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Chemistry of percolation and base-flow water in the Carso/Kras

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Chemistry of percolation and base-flow water in the Carso/Kras for the knowledge of the strategic reservoir in Trieste and Slovenian karst plateau

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Abstract

The percolation water in the Karst of Trieste have been studied for 20 months in the Trebiciano abyss, in two points at 100 and 250 m depth, in order to detect the main physical-chemical parameters, according to the rainfalls, the outside temperature, the seasons and the hydrodynamic. Parallel to the physical-chemical research, a tracing test has been carried out, which has given the average of percolation rate. The tracing has shown that major flows of the percolating waters of the abyss are connected with the overlying dolines. The percolation has been studied by the relations between the physical-chemical characteristic of base-flow phreatic water of karst aquifer. It results that the percolating waters of the Trieste Karst are, on the average, different form the base-flow phreatic waters since: a) the percolating waters show high concentrations of Ca^{2+} and $Ca(HCO_3)_2$ and low concentrations of characteristic parameters: K^+, Na^+, Cl^- and NO_3^- ; b) base-flow phreatic waters show low concentrations of Ca^{2+} and $Ca(HCO_3)_2$, and high concentrations of characteristic parameters: K^+, Na^+, Cl^- and NO_3^-.

Key Words: Karst Hydrogeology, Vadose and Phreatic water, Hydrodynamic and Chemistry of underground water, Water monitoring in cave, Trebiciano Abyss, Carso/Kras, Karst of Trieste on NE-Italy.

1. Introduction

The percolation waters of the Trebiciano abyss (the Karst of Trieste, NE Italy), on whose bottom the underground Timavo river flows, have been studied for 20 months, in two points at 100 and 250 m depth, in order to detect the main physical-chemical parameters, according to the rainfalls, the outside temperature and the seasons. Besides studying the water dynamic and the chemistry of the abyss percolation system, the purpose was also to determine the main physical-chemical characteristics of the waters that flow in the vadose zone, since they considerably contribute to the feeding of the karst aquifer. Finally, to correlate the physical-chemical data of percolating waters with those of the base-flow phreatic waters of the Karst. The Carso/Kras region is one of main coastal karstic aquifers of southern Europe (Calaforra, Eds., et. al. 2004). The characteristics of aquifer are: medium-high permeability, semi-confined structure, springs near the coast and no-moderate seawater intrusion, moderate exploitation (Calaforra et al., 2005).

2. The aquifer in the Carso/Kras

The Karst region (Fig. 1), divided into Italy and Slovenia (Carso/Kras), is a structure made up of carbonate rocks, with an extension of about 1000 km^2 having more feeding ways (Fig.1) (Ballarin et al., 2000/a, 2000/b; Petrič and Kogovšek, Eds., 2000). In a saturated area the conduits develop both above and under the sea level and they are feeds by a thick network of vertical cavities.

The springs are mainly placed in the north-west area of the Karst where: at about 2 m above the sea level the Timavo springs, the Sardos springs, and other minor ones are located, with an overall average flow of 15-20 m^3/s and a maximum flow over 100 m^3/s. The minimum flow, even after several dry months, is of about 7 m^3/s, which puts forward the hypothesis that the low Timavo springs might be mainly fed by waters external to the karst basin as well as by deep water systems communicating through big deposits of siliceous sands and clay that act as stores and slow down the flows. The maximum flows have been reckoned in about 150 m^3/s (Gemiti, 1984, 1996).

The above-mentioned springs were used for over 50 years for the water supply of Trieste and its province. In the 80s of the former century, after severe pollution, mainly due to wastewaters from the factories in Slovenia, of the Timavo/Reka river that feeds the Karst aquifer, the new waterworks, which capture the alluvial aquifer of Friuli were built.

In Italy, at the moment the Timavo springs are used exclusively as strategic reservoirs. On the contrary the Sardos springs are used for the mixing with the water captured by the deep aquifer in the East area of Isonzo River (Friuli). In Slovenia the karstic aquifer of the Kras is captured for 1.700.000 m^3 in the Klariči pumping station (Ravbar, 2004; Ravbar and Kovačič, 2006) located 4 km northern from the springs of Timavo.

For the water protection and management, is evidence the important of the knowledge of physical-chemical in field characteristics of the karstic water (percolation water and phreatic water). In fact, all the Carso/Kras area, practically, is characterized by high vulnerability.

