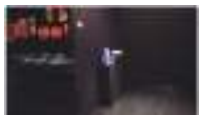
Indoor/Outdoor Particulate Matter and Bioaerosol Load of a Museum in Mediterranean Climate: The case of the Historical Museum of Crete (Greece).

T. Glytsos[1], E. Katsivela[2], I. Kopanakis[1], L. Raisi[1,2], E. Violaki[3], A. Kaloutsakis[3], A. Saridaki[1,2], N. Kalogerakis[1] and M. Lazaridis[1]

[1]School of Environmental Engineering, Technical University of Crete, Chania 73100, Greece
[2]Department of Environmental and Natural Resources Engineering, School of Applied Sciences, Technological Educational Institute of Crete, Romanou 3, Chania 73133, Greece
[3]Historical Museum of Crete, Sofokli Venizelou 27/Lisimachou Kalokairinou 7, 71202, Heraklion, Greece
(correspondence: thodoros.glytsos@enveng.tuc.gr)

INTRODUCTION-OBJECTIVES

Indoor air quality can significantly affect the state of works of art inside museum environments. Especially, exhibits made of sensitive organic materials such as wood, leather and paper, present high risk of deterioration of their characteristics, even at low pollutant's concentrations during exposures for long periods of time. Particulate matter (PM) deposition can lead to adverse effects including surface alteration, deterioration of the aesthetic appearance, mechanical damage and the transport of harmful absorbed compounds or microbiological agents as well as the structures and substances produced by those microorganisms to the surface of artefacts. The objectives of this study are to investigate the state of aerosols and bioerosols load inside the museum, to identify and characterize the microorganism's deposits in actual exhibits and finally to evaluate a continuous air pollution monitoring system based on low cost PM sensors.



Exhibition rooms 1 and 2 (Introductory *A. Kalokerinos* room and *Z. Portalakis* collection hall. Use of ionizers.

MEASUREMENTS SITES AND INSTRUMENTATION

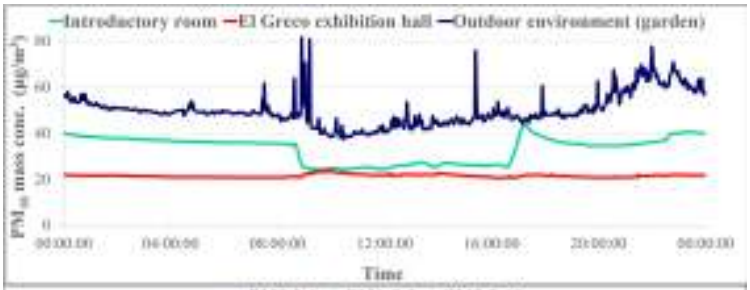
The measurements were performed during Summer and Autumn 2018, for six weeks, in the Historical Museum of Crete (Heraklio, Greece). Three different exhibition rooms inside the Museum and in one spot in the outdoor environment were selected for the campaigns. Photocatalytic ionizers (operating only during visiting hours; one Daikin MC70L Ioniser per 65 m^3 of room space) are used as precautionary measures against PM and airborne microorganisms in two of the exhibition rooms *(A. Kalokerinos* room and *Z. Portalakis* room). High time resolution portable aerosol data monitors (Dustrak II and OPS (TSI) were employed for PM mass concentrations data collection, while bioerosols sampling was performed using the MAS-100 microbial air sampler (Merck Millipore). Different microbiological growth media were used for the cultivation of viable airborne microbes (Lazaridis et al., 2015 & 2018). Concentrations of airborne microorganisms were expressed as colony forming units per cubic meter (CFU/m^3).

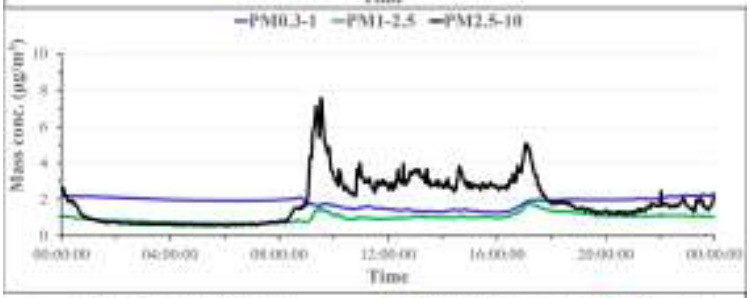
Exhibition room 3 (*El Greco* collection hall). No use of ionizers.

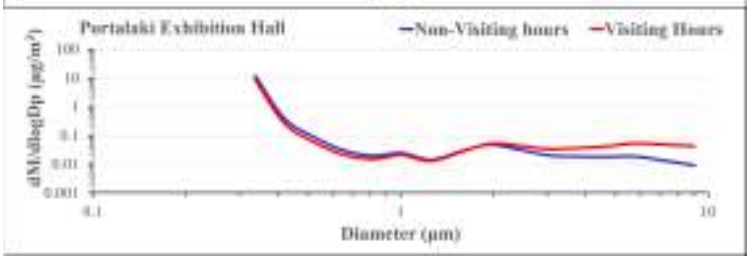
Outdoor measurements site.

