

# Biodeterioration of Roman hypogea: the case study of the catacombs of SS. Marcellino and Pietro (Rome, Italy)

Laura Bruno<sup>1</sup> · Lorenza Rugnini<sup>1</sup> · Valeria Spizzichino<sup>2</sup> · Luisa Caneve<sup>2</sup> · Antonella Canini<sup>3</sup> · Neil Thomas William Ellwood<sup>1,4</sup>

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## Abstract

No information exists on phototrophs growing on the stone surfaces of the catacombs of SS. Marcellino and Pietro (the site was only recently opened to the public in 2014). Therefore, it was decided to characterise the microbial communities and to compare them with those of the other previously studied catacombs. Moreover, a new non-invasive strategy to reduce the phototrophic growth was tested. Phototrophic microorganisms were investigated under light and confocal laser scanning microscopes from samples collected non-invasively in situ. Tests were carried out to determine the effect of the application of two essential oils (from *L. angustifolia* and *T. vulgaris*) on biofilm photosynthetic activity. Laser-induced fluorescence (LIF) and reflectance measurements in the visible range have been used to evaluate respectively, any chemical modification and discolouration on a frescoed stone that may occur after the application of the essential oils. At all the concentrations of essential oils, there was a quasi-immediate, large reduction in photosynthetic activity of the biofilms. At 10% essential oil concentration, there was no detectable photosynthetic activity after 15 min. At 1%, there was a need for two applications and after 5-day activity was undetectable. No effect of the essential oils on the substrate surface properties or colour modification of the fresco has been observed with the LIF prototype. Cyanobacterial typical of Roman catacombs were present in the sites investigated. Innovative and non-destructive strategies, involving the application of a combination of two essential oils, have been successfully tested and developed to prevent biodeterioration of these sites.

**Keywords** Biodeterioration · Phototrophic biofilms · Cyanobacteria · Essential oils · Laser-induced fluorescence

## Introduction

The catacombs of SS. Marcellino and Pietro are among of the largest catacombs in Rome and are located near the church

dedicated to the homonymous Saints and the Mausoleum of Saint Elena, the mother of the Emperor Constantine. The catacombs were excavated between the 3rd and 5th centuries CE and have 18,000 m<sup>2</sup> of galleries and chambers at around 16 m below ground level and only a part of this is open to tourists (Fig. 1).

These catacombs, like the others found in Rome, were subterranean Christian cemeteries and housed many tombs of the very rich and influential, as demonstrated by many intricate frescoes. In some of the crypt recesses, bone remains can still be found. The catacombs of SS. Marcellino and Pietro are in the southeast part of the city of Rome, a significant distance from the other better known Roman catacombs, such as those of Domitilla and S. Callixtus which have been intensively investigated over the last 20 years (Bruno et al. 2014a). At these latter sites, as a result of the lighting required for visitation, the high number of tourists and the in situ environment, conditions have become conducive for the growth of phototrophic biofilms capable of deteriorating exposed surfaces. The catacombs of Domitilla and S. Callixtus are visited by more than 500,000

✉ Laura Bruno  
laura.bruno@uniroma2.it

<sup>1</sup> Laboratory of Biology of Algae, Department of Biology, University of Rome Tor Vergata, Rome, Italy

<sup>2</sup> ENEA—Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Diagnostics and Metrology Laboratory, FSN-TECFIS-Diagnostic and Metrology Laboratory, Research Centre of Frascati, Via Enrico Fermi, 45, 00044 Frascati, Italy

<sup>3</sup> Laboratory of Botany, Department of Biology, University of Rome Tor Vergata, Rome, Italy

<sup>4</sup> Department of Science, University of Roma Tre, Viale G. Marconi 446, 00146 Rome, Italy