3. The vadose zone in the Trebiciano abyss

The Trebiciano abyss (VG 17) is located in the Karst on the side of a doline, at the height of 341 m above the sea level (Fig. 2) and it is 350 m deep. The abyss, conditioned by lithologies and by the structural asset, develops in a series of carbonate rocks of the upper Cretaceous (Jurkovšek et al., 1996): from the entrance to the depth of about 185 m in limestones, then to the maximum depth in dolomitic rocks (Forti et al., 1979). At the depth of about 270 metres the networks of shafts that characterise the abyss open in the enormous "Lindner cavern". On its bottom the underground Timavo river flows at an average height of 12-14 m a.s.l., in galleries under the sea level.

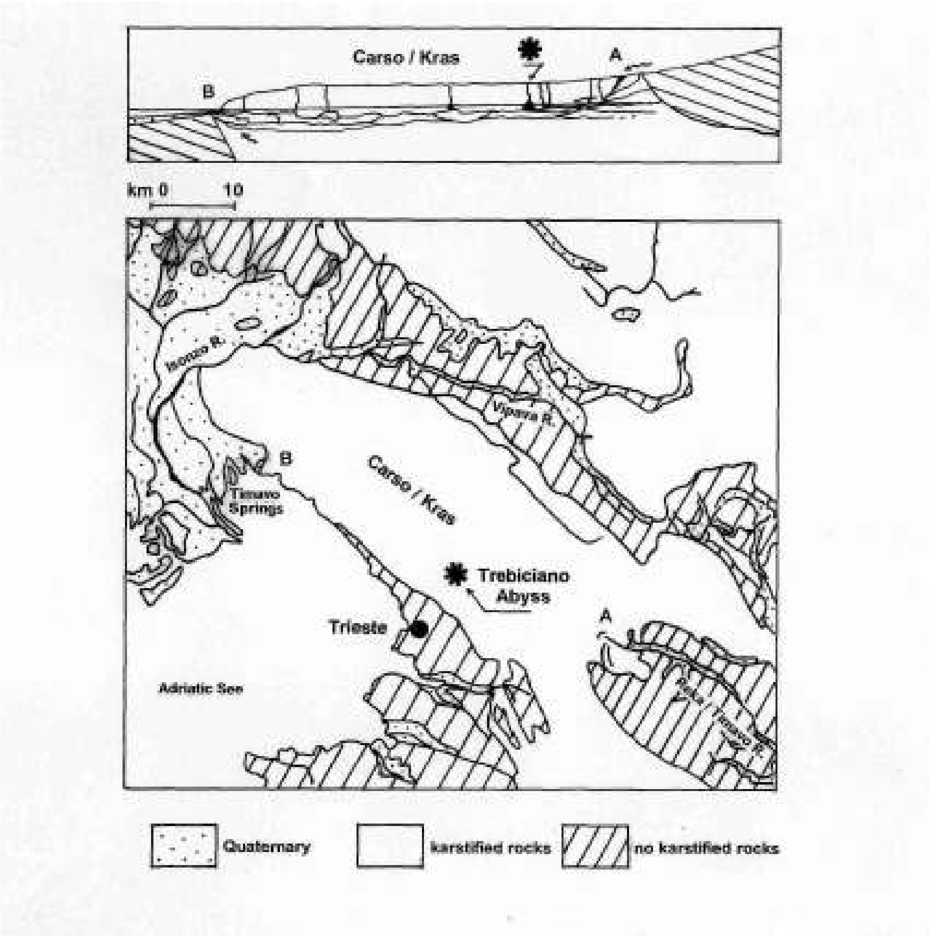

Fig. 1. The Carso/Kras. A: Timavo/Reka river in the sink hole San Canziano Caves/Škocjanske Jame; B: Timavo river springs.

The karstic hydrostructure of the vadose zone in this area is characterised by networks of shafts, which, sometimes, are supposed to be very near one another. These networks of shafts collect the waters that infiltrate through the surface, discharging them into the galleries and caverns placed in the epiphreatic area.

In the abyss two measurement stations have been placed. In the "Station A" at the depth of -100 m (points P1, P2, and P3) drip waters from stalactites have been measured and collected. In the "Station B" at the depth of -250 m (points 4 and 5**)** flowing waters have been measured and collected along the slopes and in fall. The monthly measurements refer to the period from December 1999 to June 2001.

