Multiparametric and tracer test study of a water resource in a contaminated karst mountain area

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Abstract Simultaneous detection of physical and chemical parameters is applied to real-time analysis of groundwater from an Alpine karst spring. Continuous sampling of the spring water was carried out during a half year. Following parameters were recorded by the instrument : groundwater temperature, electrical conductivity and turbidity, dissolved organic matter and concentration of injected artificial dye tracers (uranine, sulforhodamine and Tinopal during 3 tracer tests). This study permitted the identification of sources of contamination of the spring.

Keywords: Hydrogeology, contamination, fluorometer, DOM, tracer test

1. Introduction

The spring of La Puya is a karst emergence located in a highly faulted area of lower Cretaceous (Urgonian) limestones (Fig. 1). This karst system is densely fragmented by numerous faults that drain waters infiltrated at an average altitude of 1800 m. Part of the water from this spring is used for the freshwater supply of the nearby small town of Petit-Bornand-les-Glières (Haute-Savoie, France). Periodically the drinking water displays a significant concentration of bacteria of fecal origin, as well as a high turbidity (several NTU). This study aims at 1) locating the spots in the catchment area that disrupt the water quality, 2) evaluate the local infiltration rate compared to the spring outflow and 3) propose measures of purification.

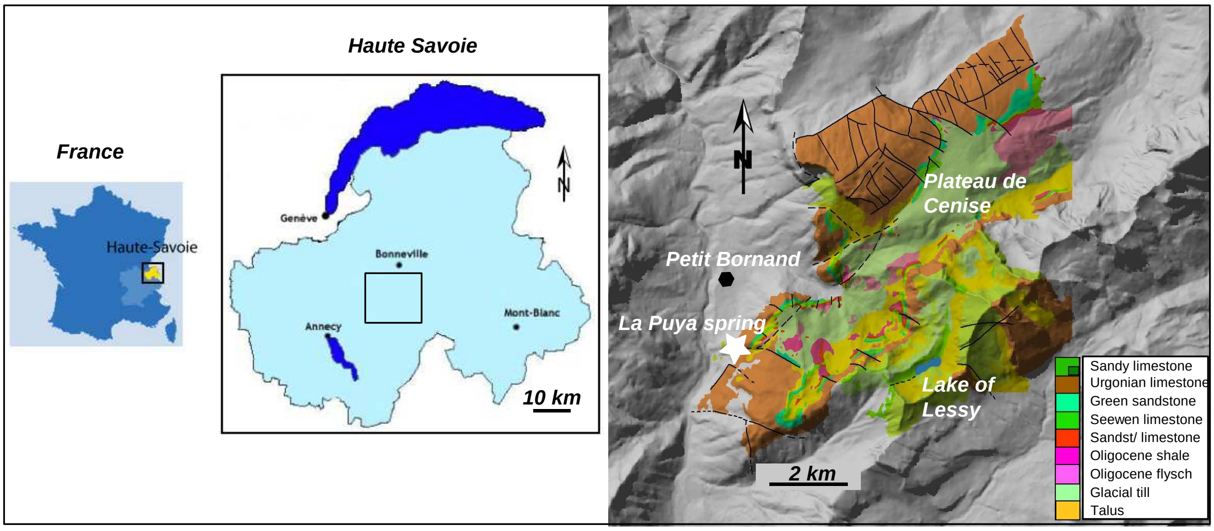

Fig. 1. Area of study. Alpine karst valley in the French department of Haute Savoie

2. Methodology

Continuous sampling of the spring water was carried out during four months (summer-autumn 2006). All investigations employed a University of Neuchatel Geomagnetism Group flow-through field fluorometer (GGUN-FL) (Schnegg 2002, Schnegg and Flynn 2002, Schnegg 2003) : Groundwater temperature, electrical conductivity, turbidity, dissolved organic matter and artificial dye tracers (uranine and sulforhodamine B during three tracer tests). In addition, water samples were brought to the laboratory for subsequent bacteriological analysis. The tracer tests were intended for determining the degree of contribution of the spring by potential contamination sites. A special technique was applied for removal of stray signal of dissolved organic matter (DOM) from the uranine signal (Fig 2). This operation was necessary since the light source used for the excitation of the uranine fluorescence (470 nm) activated also the fluorescence of the naturally occurring DOM. The method is described in Schnegg and Le Doucen (2006) and the general problem of DOM interference is commented in Meus et al. (2006).

