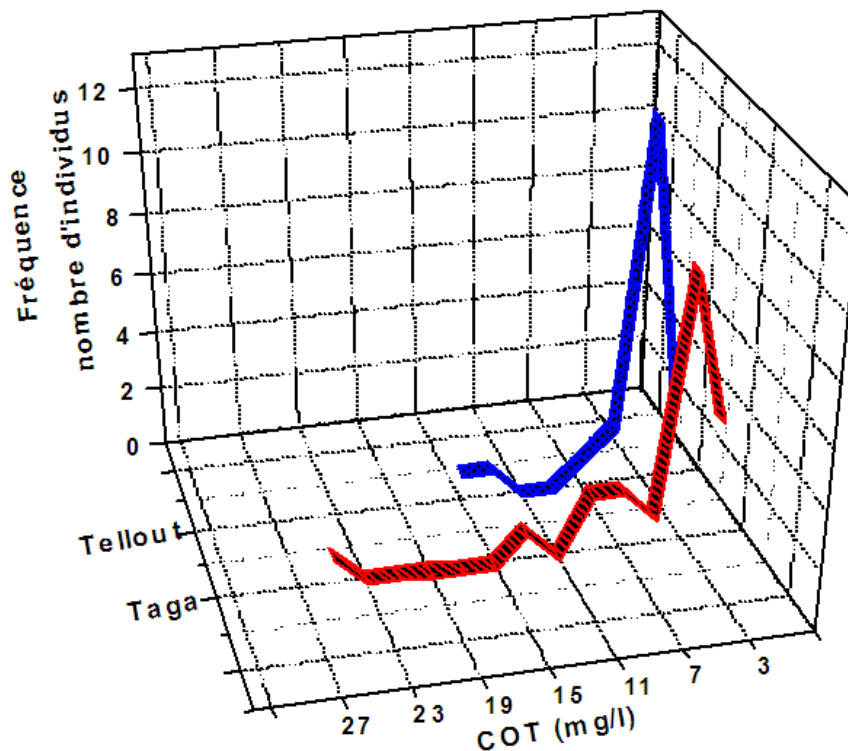
Fig. 1: Location and geological map of the studied area

## 2. CHARACTERIZATION OF THE AQUIFERS FUNCTIONNING ACCORDING TOC CONTENTS AND FROM THEIR VARIABILITY AT THE OUTLET

The TOC is a very sensitive tracer of infiltration. The analysis of the variations of TOC contents at the outlet of the main springs will allow us to compare these systems and to put in evidence their differences of functioning.

Systems characterized by a high mean content of TOC ( $\geq 5\text{mg/l}$ ) and important variations (standard deviations  $\geq 5\text{ mg/l}$ , curve frequency distribution plurimodal (**Fig.2**)).

Taga (perched system) spring belong to this group. This system is fed with high proportion by surface waters. We have previously seen that, this spring drains a perched aquifer, located on the Terni plateau, where forest cover is relatively dense. This facilitates concentrated infiltration of water relatively charged in TOC.



**Fig. 2:** Frequency distributions of Taga and Tellout systems

## 3. SYSTEMS CHARACTERIZED BY A MEAN VALUE TOC $\leq 4.0\text{ mg/l}$ WITH RESTRICTED WITH RESTRICTED FLUCTUATIONS (STANDARD DEVIATION $\leq 4\text{ mg/l}$ AND CURVE FREQUENCY DISTRIBUTION UNIMODAL)

Tellout system represents this cluster of fluctuations. This system is characterized by its size and especially by the presence of an important unsaturated zone (as we have seen previously). The average contents of TOC slightly lower ( $4.0\text{ mg/l}$ ) and their unimodal distribution of frequencies, suggest an inertial system with a relatively slow infiltration. Indeed, this result from the existence of an epikarst dolomitic zone which their relatively low permeability retards the infiltration. Furthermore, the importance of the saturated zone implies a residence time sufficiently long for much of the TOC was mineralized by bacterial activity during its transit within the aquifer.

## 4. TOC AND Mg: TWO OPPOSITE AND COMPLEMENTARY TRACERS IN THE STUDY OF WATER TRANSIT IN KARSTIC SYSTEM

The study of the relation TOC-Mg<sup>2+</sup> in Taga and Tellout systems (**Fig. 3**) allowed us to identify two clusters of springs in Tlemcen Mountains, whose characteristics are the following:

- Weak variations in Mg<sup>2+</sup> (from 10 to 48 mg/l) and high variations in TOC (undetectable to 24.5 mg/l). Taga spring is a part of this group. As we have seen previously, this system is shallow (perched system) and characterized by a transit time relatively short;
- High variations in Mg<sup>2+</sup> (29 to 85 mg/l) and relatively low variations in TOC (undetectable to 15.3 mg/l). Tellout systems represent this type of fluctuations. The importance of the unsaturated and saturated zones of these systems impose a contact time of water with aquifer sufficiently length so that the magnesium is dissolved. The waters of low flow are characterized by high Mg<sup>2+</sup> contents (85 mg/l) and very low TOC concentrations (not detectable). In high water period, the participation of water with low residence time generates a reduction of magnesium contents ( $\approx 25$  mg/l) and an increase of TOC contents ( $\approx 8.4$  mg/l).