Parallel to the physical-chemical research, a tracing test with Uranine and Tinopal CBS-X has been carried out, which has given the average percolation rate. The alkalinity (HCO_3^-), electrolytic conductivity and pH measurements have been carried out on the field together with those of temperature and percolation flow. The tracing has shown that major flows of the percolating waters of the abyss are connected with the overlying dolines (Semeraro et al., 2006).

4. Physical and chemical characteristics of vadose water in the Trebiciano Abyss

The alkalinity (HCO_3^-), electrolytic conductivity and pH measurements have been carried out on the field together with those of temperature and percolation flow. The results are as follows:

a) 94-97% of the ionic contents is composed of $Ca(HCO_3)_2$;

b) the pH has always a seasonal variation with maximum values of 8.20 between December and February, and minimum values of 7.10 between July and October, following the trend of the ground temperature;

c) the water mineralization shows seasonal variations but is basically affected by the rainfalls, with minimum $Ca(HCO_3)_2$ values of about 180 mg/L in dry periods and maximum $Ca(HCO_3)_2$ values of about 510 mg/L in the following 2-5 days after heavy rainfalls;

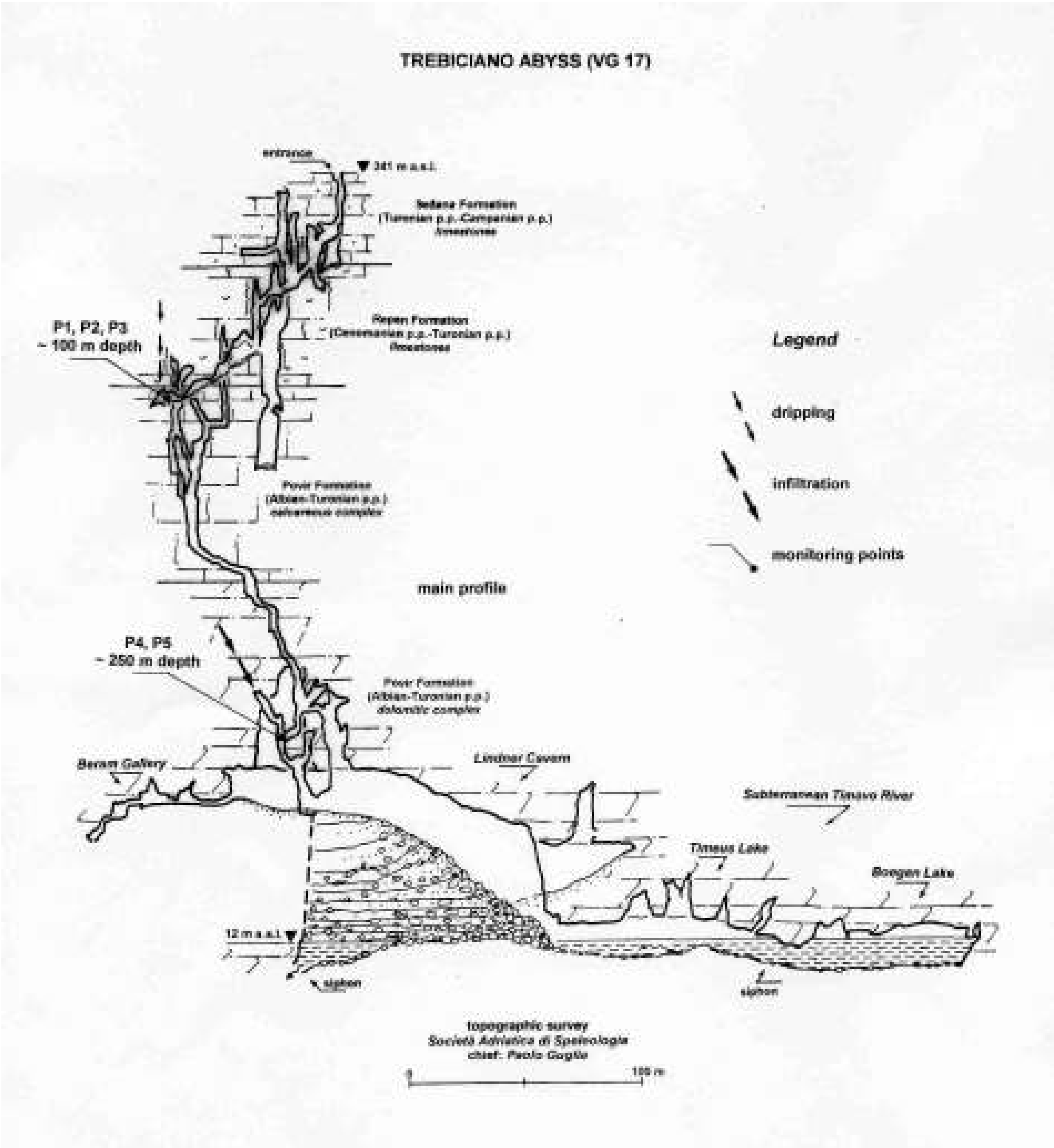

Fig. 2. Profile of Trebiciano abyss. The monitoring points: “Station A” at the depth of -100 m (points P1, P2, and P3) and “Station B” at the depth of -250 m (points 4 and 5).

d) the typical ions of water (Mg^{2+}, Na^{+}, K^{+}, NH_4^{+}, Cl^{-}, NO_3^{-}, SO_4^{2-}, PO_4^{3-}) are always present in small quantities, except for SO_4^{2-} which ranges from 7 to 11 mg/L;

e) the phosphates and the ammonium are present in traces;