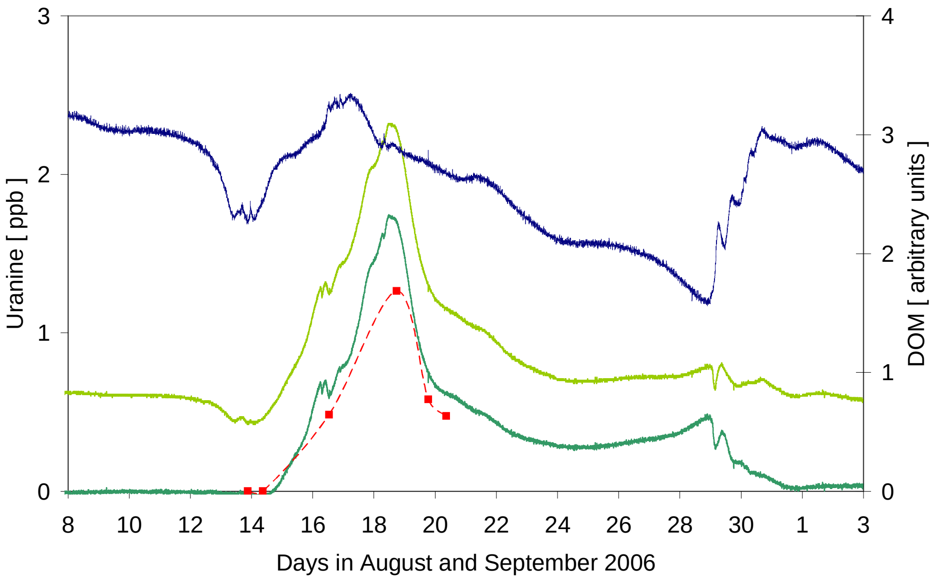

Fig. 2. DOM signal removal from the uranine curve. From top to bottom: DOM curve, uncorrected uranine, corrected uranine, broken line: laboratory analysis of tracer for comparison

3. Results

From a physico-chemical point of vue, only the water turbidity displays chronically non-conform values. Due to pasture activities (bovines and ovines) two areas of the catchment are responsible for the bacterial contamination of the spring, namely the Plateau de Cenise and the subterranean outlet of the Lake of Lessy. Tracer tests carried out during high water between the eastern outlet of the Lake Lessy (Fig. 3 and 4), the sink hole of the Plateau de Cenise (Fig. 5) and the La Puya emergence indicate recovery rates of 11%. Maximum flow velocities reach 30 metres/hour.

Date and time of injection	08.08.06 14:50
Injection point	Lake Lessy E outlet
Survey point	La Puya spring
Distance to spring	3350 m
Difference in height	880 m
Tracer	1 kg sulforhodamine B
Spring mean flowrate	160 L/s
Transit time	120 h
Flow velocity	26 m/h
Restitution rate	9%
Contribution rate	0.3%

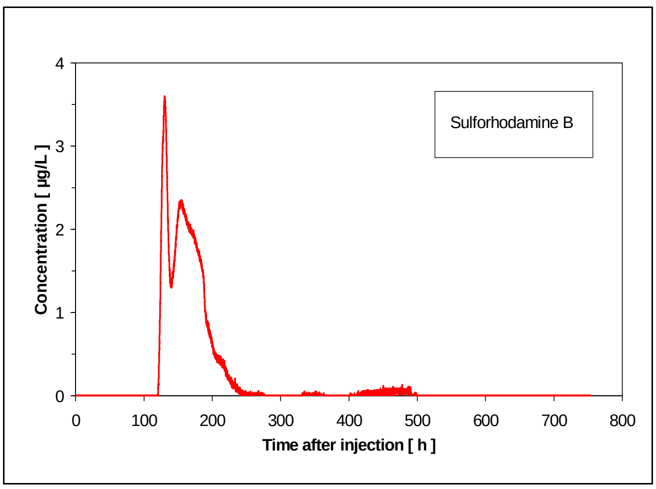

Fig. 3. Tracer test at Lake of Lessy during high water.

Date and time of injection	10.10.06 12:50
Injection point	Plateau de Cenise
Survey point	Lake Lessy E outlet
Distance to spring	La Puya spring
Difference in height	3350 m
Tracer	880 m
Spring mean flowrate	77 L/s
Transit time	220 h
Flow velocity	10 m/h
Restitution rate	17%
Contribution rate	0.45%

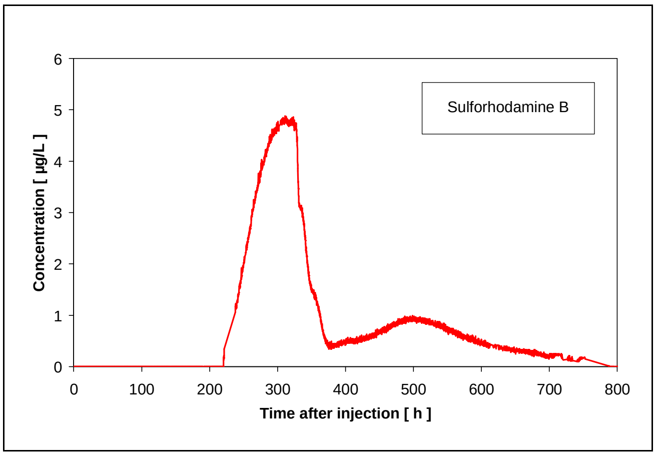

Fig. 4. Tracer test at Lake of Lessy during low water.

