Editorial on special issue for European Conference on Biodegradation of Stone Monument 2020 (VSI-ECBSM2020)

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Editorial

Deterioration and degradation linked to living organisms, and more particularly to microorganisms, are one of the major sources of alteration of stone monuments. To combat biodeterioration and biodegradation of stone monuments, it is necessary to diagnose them, i.e., to evaluate them qualitatively and quantitatively, set up a restoration strategy that respects the heritage value of the site or object, and then monitor the restored monument over time. Thus, this fight mobilises the extremely varied skills of experts, researchers and conservators by mobilising both innovation and tradition. It is essential that these different communities meet, exchange, and then collaborate to integrate their skills for heritage preservation. The European Conference on Biodeterioration of Stone Monuments (ECBSM) is an opportunity to gather researchers, restorers, industrial experts, and teachers who are working on the biodeterioration of stone monuments in the context of cultural heritage preservation.

This special issue of the journal "International Biodeterioration & Biodegradation" consists of 18 selected papers presented at the 4th European Conference on Biodeterioration of Stone Monuments (ECBSM2020), which was held virtually from 5th to 6th November, 2020 due to the COVID-19 pandemic. Since its inception in 2014 at the University of Cergy-Pontoise in France, the ECBSM has been held every two years, with the 2020 edition co-organised by the University of Rome Tor Vergata, the University of Milan and the University of Cergy Paris. The conference program was organised into three sessions: Ecology of microorganisms colonizing stone monuments, Alteration mechanisms and materials, Prevention and treatment. The special issue covers the following topics: Biodeterioration and biodegradation of materials of stone monument, Agents and mechanisms of stone monuments biodeterioration in outdoor and confined environments, Assessment and monitoring of stone damage on monuments, Ecology of biofilms on stone monuments, Biodeterioration and climate change, Application of innovative and non-invasive technologies on the study and the conservation of stone monuments, Environmentally friendly antimicrobial treatments.

The study presented by Zhang et al. (2021) is a great example of how modern molecular biology technologies can give extensive information about lithic microbial ecology in an open-air stone monument. Using a next-generation sequencing approach, the authors described the seasonal variations and the dominant phyla associated with biodeterioration phenomena. The structure of bacterial and algal communities appeared to be closely correlated with climate parameters. This type of approach also makes it possible to study the ecology of biofilms growing on sandstone in temple caves (Duan et al., 2021), the ecology of subaerial biofilms growing on tombstones, and to determine the origin of the sessile microorganisms (Gambino et al., 2021), to study the diversity of pioneer microorganisms colonizing ceramic roof tiles during outdoor exposure (Romani et al., 2021), and to compare normal and biodeteriorated wall paintings during a microbe outbreak (He et al., 2021). Pasteur's microbiology still has its place in isolating and characterising the major microorganisms of such outbreaks (He et al., 2021), or to describe the seasonal diversity of algae and/or cyanobacteria colonizing monuments (Keshari et al., 2021; Mondal et al., 2022). Scanning electron microscopy (SEM), by allowing the observation of microorganism-stone interactions, provides valuable information on the bioreceptivity of the material, the availability of water on a microscopic scale, and the influence of these parameters on biofilm development (Duan et al., 2021). Confocal laser scanning microscopy (CLSM) gives information about the thickness, cellular volume, and exopolysaccharides of biofilms on different materials in environments with varying relative humidity (Del Mondo et al., 2021). Combining SEM, CLSM, culture-based, and high-throughput sequencing approaches allows to characterise taxonomically and functionally the microorganisms involved in biofilm formation while analysing the properties of biofilms formed under different conditions (Romani et al., 2021). High-throughput sequencing and bioinformatic analyses can also give access to the prediction of ecological functions of microbial communities (Wu et al., 2021). For example, chemoheterotrophy, phototrophy and aerobic ammonia oxidation have been shown to ensure the joint survival of biodeteriogens on the sandstone cliff of the Beishiku Buddhist temple (Fasi Wu 2021).

