Environmental characterization of karst caves: evaluation and monitoring for a correct show caves management

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Introduction

Usually, the studies concerning the tourists impact in show caves take into account their "energy level" (Heaton, 1986), in which caves' vulnerability is directly proportional to the energy level lowering. In “high energy” caves natural energy contributions are able to periodically cancel any microclimatic changes induced by the visits, therefore, there are no restrictions for visitors. On the contrary, in “low energy” and “moderate energy” caves the energy contribution introduced into the environment by tourists becomes comparable with the natural energy balance of the cave, therefore, a substantial ecosystem alteration in the ecosystem is possible.

The distinction between high, moderate and low energy levels proposed by Heaton (1986) is very subjective and does not provide guidelines for the show caves management. Different subsequent authors highlighted these limitations (e.g. Chiesi 2000, Cigna 2013, Pani et al. 2013), however, more detailed solutions were not proposed.

The natural energy contributions in caves is a fundamental parameters to know, therefore, it should be monitored through an appropriate monitoring system, useful also for the tourists impact monitoring (anthropic contributions). Through these information it will be possible applying a parametric evaluation at score system to recognize the caves vulnerability and follow any environmental parameter changes over time, related to a not-correct use of show caves or to the climate change.

Natural energy input in karst caves

- *Water circulation*: presence of collectors (streams in the unsaturated area), diffuse percolation (drips), karst aquifer (lakes and water basins connected to the deep circulation (Fig. 1)
- *Air circulation*: “closed circulation caves“ or “chimney caves". It influences air temperature in the initial part of the cavities (Fig.2), condensation processes and their corrosion phenomena
- *Endogenous contribution*: deep CO_2 and H_2S flows and related corrosion phenomena (Fig.3), radon
- *Thermal conduction*: air-rock-water temperature exchanges in the superficial rock mass
- *Biologic contribution*: feces, decomposing organic matter, bacterial activity
- *Climate change*: progressive changes in air and water circulation due to the global temperature increase, extreme phenomena increase such as drought or exceptional rainfall

Sources of anthropic energy in karst caves

- *Lighting system*: lampenflora (Fig.4) and air temperature increase (Fig. 5a)
- *Tourists*: CO_2 concentration increase (Fig.5b), air temperature increase, RH% increase, transport of fine materials (microplastics, lint, organic matter…)
- *Door opening/closure*: changes in air circulation
- *Landscaping in the areas above the cavities*: changes in groundwater circulation

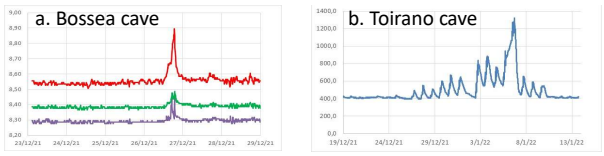


Fig.5: Air temperature increase in Bossea cave (a) and CO_2 increase in Toirano caves (b) during the Christmas holidays.

Fig.1: Gulliver lake, Borgio Verezzi cave, is subject to significant changes in water levels.

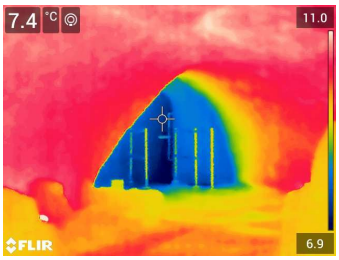


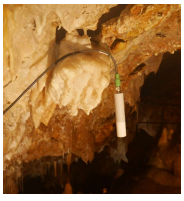
Fig.2: Thermography in the initial gallery of the Toirano caves, showing the different rock temperatures.

Fig.3: Corrosion phenomena in the upper part of a gallery in Toirano caves.

Fig.4: Lampenflora in Bossea cave.

High frequency instrumentation installed in Bossea, Toirano and Borgio Verezzi caves

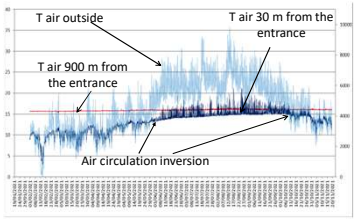
Automatic instrumentation for rock and air temperature and CO_2 monitoring.



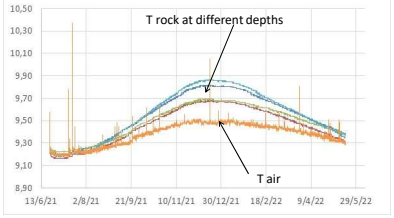
Drip and water supply flow monitoring.

Air direction and speed monitoring.

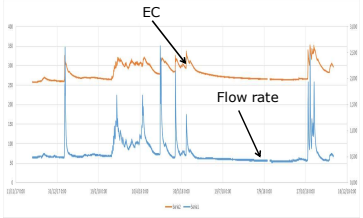
Annual high frequency monitoring of different environmental parameters



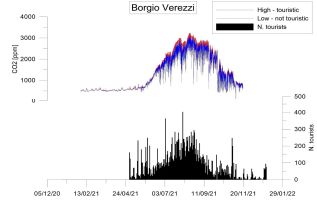
Air temperature outside and near the entrance of Toirano caves.



Rock and air temperature in Sacrestia area, Bossea cave.



Water flow and EC of a modest water supply in Bossea cave.



CO_2 and number of turists in Borgio Verezzi cave.