## 5. USE OF THE RELATION (Mg<sup>2+</sup>/Ca<sup>2+</sup>)-TOC IN THE UNDERSTANDING OF SYSTEMS FUNCTIONING

The relation (Mg<sup>2+</sup>/Ca<sup>2+</sup>)-COT appears interesting in the study of the karst systems functioning and the characterization of the different water types participating in the drainage (Azzaz, H., 2008). Tellout spring was chosen to illustrate this relationship because of their karstification degree and inertia, where the waters of different origin and evolution arrive at the outlet. Different water types participating in the flow, inform us about the hydrodynamics functioning of this system.

The waters flowing at the low water and at resumption flood shows a high ratio Mg<sup>2+</sup>/Ca<sup>2+</sup> (1.2 to 1.7) and a low TOC concentrations (< 3 mg/l) (**Fig. 4**). This characterizes water having a prolonged residence time in the aquifer, essentially derived from the saturated zone. More the low water period is pronounced, more this ratio Mg<sup>2+</sup>/Ca<sup>2+</sup> increases and TOC concentrations decrease. The resumption flood presents the same characteristics as the waters of low water, but progressively, the rising flood, the ratio Mg<sup>2+</sup>/Ca<sup>2+</sup> decreases and TOC increases. This attests the increasing participation to the flow of water at low residence time and thus, the growing influence of the unsaturated zone. Conversely, more the flood recession starts more the influence of the unsaturated zone decreases and that of the saturated zone increases. This functioning is generally always the same regardless of the study period.

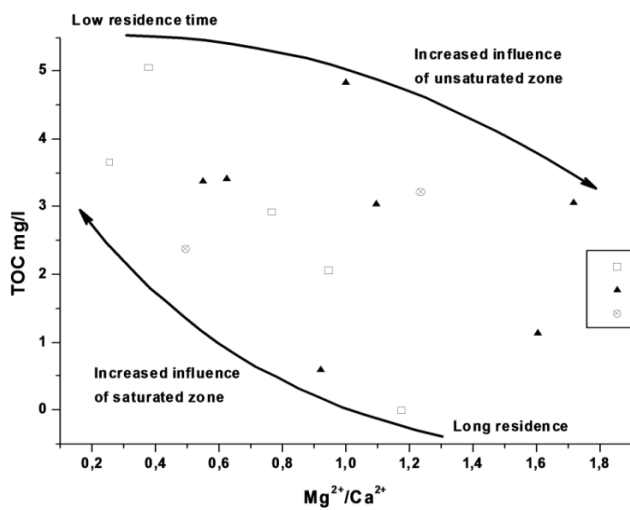
The complementarity of magnesium and TOC appears very interesting in understanding of karst systems functioning in the Tlemcen Mountains. These two elements vary in opposite directions. In floods period, the arrival at the outlet of water with a low residence time from the unsaturated zone is displayed by the decrease of magnesium and the net increase of TOC concentrations. In the other, during low water, water flowing with a long residence time (saturated zone) at the outlet is characterized by increased values of magnesium and lower concentrations of TOC. The evolution of the relationship (Mg<sup>2+</sup>/Ca<sup>2+</sup>)-TOC at Taga and Tellout system has proved relevant in the study of its functioning and characterisation of the different water types emerging at the outlet of this system.

The influence of infiltrated rainfall during summer has been displayed through the TOC (increase from 1 to 14 mg), whereas the variation of (Mg<sup>2+</sup>/Ca<sup>2+</sup>) remains relatively low during this period (1,3 to 1,6).

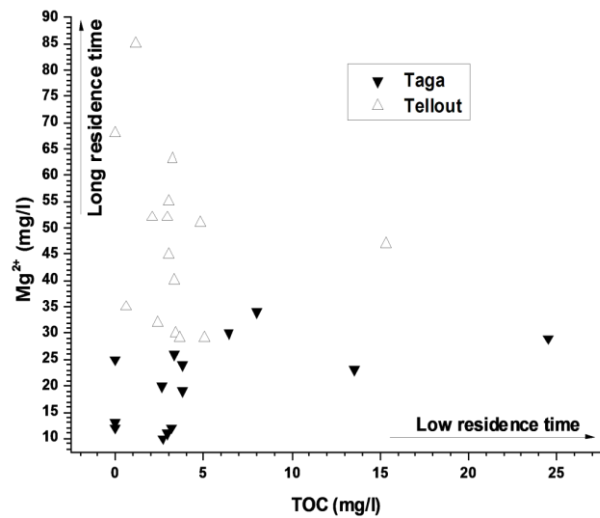
## 6. CONCLUSION

The complementarity of magnesium and TOC appears very interesting in understanding of karst systems functioning. The results of this investigation show a major role of the unsaturated zone in the karstic aquifers functioning. These two elements (magnesium and TOC) vary in opposite directions. In floods period, the arrival at the outlet of water with a low residence time from the unsaturated zone is displayed by the decrease of magnesium and the net increase of TOC concentrations. In the other, during low water, water flowing with a long residence time (saturated zone) at the outlet is characterized by increased values of magnesium and lower concentrations of TOC. The evolution of the relationship (Mg<sup>2+</sup>/Ca<sup>2+</sup>)-TOC at Taga and Tellout system has proved relevant in the study of its functioning and characterisation of the different water types emerging at the outlet of this system.

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**Fig. 4:** Relationship ( $Mg^{2+}/Ca^{2+}$ )-TOC for the system of TlemcenMontains



**Fig. 3:** the relation COT- $Mg^{2+}$  in Taga and Tellout systems

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