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Nota Tecnica - Technical Note

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Tracciamento Frenzela 2024: a new tracing test on the Sette Comuni Plateau, Vicenza, Italy

Tracciamento Frenzela 2024: una nuova prova di tracciamento nell'Altopiano dei Sette Comuni, Vicenza, Italia

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Introduction

The purpose of this note is to describe the preliminary results of a tracing test conducted in a karstic area of the italian Eastern Southern Alps. The goal of the test was to find the relationship between a sinking creek of the Sette Comuni Plateau and the springs at its base (Fig. 1). The most important spring is Oliero spring which is also used to provide water for human consumption.

Karstic aquifers due to their hydrological characteristics show a high sensitivity to contamination propagation and wide catchment areas. Protection of karst water resources is among the most important measures for karstic water resources management. The so called "water safety plan", according to European regulation and WHO guidelines, is a complete risk-based approach to water safety, covering the whole supply chain from the catchment area, abstraction, treatment, storage and distribution to the point of compliance has to be developed. For risk assessment on karst aquifers, multidisciplinary environmental monitoring approaches has to be adopted and the support of speleologists and geologists and their investigation tools is fundamental.

Understanding the path and velocity of groundwater is crucial to managing and protecting water resources. This study is part of the water suppliers' activities (Etra S.p.A. SB in this case) for the implementation of the water safety plan. The project is a cooperation between ETRA SpA Società

Benefit (water utility), ARPAV (environmental agency of the Veneto Region), istituto Agrario Parolini (agricultural school), GGGM (local caving club).

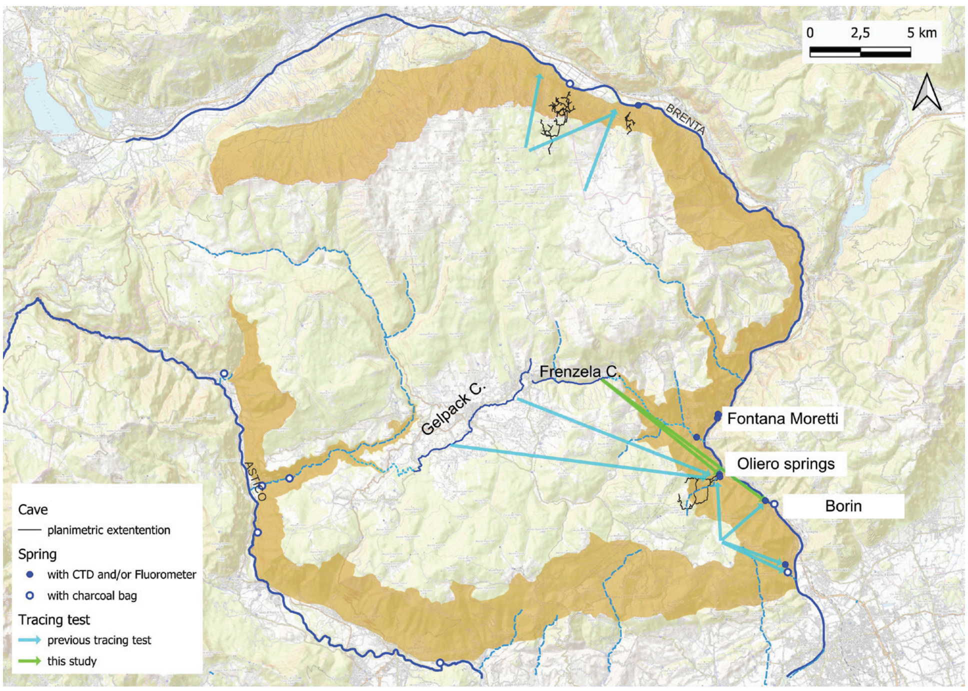

Fig. 1 - Schematic map of the Sette Comuni Plateau. The brownish ribbon represents the steeper slopes. Schematic representation of only the major caves near or under the phreatic level. There are represented the monitored springs and the hydrogeological connections by tracing test. Base map from Open Street Map.

Fig. 1 - Carta schematica dell'Altopiano dei Sette Comuni. La banda marrone evidenzia i versanti più ripidi. Riportate le planimetrie schematiche delle principali grotte prossime o sotto il livello freatico. Sono rappresentate le sorgenti in monitoraggio e le connessioni idrogeologiche da prove di tracciamento Base topografica da Open Street Map.

