University of Salerno

Department of Chemistry and Biology "Adolfo Zambelli"

PhD Thesis in Chemistry - XXXIV Cycle - Academic year 2020/2021

"New insights on the ecology of underground ecosystems toward a sustainable management strategy"

Candidate: Dr. Rosangela Addesso

Supervisor: Prof. Daniela Baldantoni

Coordinator: Prof. Claudio Pellecchia

Abstract

Underground cavities represent some of the less explored places on the planet. In fact, excluding the known carbonate dissolution/precipitation processes, leading to the formation of holes in the host rock, as well as speleothems, little is known about the ecology of these fascinating and enigmatic ecosystems. In spite of this, caves are generally object of tourist adaptations, which can activate an irreversible impairment of the biogeochemical equilibria, whose load, until now, is not estimated accurately, due to the scanty information in this regard.

In this study, the most of research activities were carried out in the karst system of the Pertosa-Auletta Cave (Southern Italy), located in the Cilento, Vallo di Diano and Alburni National Park, chosen as study model for the different natural characteristics (the fossil trail without flowing waters and the active trail crossed by a perennial subterranean river) and diverse human fruition (tourist and closed to the public paths), hosting more than 60.000 visitors per year.

The project aimed at shedding light on the abiotic (clastic sediments and vermiculations, water and atmosphere) and biotic (microbiota and lampenflora) compartments of this relatively unknown ecosystem and at the understanding of the effects of tourist adaptations in cave environment, with the definition of sustainable strategies for the mitigation of the related damages. Firstly, adopting an integrated approach, we characterized cave vermiculations, obtaining a comprehensive knowledge of their chemistry and microbiology: the abundance of calcite in their mineral composition and traces of microbial activity, with evidences of dissolution morphologies and organic matter, as well as biologically mediated secondary minerals precipitation. Microbial community, involved in vermiculation formation processes, is characterized by the dominance of *Proteobacteria*, *Acidobacteria* and, in higher humidity conditions, of *Actinobateria*, with several unknown groups.

Calcite and dolomite minerals mainly constitute cave sediments, as expected according to the lithology of the host rock, and appear to affect also the composition of drip and river waters, showing high calcium concentrations. In terms of organic constituents, bat guano affects the chemical composition of both sediments and waters, especially in the fossil trail, demonstrating the important organic supply that bat colonies provide in cave environments. The seasonal dynamics in the chemical composition of cave waters highlight its tight coupling with climate, with increases in several element concentrations during summer, probably due to the dry weather reducing the dilution effect.

In terms of temporal dynamics, the development of innovative low-cost monitoring devices for the high-resolution analysis of cave atmosphere, allowed shedding light on the multi-scale fluctuations in cave climate and on their tourist-induced alterations. In particular, air monitoring highlighted the role of cave humidity and CO_2 concentrations in the dampening of tourism induced alterations, resulting in their occurrence over short time and spatial scales. COMSOL Multiphysics® demonstrated to be a good tool supporting the tourism planning in underground environments, such as in the choice of visit-break locations and time during the tours, avoiding the most exposed sections to the deposition of particles and suggesting to install mitigation systems where anthropogenic impacts are more relevant.

The investigation on lampenflora biofilms, communities developing on artificially lit surfaces, showed peculiar optical features, with almost homogeneous absorbance of the entire visible spectrum, likely thanks to the capability of photoautotrophic organisms to produce a wide range of accessory pigments. These communities are mainly composed by filamentous organisms, in interaction with the mineral substrate, dominated by *Brasilonema angustatum* cyanobacterial species, and, among the Eukaryotes, by *Ephemerum spinulosum* and *Pseudostichococcus monallantoides.* Microscopy

highlighted precipitation of $CaCO_3$ secondary minerals, like moonmilk, and corrosion shapes, demonstrating the irreversible damages of colonized substrates.

The effects of the most employed chemical (NaClO, H_2O_2) and physical (UVC) methods for lampenflora control were evaluated not only in relation to their effectiveness on lampenflora, but also in relation to their compatibility with the substrate, revealing the good properties of NaClO in terms of biomass elimination, sterilization and integrity of surfaces. Other methods showed either reduced effectiveness in lampenflora removal, such as UVC radiation, or corrosion of the surfaces, especially if covered by vermiculations, with limited capability of oxidizing organic matter, such as H_2O_2.

Overall, the research highlights that tourism and its associated activities trigger various knock-on effects with irreversible repercussions in all the system. Anyway, only an accurate and integrated characterization of the cave environment, providing information about the fundamental natural processes characterizing the system, allows proposing sustainable management strategies.