Monitoring microbial growth on stones and evaluating the effectiveness of antimicrobial treatments applied to stone surfaces can be done with simple, non-invasive techniques. For example, the colorimetric analysis makes it possible to monitor the kinetics of biological colonisation over several years on a stone monument (Bartoli et al., 2021). The joint use of ATP-metry (measurement of ATP concentration by bioluminescence) and UV fluorescence imaging of chlorophyll a is an effective non-invasive approach to assessing the effectiveness of a treatment and monitoring its evolution over time (Spada et al., 2021a).

For several years, restorers have been looking for more environmentally friendly and less toxic biocidal treatments to deal with biodeteriorations. One of the most environmentally friendly solutions is certainly bio-cleaning, such as the use of micro-organisms to clean graffiti (Bosch-Roig et al., 2021). In the study published by Spada et al. (2021b) mixtures of essential oils containing carvacrol, eugenol, cinnamaldehyde and thymol, have demonstrated their efficiency at low concentration for the treatment of a marble statue. The use of biocides, whether artificial or natural, is not only based on a choice of active ingredients but also on a choice of concentrations, duration and method of application (Spada et al., 2021a; Ranaldi et al., 2022). Ranaldi and his colleagues have developed an innovative application protocol based on the encapsulation of essential oils in an alginate hydrogel. This allows the use of a low concentration that reduces volatility problems and allows the treatment of vertical surfaces

covered with phototrophic biofilms (Ranaldi et al., 2022). Other biocides like titanium dioxide or sodium dichloroisocyanurate have been efficiently encapsulated in alginate gels, which proved their high potential for the treatment of phototrophic biofilms (Gabriele et al., 2021). Díaz-Alonso and collaborators described a cold diffusion system of essential oils for using in indoor environments (Díaz-Alonso et al., 2021).

Air pollution is known to have an impact on the microbial colonisation of stone surfaces in urban areas, but what about light pollution? To answer this question, Sanmartin and colleagues tested the effect of UV-A and UV-B radiation and red LED light on the biofilm growth and diversity of different phototrophic biofilms (Sanmartin et al., 2021). This study showed proliferation-inducing effects of certain light cocktails that vary according to the type and ratio of phototrophs in the sessile biomass.

The effects of climate change on the biodeterioration and biodegradation of stone monuments are increasingly being studied. Different papers in this special issue are devoted to or refer to this issue (Fuentes and Prieto 2021; Mondal et al., 2022; Zhang et al., 2021).

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References

Flavia Bartoli, Annalaura Casanova Municchia, Marcello Leotta, Sebastiano Luciano, Giulia Caneva, Biological recolonization dynamics: Kentridge's artwork disappearing along the Tiber embankments (Rome, Italy), International Biodeterioration & Biodegradation, Volume 160, 2021, 105214.

P. Bosch-Roig, J.S. Pozo-Antonio, P. Sanmartín, Identification of the best-performing novel microbial strains from naturally-aged graffiti for biocleaning research, International Biodeterioration & Biodegradation, Volume 159, 2021, 105206.

Angelo Del Mondo, Gaetano Zuccaro, Mariagioia Petraretti, Antonino Pollio, Antonino De Natale, Water absorption coefficient drives Nostoc sp. colonization on mineral substrates, International Biodeterioration & Biodegradation, Volume 164, 2021, 105291.

Julia Díaz-Alonso, Andrea Bernardos, José Luis Regidor-Ros, Ramón Martínez-Máñez, Pilar Bosch-Roig, Innovative use of essential oil cold diffusion system for improving air quality on indoor cultural heritage spaces, International Biodeterioration & Biodegradation, Volume 162, 2021, 105251.

Yulong Duan, Fasi Wu, Dongpeng He, Ji-Dong Gu, Huyuan Feng, Tuo Chen, Guangxiu Liu, Wanfu Wang, Bacterial and fungal communities in the sandstone biofilms of two famous Buddhist grottoes in China, International Biodeterioration & Biodegradation, Volume 163, 2021, 105267.

Elsa Fuentes, Beatriz Prieto, A laboratory approach on the combined effects of granite bioreceptivity and parameters modified by climate change on the development of subaerial biofilms on cultural heritage, International Biodeterioration & Biodegradation, Volume 164, 2021, 105295.