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The study area

The karstic plateau raises on the North of the Venetian Plain and is bounded around by the Brenta and the Astico river valleys. The hydrographic network with runoff on the plateau is almost null despite many valleys on its surface and flanks. There are only two creeks flowing in opposite directions from the center of the plateau at the core of the syncline that is elongated almost E-W. The Gelpack creek from Gallio to the West rarely reaches the rim of the plateau because some segments of its bed are losing. The Frenzela creek instead flows from Gallio into a deep valley but only few days in a year it reaches the Brenta River. The Gelpack contribution to the karst drainage has already been studied with tracing tests (Gennari et al., 1989; Dal Molin et al., 2013). Other tracing tests from caves or sinkholes revealed connection to other springs too (Frisinghelli 2001, Marighetti 2017, Zannoni 2023). Only recently a sinking segment has been spotted along the Frenzela creek and this has allowed to plan another tracing test, "Tracciamento Frenzela 2024", to find the connection between the sinking stream and the springs.

The most important springs at the base of the plateau are located at the NE and E side along the Brenta River with a minimum distance of 7 km from the losing creek bed; their mean discharge is estimated to be approximately 10.9 mc/s for Oliero springs (Dal Prà & Stevan, 1969) and 0.5 mc/s for Fontana Moretti (Boso & D'Alberto, 2006) while other springs have discharge up to 0.1 mc/s or less (Fig. 1). Oliero include two submerged cave entrances Covol dei Siori and Covol dei Veci 100 m apart and hydrologically connected as mapped by divers.

Materials and methods

This study had three phases: 1) monitoring the hydrologic regime of the Frenzela creek; 2) monitoring the major springs; 3) tracing test. Phases 1 and 2 were useful to plan the tracing test and to understand the main characteristics of the springs. The working team, joining knowledges and instruments, has set monitoring stations with datalogger for water level, temperature and EC (Electrical Conductivity) along the Frenzela creek and at 7 springs (Subiolo, Fontana Moretti, Tovo, Covol dei Siori, Covol dei Veci, Borin, Rea-Nassa); it has equipped 4 springs with fluorometer-datalogger (Peschiera, Fontana Moretti, Covol dei Siori, Rea – Nassa) and all have charcoal bags including 7 other springs (Laghetto Bigonda, Fontanazzi di Solagna, along the Brenta, and Piasan, Ex Maglio, Sx Val d'Assa, Pedescala, Le Buse along the Astico valley). From the known data the trickiest task was to decide the amount of tracer to inject. In fact, the doubt was between to use as little as detectable tracer but not enough to color the water at the springs, or to risk to have the water green and at the same time the certainty that the test had a positive result. To choose the best amount we used the calculation spreadsheet from Currens (2013) and decided to pour in the creek 20 kg of sodic fluorescein. The parameters used in the algorithm were the distance 7 km, the tracer peak concentration as 70 µg/L, an average underground velocity of 35 m/h and a discharge of 0.5 mc/s or 6 mc/s in a secondary scenario.

Preliminary results

Phase 1. With a year of observations and monitoring for 6 months we discovered that the Frenzela creek completely sinks in less than a kilometer, next to the village of Gianesini (Gallio municipality), if its discharge is approximately less than 250 L/s. With higher discharge instead, some water overpasses this segment and flows down the valley. Comparing the discharge to the losing gravelly bed it is clear that the main sinkhole is just upstream of a basalt dike and to avoid tracer dispersion it seems reasonable to make the injection with discharge <100 L/s (Fig. 2).

The level of the creek raises in an hour or two after rainfall reaches approximately 15mm and the recession curve needs 4-6 days to drop below 100 L/s from a peak around 300 L/s.

Fig. 2 - Aerial view (30/12/2024) of the losing thalweg of the Frenzela creek at Gianesini. Creek flows from the left to the right. M: monitoring station, I: injection point, S: sinkhole, the last wet point when taken the picture (3.3 L/s), V: volcanic dyke outcrops, F: the last wet point of dispersion during the tracing test (82 L/s). For scale reference a building and a white car on the high right corner of the image can be used.

Fig. 2 - Vista aerea della parte principale disperdente del torrente Frenzela presso Gianesini immagine del 30/12/2024.Il torrente fluisce da sinistra verso destra. M: stazione di monitoraggio, I: punto di immissione, S: inghiottitoio, l'ultimo punto bagnato al momento della ripresa (3,3 L/s), V: affioramenti di vulcaniti, F: l'ultimo punto bagnato con dispersione durante la prova di tracciamento (82 L/s). Come riferimento dimensionale nell'alto a destra dell'immagine vi sono una casa e un'auto bianca.