However, the degree of contribution to the spring yield of the two contamination areas is hardly 0.6%. In summer, the content in pathogenic micro-organisms (Escherichia coli) frequently exceeds the required limits. Generally speaking, flow velocities remain low, as well as recovery rates

Date and time of injection	08.08.06 17:30
Injection point	Plateau de Cenise
Survey point	La Puya spring
Distance to spring	4325 m
Difference in height	820 m
Tracer	1 kg uranine
Spring mean flowrate	160 L/s
Transit time	144 h
Flow velocity	20 m/h
Restitution rate	11%
Contribution rate	0.15%

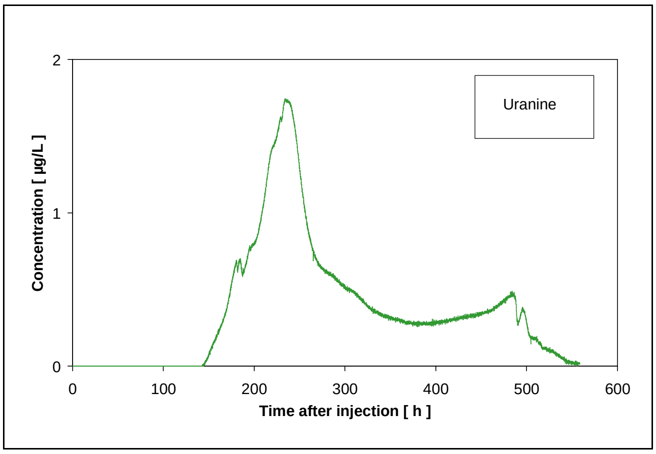

Fig. 5. Tracer test at Plateau de Cenise

Tracer tests clearly show a connection with the karst emergence. The influence of the two critical areas on bacterial contamination is extremely high due to the lack of filtering soil coverage on the limestone in a country of seasonal pasture. The reappearance at the La Puya spring (two peaks in Fig. 3) of the sulforhodamine B indicates that the coloured water remained some time in the system. The particular tailing of the uranine curve (sink hole of Plateau de Cenise, Fig. 5) is explained by the influence of fluctuations of the dissolved organic matter.

Figure 6 shows the relationship existing between several physico-chemical parameters such as rainfall, turbidity, electrical conductivity, water temperature and UV fluorescence (DOM). This figure displays these parameters during a period of important precipitations, and helps understand the functioning of the karst aquifer. Lines 1 to 5 mark a series of typical events occurring during the rise of the water level:

1) Remobilization of autogenic sediments from the karst system (primary turbidity). In fact, only turbidity and electrical conductivity increase.

2) Rise of DOM. Obviously its origin is external to the karst system. This rise is interpreted as the arrival of the first meteoric water infiltrated close to the spring.
3) Maximum values of turbidity, electrical conductivity and DOM correspond to the arrival of sediments allogenic to the karst system (secondary turbidity).
4) Delayed arrival of meteoric water infiltrated on the whole catchment.
5) DOM diminution indicates that the major part of the water has reached the spring.

The occurrence of a secondary turbidity after a primary one suggests a flush mechanism of either the karst porous matrix or of a possibly flooded zone. In addition, the temperature drop between 2) and 3) suggests either the increase of the spring flowrate or the fact that the infiltrated water is cooler.