f) the concentrations of NaCl are low and very similar to those of the rainfalls, therefore the release of NaCl from the soil is excluded;

g) the presence of nitrates and sulphates is exclusively due to the soil biological activity;

h) the concentrations of SiO_2 are constant (about 1.5 mg/L) and come from the slow release of silica and from the phyllosilicates present in the soil;

i) the water saturation index (calculated according to the AWWA principles) ranges from 0.4 to 1.2: the water is always supersaturated;

j) the percolation water, beyond 100 m of depth, has a variable temperature from 10.2 to 11.2°C depending on seasons;

k) the transfer time of the water infiltrating through the surface to the bottom (-300 m) is of a few hours, the flow and the reservoirs depend on the water storage in the epikarst.

5. Hydrodynamic and chemistry of vadose and phreatic water in the karst system

The results obtained are comparable to those detected in other cavities in the Karst basin, in different places, depths and times (Kogovšek, 1984; Gemiti & Merlak, 1999). Thus, it has been ascertained that, within the bounds of single areas characterized by specific climates, the variations of the average characteristics of water are constant, therefore predictable. This should give the possibility to define in advance the base physical-chemical parameters of the Karst percolation waters, according to of the seasons, to the rainfalls and to the areas with similar climatic features. Another interesting result is that the measurement of the specific conductivity gives the exact situation of the water mineralization (it can be used also as a quality control of the analysis) since the composition is essentially $Ca(HCO_3)_2$ and the variations of the concentration of other ions are negligible.