Phase 2. During the 4 months ahead of the tracing test at the springs we experienced the summer drought and a lot of rains during the fall. Because of different type of instruments, it is quite difficult to compare directly all the springs together; it is possible to do this only with Fontana Moretti and Covol dei Siori (Oliero) that are equipped with similar datalogger calibrated simultaneously for the fluorescein. What appears from the data is that Fontana Moretti and Borin have at the outlet the direct influx of the Brenta River level because the springs are on its bank. Covol dei Siori and Fontana Moretti are similar as EC and temperature, while the background fluorescein signal has a different behavior. At the end of the summer increasing of the background fluorescein signal is coeval for both the springs, while in October the increase is only for Covol dei Siori. It is possible that at the end of the summer the water level was so low that the flood events brought organic matter deep and close to both the springs,

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while in autumn with all the system full of water only Covol dei Siori resulted less protected by the direct seepage from the surface.

Phase 3. On the 4th of November 2024, the 20 kg of sodic fluorescein were dissolved in approximately 323 liters of water of the Frenzela creek that was discharging 82 L/s. The tanks with the solution were quickly dumped in the creek just 70 m upstream of the main sinkhole area and almost 200 m ahead of the end of the wet thalweg. Since November the 5th the charcoal bags were changed and water samples were collected following a specific schedule based on the importance of the spring, while the fluorometer data were downloaded daily from Covol dei Siori and Fontana Moretti. On the 23rd of November the fluorescein signal started to rise at Covol dei Siori. To define the specific moment of first arrival of the tracer and the background concentration registered, the signal before the injection has been analyzed (max 1.9 µg/L, average 1.3 µg/L) and also for the period 4th - 23rd November. Concentration above 1.7 µg/L has been considered as presence of the tracer and the signal is gone below this threshold on December 21st just after a minimum increase of discharge related to a rainfall event (Fig.3).

The registered curve of the concentration shows some steps: one almost at the peak related to have wiped off some biofilm from the protection pipe where is inserted the datalogger, another undetermined, and the last drop probably related to the end of the tracer due to a lower contribution of the feeding underground tributary. The concentration registered has been on average 2.4 µg/L while the maximum has been 6.7 µg/L that subtracted the background value they correspond to a real 0.7 µg/L and 5 µg/L. Despite the low concentration, surprisingly the color of the water at the spring was bright green (Fig. 4) for days because of the depth of the water at the

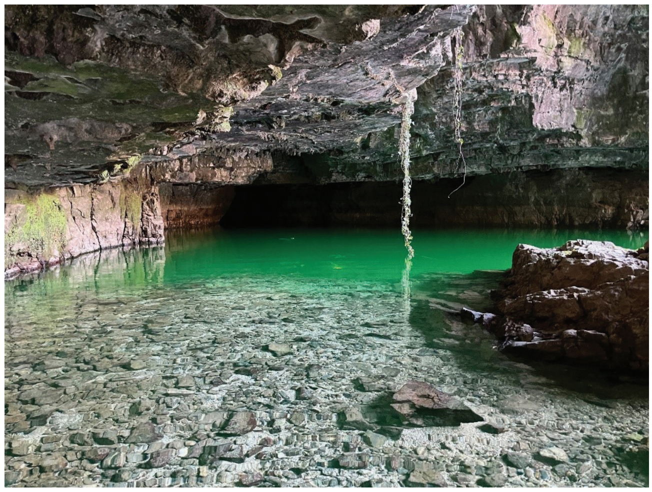

Fig. 4 - Oliero Covol dei Veci. Bright green water where the water is deep, here up to 15 m; in the foreground the depth is around 0.5 – 1 m and the color is less visible. Photo 30th November around 13:45 pm almost at the maximum concentration 6.7 µg/L registered.

Fig. 4 - Oliero Covol dei Veci. Verde acceso dell'acqua dove è più profonda (fino a 15 m), mentre in primo piano la colorazione è meno visibile con una profondità di circa 0.5 – 1 m. Foto del 30/11 intorno alle 13:45 all'incirca alla concentrazione massima di 6.7 µg/L registrata

