THE RELEVANCE OF MONITORING THE MICROCLIME IN MUSEUMS THE CASE OF COLLE DEL DUOMO IN VITERBO

Luca Lanteri[1], Claudia Pelosi[1*] and Angela Lo Monaco[2]

[1] *University of Tuscia, Department of Economics, Engineering, Society and Business Organization (DEIM), Largo dell'Università, 01100, Viterbo, Italy*
[2] *University of Tuscia, Department of Agricultural and Forestry Sciences (DAFNE), 01100, Viterbo, Italy*

(Received 7 March 2020)

Abstract

Microclimate monitoring is a fundamental step in preventive conservation and must be taken into account in the planning of museum expositions and in other confined environments, as stated by international standards produced by the technical body CEN/TC 346. This contribution synthesizes the results of extensive monitoring campaigns in the Museum of Colle del Duomo, a diocesan museum located in the important complex of the Papal Palace of Viterbo (Central Italy). The museum contains different kinds of religious objects such as reliquary busts in wood, papier-mâché and metals, sacred clothes, panel paintings, gypsum 'modelli', and also archaeological artefacts. This wide variety of materials makes particularly difficult to maintain environmental parameters, such as light, relative humidity and temperature, within the ranges of values recommended by the Italian and European standards for Museum conservation. However, the monitoring campaigns allowed to know the most critical situations and to intervene with solutions aimed at mitigating the effects of microclimate on the artefact materials. Three main rooms were monitored for one year: the Sacred Vestments room, the papier-mâché reliquary room and room of Baroque wall paintings with the beautiful wooden choir in a closed area of the Cathedral, immediately adjacent to the Museum. The continuous monitoring was performed by means of portable data-loggers. Irradiance (W/m^2) and illuminance (lux) were measured only in the Sacred Vestments room, being textiles highly sensitive to light.

Keywords: European, standards, preventive, conservation, data-logger

1. Introduction

The conservation of artworks in confined spaces poses the problem of controlling the microclimatic parameters that, for certain materials are fundamental for their preservation [1-4]. In our century, the growing air pollution and especially for the works of art in museums, the great flux of public have led

[*]Corresponding author, e-mail: pelosi@unitus.it, tel: +390761357017

to an increasingly careful consideration of the problem of conservation in confined spaces also in order to limit restoration interventions [5, 6]. In this regard, especially in the last decades, a series of rules and recommendations have been developed whose knowledge is fundamental for the management of cultural heritage conservation [7-14; *Decree n. 238 of 10 May 2011*, *Atto di indirizzo sui criteri tecnico-scientifici e sugli standard di funzionamento e sviluppo dei musei* (G.U. n. 244 – Serie generale, S.O. n. 238), Ministry for Cultural Heritage and Activities, 2001].

The control of the microclimate becomes all the more important the more the works of art themselves are made up of composite materials and/or sensitive to thermo-hygrometric variations. In fact, sensitive materials such as organic materials (paper, wood, fabrics, etc.) require stable relative humidity and temperature conditions, above all avoiding sudden changes.

It should be emphasized that the control of the thermo-hygrometric conditions of an environment, if air conditioning and heating systems are used, can become a very complex problem, both because it is not always easy to achieve uniform conditions of temperature and humidity in space and time, but also because it is necessary to constantly check the operation of the air conditioning systems [3, p. 19-21].

Taking all these aspects into consideration, it is possible, even if not simple, to program microclimate control correctly and as completely as possible, by using small portable environmental detection instruments [15-18].

Starting from this general framework, the present work reports the results of the thesis experiences made by some students of the course of Cultural Heritage and Technologies for Conservation of Cultural Heritage, in the context of the collaboration between the Department of Cultural Heritage Sciences of the University of Tuscia and the Colle del Duomo Museum, and related to microclimatic monitoring in some of the museum’s exhibition areas.

In chronological order, the theses were those of Monica Pace entitled: *Microclimatic control of the Hall of Sacred Vestments at the Colle del Duomo Museum in Viterbo* discussed on October 13th 2011; the thesis of Sara Clementi titled: *The papier-mâché reliquary busts of the Colle del Duomo Museum in Viterbo: investigations into the execution technique and the conservation environment* discussed on 11th May 2012 and that of Federica Macca entitled: *The tribune of the choir in the Cathedral of San Lorenzo in Viterbo. Conservation issues and microclimatic monitoring* discussed on December 3rd 2012.

Microclimate monitoring was possible thanks to the availability of the Archeoares Company which manages the Museum and which with great participation made it possible to take the measures.

2. Experimental

Three main rooms were monitored: the room of Sacred Vestments in which different sacred textiles are exposed; the room of the reliquary busts containing papier-mâché, metal and wooden objects; the room of the choir tribune that contains Baroque wall paintings, a canvas and a beautiful wooden choir. This room is located in a closed area of the Cathedral, immediately adjacent to the Museum [19].

