Microplastic pollution in marine caves

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Marine caves are mostly formed by dissolution processes in carbonate massifs and may be of karst origin, as the last part of a large terrestrial aquifer, or can originate at the sea level through different processes such as chemical dissolution and mechanical action of sea waves. They are affected by wide spatial and temporal environmental variability and/or extreme values of environmental conditions (light, nutrients, oxygen, pH, hydrodynamic conditions, difficulty of larval dispersion etc.). Despite this seemingly hostile environment, marine caves are biodiversity hotspots and refuge habitats, hosting many crevice-dwelling and deep-water species, but also some obligate cave-dwelling organisms.

Studies on anthropogenic pollution of marine caves, generally believed to be pristine environments, are practically missing. Only recently, the microplastic (MP) pollution in sediments, water, and in some benthic, sediment-dwelling organisms (benthic foraminifera, hard-shelled protozoans) of two Mediterranean marine caves has been recorded. The first one was the Bue Marino cave, a huge karst cave of the Gulf of Orosei (Sardinia, Italy) where microplastic was detected at rather low concentrations of 10-27 items kg$^{-1}$ and 18-22 items l$^{-1}$, in sediments and water, respectively. Microplastic was also recognised, through Micro Fourier Transform Infrared Spectroscopy (μFTIR), in the shell of the agglutinated foraminifer *Eggerelloides advena*. Microplastic was also recorded in sediments of the small Argentarola cave (Tuscan coast, Italy) at concentrations of 5.4-11.9 items kg$^{-1}$, and in the shell of the agglutinated foraminifer *Lagenammina diffugiformis*. Polyethylene, the most abundant polymer in sediments of both caves, was the one detected in the foraminiferal shells.

These studies have demonstrated that some foraminiferal species, building their shell by collecting sediment particles, also collect tiny MP fragments of the order of magnitude of a few microns due to a scarce selection ability. Consequently, MPs enter the trophic chain because foraminifera are preyed upon by many marine organisms such as gastropods, scaphopods, fishes, decapods, and polychaetes.

The research carried out in marine caves has demonstrated that MP has reached also these remote and enclosed habitats and that MP deposited in sediments is available to the benthic organism and enters the trophic chain at very low phylogenetic levels. Foraminiferal agglutinated species including MP polymers, even if present at low concentrations, may be considered early
indicators of MP pollution. A clear indication to consider MP pollution not only in water but also in sediment, to preserve the ecosystem of marine caves, was a relevant result of this research.