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Lighting by LEDs and Case by Case Procedure Suitable to Inhibit the Growth of Photosynthetic Biodeteriogens in Hypogean Environments

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Abstract

The presence of biodeteriogens is one of the major conservation problems for any object and environment, especially in the case of Cultural Heritage. They are responsible of physical and chemical degradation or at least alteration mainly chromatic. In the case of underground environments, characterised by almost constant thermo-hygrometric conditions but with high humidity values, the problem starts at the time of the excavation, and/or restoration, and end with the need to light them for the visitors fruition. Really, light is the source of energy for almost all the living organisms including plant and most of the last use it in the photosynthesis, so needing the presence of well-defined wavelengths in the emission spectrum of the radiation source. On this bases we constructed a prototype lighting system, using LEDs, and propose an analytical procedure that, case by case, allows us to choice the optimal series of LEDs.

Introduction

Up-today the well known problem, bound to the presence of biodeteriogens on the surfaces of stone materials, is solved by chemical (for example biocides), physical (UV rays), mechanical (extirpation) methods or combination thereof; unfortunately, each of them could pose a risk to the artefact itself and/or to the operator. Our approach is based on the knowledge of the photosynthetic mechanisms and on the current availability of LEDs that emit specific wavelengths in a narrow band [1]. Some examples already exist [2] but are applied in the agricultural sector where, contrarily to the case of Cultural Heritage, i.e. our case, it is not needed an illumination with a light that not alters the colour of the environment; essential condition for their fruition.

The biodeteriogen colonization occurs by steps with variable length depending on the characteristics of the growth environment. It starts with a non-colonized environment and/or the presence of silent species; then, as a result of illumination, a greenish halo appears on the stone surface which is more or less visible to the naked eye (biofilm) and ends with the growth of superior species having rough or complex root systems. In the biofilm step mainly an aesthetic and chemical damage occur, due the use of the substrate for the metabolic activity and consequent release of metabolites; a further damage consists in the lowering of transpiration of the surfaces that so tend to retain a high humidity. In the last step, mainly a mechanical (physical) damage must be imputed to the growth of the root that implies fracturing. Obviously chemical and physical mechanisms act synergistically in create damage. In our research we propose a procedure that, step by step, allows to choice the best “light” to be used in a particular environment; on such basis we perform a preliminary study on the microclimatic conditions, the characterization of the stone materials and of the biodeteriogens already present or that can live in such environment (basing on literature).

Materials & Methods

As case study, a hypogeum dated II-III century AD was chosen. Microclimate (Temperature, Relative Humidity and Illuminance) was monitored by Hobo U12-012 (by Onset USA) positioned close to the colonized zones. Spot on site measures were performed by: a Luxmetro Mavolux (Gossen GmbH) for illuminance; IR thermometer IR810 (Testo AG GmbH) for room and no-contact temperature; hygrometer SurveyMaster (Protimeter USA) for contact humidity; Minolta CM2600-D spectrocolorimeter (Minolta Japan) for reflectance spectra. Spectrophotometric measures were performed, on biodeteriogen extracts or leaves such as, by UV-Vis Perkin-Elmer Lambda 16; emission spectra of LEDs and lamps were acquired by optical fiber spectrometer SpectroVis Plus (Vernier, USA). Biodeteriogens were recognized, thanks to Dr Oriana Maggi, using an optical microscope BA200 (Motic, Japan)equipped with an optic fiber MLC-150C. The prototype was constructed using LEDs principally from Mouser and RS suppliers.

Results

Briophitae (Muscii and Hepaticae), i.e. typical species of wet and dark environments were identified together with Pteridophitae the presence of which, being an allochthonous species, must be imputed to spores carried inside the archaeological site by visitors. Several fungi (not photosynthetic organisms) were also identified. UV-Vis spectra of the different species result almost but not exactly similar, obviously with maximum absorption typical of chlorophylls. Temperature and Humidity trends resulted not exactly those expected for hypogeum because partially influenced by the on-off of the lamps that, in same cases, produced values of Illuminance higher than those suggested by the norms for Cultural Heritage.

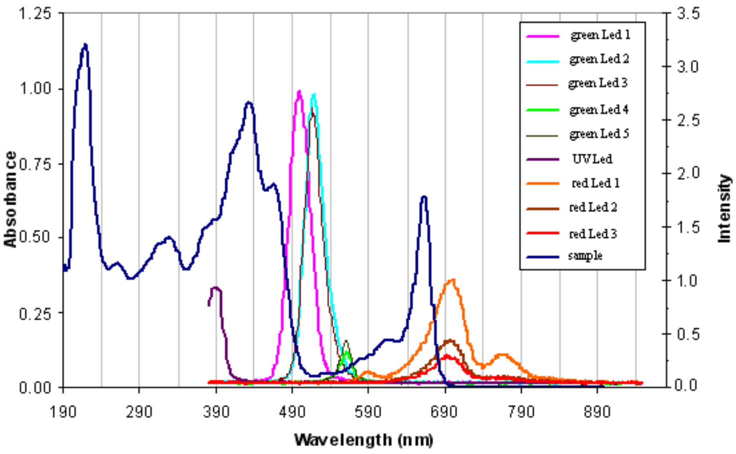

Fig. 1; Comparison of the emission spectra of the Leds used to construct the prototype and the absorbtion spectrum of one biodeteriogen sample

In fig. 1 the absorbance spectra of one of the sampled biodeteriogen is reported together with the emission spectra of the LEDs chosen to construct the prototype (5 green, 3 red and 1 UVA). An additional UV LED is foreseen that must be keep switched on only in the absence of visitors and therefore controlled by proximity sensors. The light intensity can be varied for each LED or the series of same wavelength; in order to find the minimum at which the inhibiting action starts, we used a low power LEDs and first results, on site, indicates that no difference in the inhibiting effect results in comparison with a commercial white LED of the same power. We are now increasing the light intensity and are planning lab tests in order to speed up the prototype optimization.

Conclusions

A prototype of a LED lighting system, already presented for patent, was constructed and ready to be optimized to obtain the minimum intensity useful to hinder the growth of photosynthetic biodeteriogen organisms and, at the same time, to allow a vision no too much altered in colour of the lighted environment, essential condition for the fruition of Cultural Heritage. LEDs were chosen basing on the absorption spectra of the colonizing species, on the microclimatic conditions of the room to be illuminated as well as on the colour of its surfaces; so, a preliminary study is needed case by case following a procedure also indicated in the patent. The light intensity can be varied for each LED and the LEDs itself can be easily changed if the initial colonizing species disappear and new ones appear. In order to exploit a further disinfesting mechanism, an UVC LEDs can be added that could be switched on in absence of visitors i.e. controlled by proximity sensors.

References

1) European Patent Pending, M.P. Sammartino, G. Visco; *Impianto di illuminazione a LEDs e relativo procedimento per inibire lo sviluppo di organismi biodeteriogeni fotosintetici in ambienti ipogei*, La Sapienza University, n. RM2014A000193, 10/04/2014

2) E. Olvera-Gonzalez, D. Alaniz-Lumbreras, R. Ivanov-Tsonchev, J. Villa-Hernandez, I. de la Rosa-Vargas, I. Lo´pez-Cruz, H. Silos-Espino, A. Lara-Herrera, Chlorophyll fluorescence emission of tomato plants as a response to pulsed light based LEDs, *Plant Growth Regul*, 69(2), (2013) 117-123.