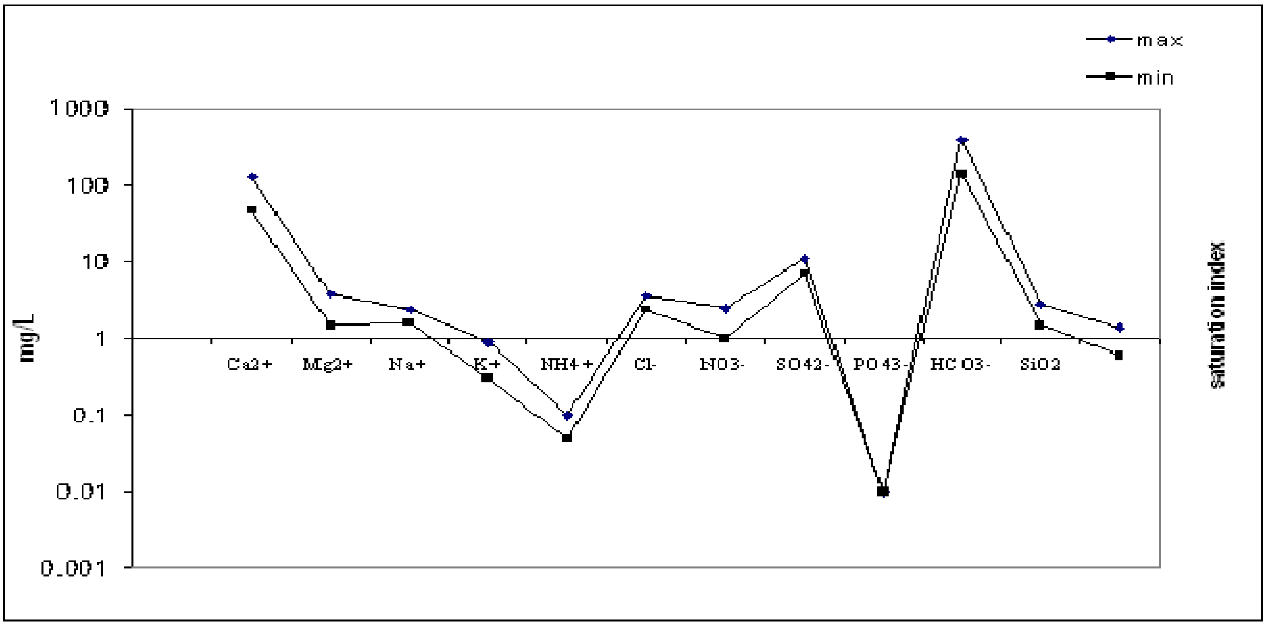

Fig. 3. Maximum and minimum concentrations of the solute (mg/L) Ca^{2+}, Mg^{2+}, K^+, NH_4^+, Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, HCO_3^-, SiO_2 and of the Saturation Index (Sat. Ind.) during the period of 20 months, in the percolating water of the Trebiciano abyss.

In Fig. 3 are the maximum and minimum ionic concentrations (mg/L) of the percolating waters in the Trebiciano abyss at the depths of 100 and 250 metres (average of the values measured). The chemical picture is similar to those surveyed in other six caves of the area. It shows that $Ca(HCO_3)_2$ represents about the 90-95% of the total composition. The major seasonal variations regard calcium and bicarbonate as shown in Fig. 4, they change depending on the season and depending on rainfalls.

The evaluation of the differences between the percolating waters of the Trieste Karst and other waters of the karstic system is interesting.

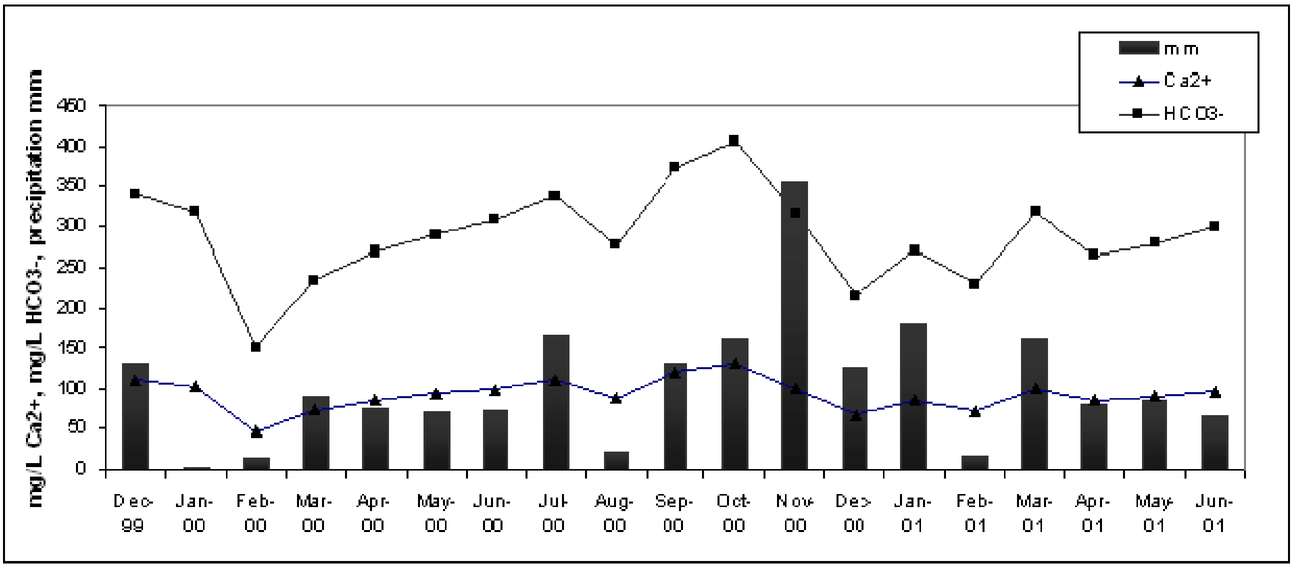

Fig. 4. Ca^{2+} and HCO_3^- (average) in the percolating water of the Trebiciano Abyss and the relation to the rainfalls.