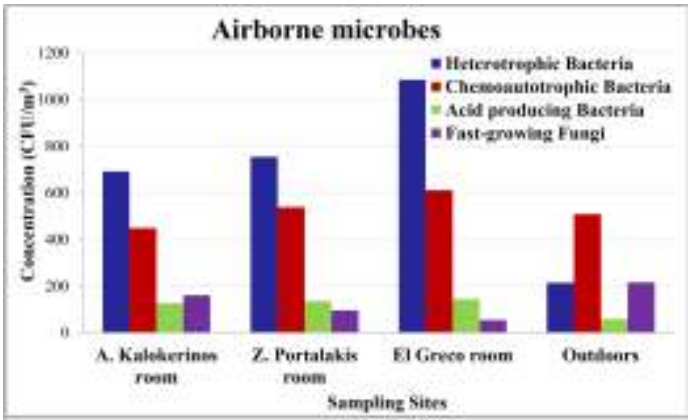
RESULTS

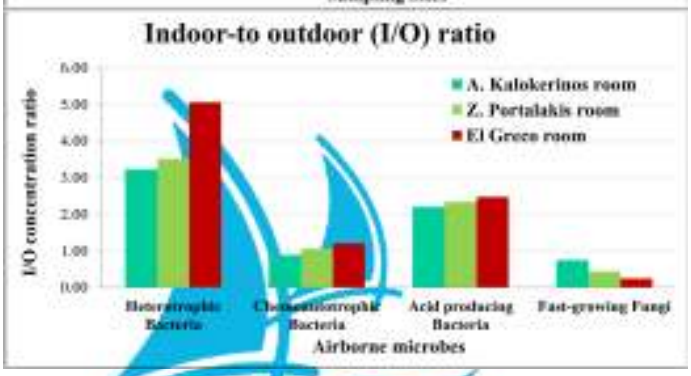
- Indoor PM concentrations are affected by the PM load of the outdoor environment.
- The presence of people (visitors of the Museum) results in the transportation of coarse particles indoors and microbes, which are resuspended and dispersed in the air during visiting hours.
- PM_{10} mass concentrations are lower during visiting hours, due to the use of ionizers *(A. Kalokairinos* and *Z. Portalakis* rooms). On the contrary, moderate increase in average daily PM_{10} mass concentrations was recorded in exhibitions rooms without ionizers (*El Greco* collection hall).
- Particles with aerodynamic diameter between 0.3-10 μm presented mass and number distributions with similar shapes for visiting and non-visiting hours. Coarse particle mass concentrations ($PM_{2.5}$-PM_{10}) were higher during visiting hours.
- Airborne viable cultivable bacteria (heterotrophic bacteria, chemoautotrophic bacteria, and acid producing bacteria) presented higher concentrations indoors than outdoors.
- Especially, exhibition rooms without air purifiers (*El Greco* room) showed Indoor-to-Outdoor ratio (I/O) 1.5 time higher for opportunistic pathogenic heterotrophic bacteria.
- Airborne fast-growing fungi were not enriched indoors and presented higher concentrations outdoors.











CONCLUSIONS

- The use of ionizers should be extended in all exhibition rooms and also during non-visiting hours, since the indoor environment is strongly affected by outdoor emissions.
- Measures should be taken to reduce the transportation of coarse particles indoors.
- The photocatalytic ionizers showed higher efficiency for fine particulate matter with aerodynamic diameters from 0.3 to 2.5 μm, and airborne opportunistic pathogenic heterotrophic bacteria. In comparison, coarse PM ($PM_{2.5}$-PM_{10}), chemoautotrophic bacteria, and acid producing bacteria were not removed efficiently.

FUTURE WORK

- Installation and evaluation of a PM and air gaseous pollutants monitoring system, based on low cost pollution sensors.
- Gravimetric sampling using personal cascade impactors (SKC) analysis of the collected filters by ion chromatography (IC) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS).
- Metagenomic analysis of the airborne microbial community inside the museum and outdoors.

References
Lazaridis. M., Katsivela, E., Kopanakis, I., Raisi, L. and Panagiaris, G. (2015). Indoor/Outdoor Particulate Matter Concentrations and Microbial Load in Cultural Heritage Collections. *Heritage Science* 3, 34. DOI 10.1186/s 40494-015-0063-0
Lazaridis. M., Katsivela, E., Kopanakis, I., Raisi, L., Mihalopoulos, N., and Panagiaris, G. (2018). Characterization of Airborne Particulate Matter and Microbes inside Cultural Heritage Collections. *Journal of Cultural Heritage* 30, 136-146 . DOI:10.1016/j.culher.2017.09.018

ACKNOWLEDGEMENTS
This work was performed under the Operational Cooperation Programme «Interreg V-A, Greece-Cyprus 2013-2020» and was co-financed by the European Union (ERDF) (80%) and National Funds of Greece and Cyprus (20%)

Presented at the 2019 European Aerosol Conference (EAC 2019), August 26-30, 2019, , Gothenburg (Sweden)