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Selection of LED lighting systems for the reduction of the biodeterioration of speleothems induced by photosynthetic biofilms in the Nerja Cave (Malaga, Spain)

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ABSTRACT

Electrical lighting favours the development of photosynthetic biofilms in caves which can induce biodeterioration in the colonized substrates. The use of specific lights as a limiting factor for biofilm growth could be effective in their control and represents an alternative to chemical methods since they can damage the substrate. However, studies about lighting and the photosynthetic activity of organisms in caves are scarce. In order to select the most effective LED light source in reducing photosynthesis and therefore, in reducing the growth rates of microalgae and cyanobacteria, four biofilms in the Nerja Cave were illuminated by several light emitted diodes (LEDs) with different spectral compositions and the photobiological responses were measured both by empirical and theoretical methodologies. The empirical approach was based on the photosynthetic efficiency, by measuring the *in vivo* chlorophyll *a* (Chl *a*) fluorescence and the theoretical approach was based on the photonic assimilation performance related to the proportion of the light quality used for photosynthesis, according to the action spectra for photosynthesis available in the literature. The photobiological responses showed differences between the empirical and theoretical approach mainly in biofilms dominated by cyanobacteria and red algae, probably because the available action spectra were not useful for monitoring these Nerja Cave biofilms. However, the expected spectral responses of photosynthesis were observed in green microalgal biofilms with maximum photosynthetic efficiency in red and blue light although the green light was also unexpectedly high. The high photosynthetic efficiency in green light could be explained by the predictable high chlorophyll content due to a very dark environment. The results were not conclusive enough for all the biofilm types to be able to recommend a specific lighting system for the photocontrol of biofilm expansion. Therefore, new action spectra for photosynthesis of the extremophile organisms of the Nerja Cave are required. This approach, based on theoretical and empirical methodologies, is a useful tool to obtain information to allow the design of the most adequate lighting systems to reduce photosynthetic activity and favour the conservation of the caves.

1. Introduction

Caves are natural underground chambers which are considered as extreme environments. They are mainly characterized by total darkness or low levels of light, stable temperatures and high humidity. Some of these subterranean environments had been used over time for human activity and may be used as a tourist attraction or as a geological, biological or archaeological laboratory. For recreational purposes the most important change, which alters the initial conditions, is the viewing light. Visitors cause the so-called “anthropic impact” that may be related to hydrogeological, geomorphological, environmental, microbiological or faunistic changes [1]. In tourist caves, electric lighting encourages the development of photosynthetic microorganisms on the surface of speleothems and walls. These microbial communities

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