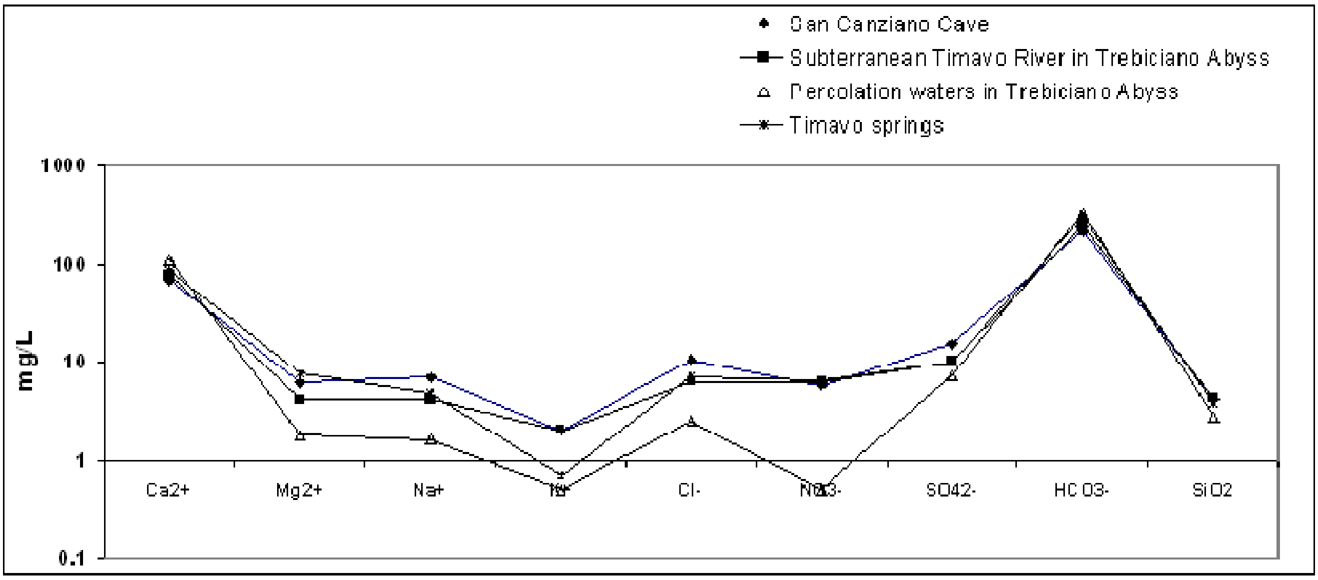

Fig. 5. Variations of the average concentrations of the main chemical parameters of the water of the karstic system in the period November-December 1999.

In Fig. 5 are the values of the average concentrations measured in the period November-December 1999 in the following waters:

a) the river Timavo/Reka, in the locality of Vreme, before entering San Canziano Cave/Škocjanske Jame;
b) the underground Timavo river in the Trebiciano abyss;
c) the percolating water in the Trebiciano abyss;
d) the Timavo river springs.

It results that the percolating water of the Trieste Karst are, on the average, different form the base-flow phreatic water since:

a) the percolating water show high concentrations of Ca^{2+} and $Ca(HCO_3)_2$ and low concentrations of characteristic parameters: K^+, Na^+, Cl^- and NO_3;
b) base-flow phreatic water show low concentrations of Ca^{2+} and $Ca(HCO_3)_2$, and high concentrations of characteristic parameters: K^+, Na^+, Cl^- and NO_3.

The only exceptions to this framework concerns ascertained case of surface pollution concentrated in single areas. It is the case of the cave VG 6163, placed at about 200 metres from the Trebiciano abyss and developed under the ex uncontrolled landfill of the Town hall of Trieste, closed in 1972. After more than thirty years, in this cave in the percolating water the values of 170 mg/L of SO_4^{2-} and of 25 mg/L of K^+ can be measured.

The knowledge of chemical characteristic of percolation and base-flow phreatic water are fundamentals for the protection of the Carso/Kras aquifer.

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