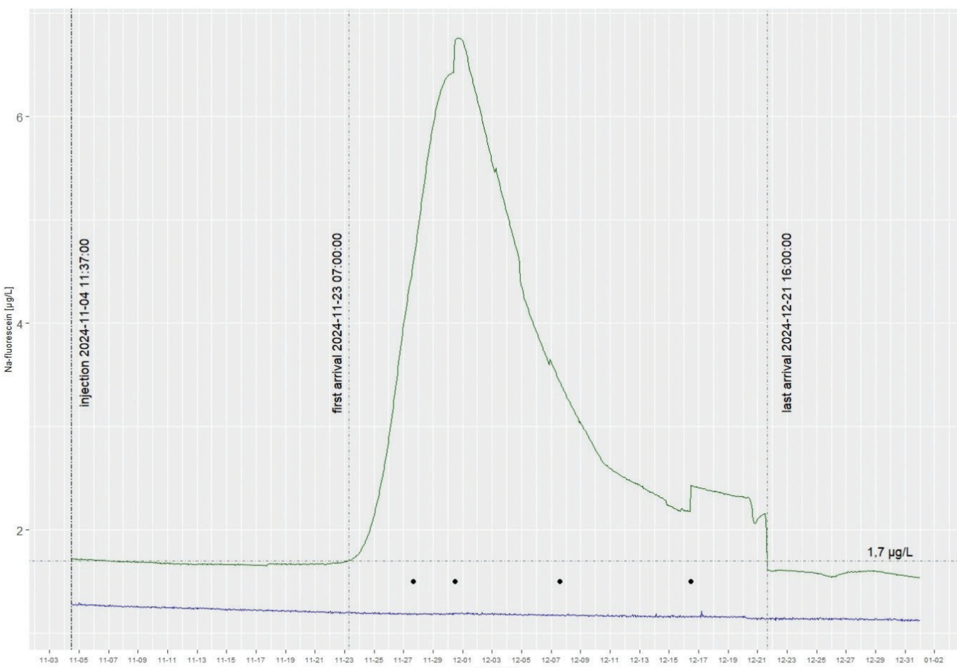

Fig. 3 - Breakthrough-curve of the fluorescein (horizontal axis month-day, vertical axis fluorescein concentration as µg/L): dark green line fluorometer recording at Covol dei Siori, blue line at Fontana Moretti; horizontal dashed line background fluorescein signal; vertical dashed lines from the left: injection, first arrival, last arrival; black dots timing of discharge measurement.

Fig. 3 - Registrazione concentrazione fluoresceina (asse orizzontale mese-giorno, asse verticale concentrazione in µg/L): linea verde scuro fluorimetro al Covol dei Siori, linea blu a Fontana Moretti; linea tratteggiata orizzontale valore di fondo registrato; linee tratteggiate verticali da sinistra: immissione, primo arrivo, ultimo arrivo; punti neri momenti delle misure di portata.

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outlet that is probably more than a meter, while the references cite as threshold for visual detection (in a glass or cuvette?) a concentration of 50 or 70 µg/L.

Final remarks

No positive signal by the other fluorometers at Fontana Moretti (2 different instruments for comparison) and at Peschiera spring on the NE side (Grigno municipality) neither at Rea-Nassa on the S (Bassano del Grappa municipality). From the charcoal bags it seems that only Oliero (C. dei Siori and C. dei Veci) and Borin springs result connected to the Frenzela creek. Using the time of travel calculated for the first arrival, the mean velocity results to be around 20 -26 m/h, while for the peak concentration the velocity results around 14 – 19 m/h. The range of velocity is due to different calculations based on minimum straight distance or a more probable path obtained by the length of the submerged Oliero Cave system and its sinuosity also for the unknown part of the path.

Because the fluorescein appeared only at the Oliero springs, monitored with datalogger and characterized by a low stage-discharge equation, it is possible to estimate a preliminary mass recovery.

Assuming that the tracer concentration was the same at both the Oliero cave springs (Covol dei Siori and Covol dei Veci) and correlating the water level to the discharge the total tracer outflowed is around 15.9 - 16.2 kg. At present day the uncertainties are mainly related to occasional and artificial lowering of the water basin in front of the springs that create an apparent drop in the discharge.

Hydrologically it is interesting to observe that how well defined is the fluorescein breakthrough-curve because there is only a single peak and with a short decreasing curve. Considering the discharge at the springs above 4 mc/s at first arrival and the flowing rate of the creek during the injection, it is possible the tracer-plume arrived compact to the phreatic surface of the groundwater system and in a point where it was rapidly carried out. The tracer test was made in a very favorable situation because the injection was just after the end of a long period of rainfall when probably the underground system was still saturated as matrix porosity, while the main channels were already becoming empty and followed by two months without precipitation.

Useful data has been obtained for the risk assessment and for the activation of the static and dynamic protection of the Oliero springs.

Notes:

- The datalogger used are from: AquaRead, HOBO, In-Situ, Ott; while the fluorometer are Aquatroll 500 and 600 In-Situ, FL24 and GGun FL30 – Abillia.
- Data elaboration with software R and R-studio
- The project has benefited of the technical support of the Servizio Geologico della Provinica di Trento (Casagrande M., Poli M., Valcanover E., Visintainer P.), of Viacqua water utility (Novello A.), of scuba-cavers (Aldegani D., Barbera L., Gualtieri S., Mele A., Milani G., Todesco A.) and others (Ceccon C., Lucianetti G., Ronchi C.)

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