Francesco Gabriele, Alice Vetrano, Laura Bruno, Cinzia Casieri, Raimondo Germani, Lorenza Rugnini, Nicoletta Spreti, New oxidative alginate-biocide hydrogels against stone biodeterioration, International Biodeterioration & Biodegradation, Volume 163, 2021, 105281.

Michela Gambino, Gloria Lepri, Adam Štovícek, Lusine Ghazayarn, Federica Villa, Osnat Gillor, Francesca Cappitelli, The tombstones at the Monumental Cemetery of Milano select for a specialized microbial community, International Biodeterioration & Biodegradation, Volume 164, 2021, 105298.

Dongpeng He, Fasi Wu, Wenxia Ma, Yong Zhang, Ji-Dong Gu, Yulong Duan, Ruihong Xu, Huyuan Feng, Wanfu Wang, Shi-Weng Li, Insights into the bacterial and fungal communities and microbiome that causes a microbe outbreak on ancient wall paintings in the Maijishan Grottoes, International Biodeterioration & Biodegradation, Volume 163, 2021, 105250.

Nitin Keshari, Sudipta Kumar Das, Siba Prasad Adhikary, Colonization and survival of a stress tolerant cyanobacterium on a heritage monument of Santiniketan, India, International Biodeterioration & Biodegradation, Volume 164, 2021, 105294.

Arka Mondal, Sikha Mandal, Jnanendra Rath, Seasonal diversity of cyanobacteria and new report of Brasilonema sp. colonizing the monuments of Santiniketan and Bishnupur (India), International Biodeterioration & Biodegradation, Volume 167, 2022, 105350.

Roberta Ranaldi, Lorenza Rugnini, Francesco Gabriele, Nicoletta Spreti, Cinzia Casieri, Gabriele Di Marco, Angelo Gismondi, Laura Bruno, Plant essential oils suspended into hydrogel: Development of an easy-to-use protocol for the restoration of stone cultural heritage, International Biodeterioration & Biodegradation, Volume 172, 2022, 105436.

Mattea Romani, Emilie Adouane, Claire Carrion, Carole Veckerlé, Dominique Boeuf, Frédéric Fernandez, Manon Lefèvre, Laurent Intertaglia, Alice M.S. Rodrigues, Philippe Lebaron, Raphaël Lami, Diversity and activities of pioneer bacteria, algae, and fungi colonizing ceramic roof tiles during the first year of outdoor exposure, International Biodeterioration & Biodegradation, Volume 162, 2021, 105230.

Patricia Sanmartín, Anxo Méndez, Rafael Carballeira, Elena López, New insights into the growth and diversity of subaerial biofilms colonizing granite-built heritage exposed to UV-A or UV-B radiation plus red LED light, International Biodeterioration & Biodegradation, Volume 161, 2021, 105225.

a Mariagiulia Spada, Franca Sorella, Monica Galeotti, Isetta Tosini, Oana Adriana Cuzman, Non-invasive technologies to timely screen out different application conditions of essential oils on stone, International Biodeterioration & Biodegradation, Volume 163, 2021, 105285.

b Mariagiulia Spada, Oana Adriana Cuzman, Isetta Tosini, Monica Galeotti, Franca Sorella, Essential oils mixtures as an eco-friendly biocidal solution for a marble statue restoration, International Biodeterioration & Biodegradation, Volume 163, 2021, 105280.

Fasi Wu, Yong Zhang, Dongpeng He, Ji-Dong Gu, Qinglin Guo, Xiaobo Liu, Yulong Duan, Jianhua Zhao, Wanfu Wang, Huyuan Feng, Community structures of bacteria and archaea associated with the biodeterioration of sandstone sculptures at the Beishiku Temple, International Biodeterioration & Biodegradation, Volume 164, 2021, 105290.

Yong Zhang, Fasi Wu, Min Su, Dongpeng He, Ji-Dong Gu, Qinlin Guo, Mian Adnan Kakakhel, Yue Yang, Wanfu Wang, Huyuan Feng, Spatial and temporal distributions of microbial diversity under natural conditions on the sandstone stelae of the Beishiku Temple in China, International Biodeterioration & Biodegradation, Volume 163, 2021, 105279.