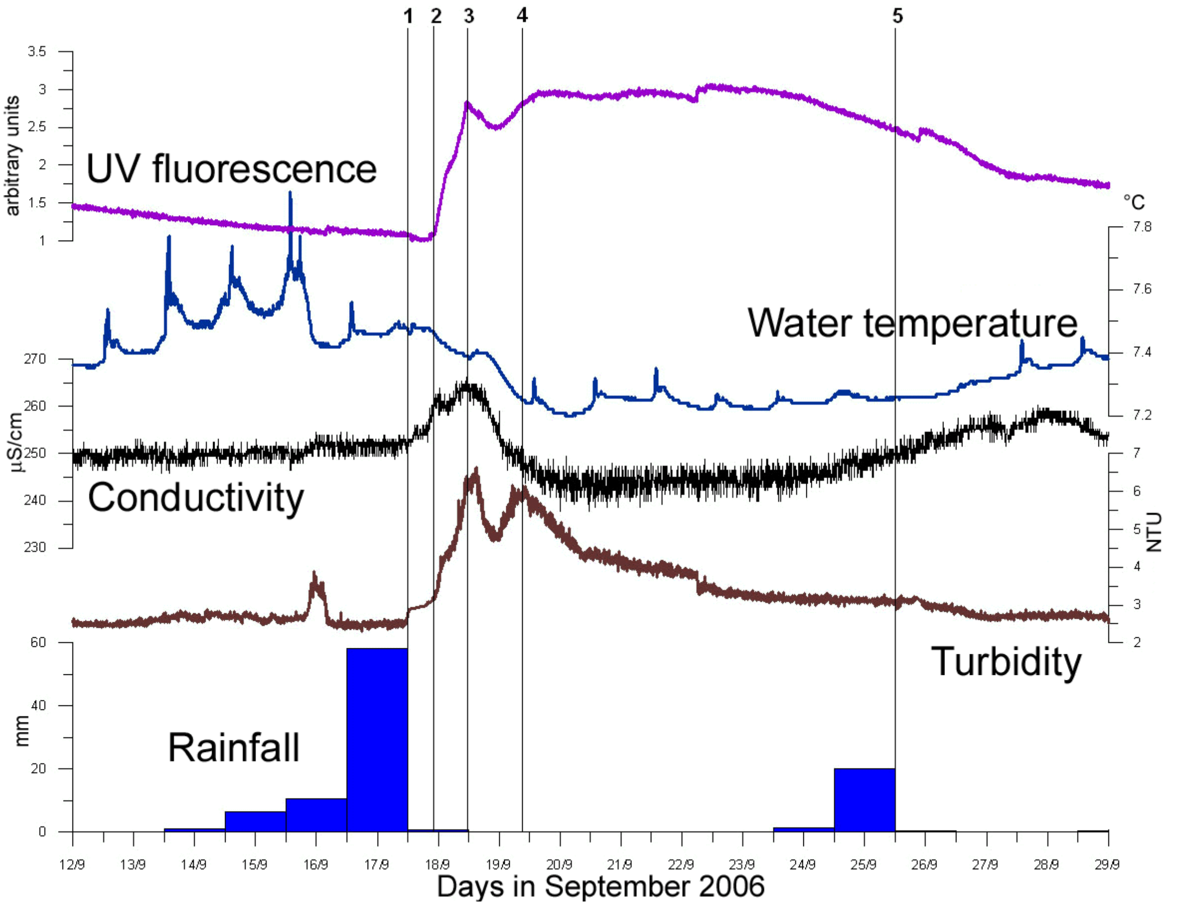

Fig 6. Series of typical events marked 1 to 5 during rise in the water level after rainfall. Daily spikes in water temperature is caused by poor isolation from the air. UV fluorescence results from dissolved organic matter (DOM). Rain height was recorded in the nearby valley of Grand Bornand

4. Conclusions

The bacteriological quality of the water at La Puya spring is periodically influenced by the pastoral activity in the catchment of Plateau de Cenise. Tracer test carried out during high and low water allowed determination of the contribution to the spring of the injection points. This contribution is small, not exceeding 1%. Therefore it is assumed that the aquifer is mostly fed by infiltration on the whole catchment area. Beside this main input, the sink hole of Plateau de Cenise represents only a small contribution. The same remark holds for the contribution of the Lake of Lessy (only 0.45% of total flowrate). However, even if these inputs are small, they are still sufficient to contaminate the La

Puya spring. Analysis of charcoal fluocaptors installed all over the catchment area showed negative results, i.e. no tracer was detected aside from the La Puya spring. This suggests that the La Puya springs is really the main oulet of the karst aquifer.

Water purification requires the set-up of a protection zone, because vulnerability and risk maps allow a better determination of the zone to be protected. A small buffer zone of twenty metres around the sink hole located at Plateau de Cenise could represent a sufficient protection zone. This zone could help avoid direct contamination of the karst aquifer.

Continuous monitoring of the La Puya spring during the summer 2006 has contributed improving the knowledge of the karst aquifer. Observation of a primary (autochtonous) turbidity is a clue for a pressurization mechanism of the aquifer. This mechanism, in turn, is leading to the flush of the karst conduits. Then, the fast arrival of a secondary (allochtonous) turbidity indicates a short transit time not favourable for water to settle and results in turbid water down to the tap.

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