Relative humidity (RH%) and temperature (T in °C) were measured for one year in each selected room: in the Sacred vestments room from March 2011 to February 2012, in the reliquary room from December 2011 to November 2012, in the choir tribune from May 2012 to April 2013. Two different data-loggers were used: Testo 175-H2 and Testo 177-H1 with measuring range from 0% to 100% for RH% and precision +/- 3.0%, and from -20°C to +70°C for temperature with a precision of +/- 0.5°C. In all cases, the data-loggers were set for registering the values of RH% and T (°C) at hour intervals so that 24 measures were gathered each day. The memorized data were then transferred on a computer and elaborated through Excel software in order to obtain maximum, minimum, average values and seasonal trends. For each month the tolerance matrix was obtained according to the model proposed in the literature [20]. Tolerance matrices are graphs that show all the recorded temperature values as a function of relative humidity and trace the segments that define the thresholds established by the UNI 10829 (1999) Italian standard. These segments define an area (tolerance area) within which the pairs of T-RH% values should be to ensure the well-being of the artefact.

For textiles, the values are: 30-50% for the RH% with a maximum daily excursion of 6%; 19-24°C for the temperature with a maximum daily excursion of 1.5°C. For papier-mâché artefacts the values are: 40-55% for the RH% with a maximum daily excursion of 6%; 18-22°C for the temperature with a maximum daily excursion of 1.5°C. Finally, for wooden artefacts the reference values are: 45-60% for the RH% with a maximum daily excursion of 4%; 19-24°C for the temperature with a maximum daily excursion of 1.5°C. In the case of the choir tribune there are different types of artefacts: wall paintings, a canvas and the wooden choir, therefore the choice of the values to be taken as reference was made considering the most sensitive material to the variations of the thermo hygrometric parameters, i.e. the wood. Finally, for each monitored season, the data for a single month is reported.

In the Sacred vestment room illuminance values (lux), total radiance ($\mu W/cm^2$) and UVA radiation ($\mu W/cm^2$) were also measured. A luxmeter HD 8366 and a radiometer DeltaOhm HD2102.2 with total radiance and UVA probes (LP417RAD from 400 to 1000 nm and UVA LP417UVA from 315 to 400 nm, 0.1 mW/m^2 - 2000 W/m^2) were used.

3. Results and discussion

3.1. The room of Sacred Vestments

In the case of the Sacred Vestments room (Figure 1), in addition to the RH% and T (°C) values, the illuminance and radiance values were also recorded with both the closed and the open windows. The values obtained on a sunny day in June (Table 1) highlight that, especially with the windows open, the maximum permitted by the UNI for illuminance (50 lux) is far exceeded.

Figure 1. A view of the Sacred Vestments room and a detail of discoloration due to light. The part covered by the coat hanger clearly maintained its original blue colour.

For this reason it was suggested to leave the windows closed, especially during the hours of maximum sunshine, and to provide the windows with simple screening systems. For completeness of information, it would obviously be necessary to carry out a monitoring all year round in order to calculate the annual dose of light and ultraviolet radiation that the artefacts receive and that is responsible for the strong discoloration observed in the hangings during the disassembly and re-fitting operations performed by the Ancient Textile Laboratory of Viterbo. The measures reported are therefore only indicative but still useful for identifying the general problem.

With regard to the measurement of thermo-hygrometric parameters, we report the months of April for spring, August for summer, October for autumn and February for winter (Figure 2). In April 2011, the data-logger positioned above one of the windows of the vestments room registered values of RH% and T that falling outside the wellness area in the tolerance matrix. Only a small percentage of the recorded data is found within the tolerance area (safety area). During the month of April, the temperature data are largely within the limits set by the regulations (between 19 and 24°C). Given that there are no air conditioning systems inside the museum, it is obvious that the data of relative humidity and temperature are influenced by the external climate and therefore the increase in temperatures and consequently the decrease in RH% values, are related to spring season typical of Tuscia region [http://my.meteonetwork.it/station/laz212/statistiche]. Finally, a fair stability of thermohygrometric data is underlined, also in this case due to the season characteristics.

Table 1. Values of illuminance, total radiance and UV components in the showcases of the Sacred Vestments room.

Measuring point	Illuminance (Lux)	RAD TOT (Wm^{-2})	UVA (Wm^{-2})	UVB (Wm^{-2})
Showcase nr.1 long side, closed window	166	$610x10^{-3}$	$0.8x10^{-3}$	$0.8x10^{-3}$
Showcase nr.1 short side, closed window	153	$501x10^{-3}$	$0.9x10^{-3}$	$1.1x10^{-3}$
Showcase nr.2 long side, closed window	157	$568x10^{-3}$	$0.8x10^{-3}$	$1.1x10^{-3}$
Showcase nr.2 short side, closed window	160	$365x10^{-3}$	$1.8x10^{-3}$	$0.8x10^{-3}$
Showcase nr.3 long side, closed window	182	$599x10^{-3}$	$0.3x10^{-3}$	$0.7x10^{-3}$
Showcase nr.3 short side, closed window	197	$515x10^{-3}$	$0.6x10^{-3}$	$1.4x10^{-3}$
Showcase nr.4 long side, closed window	147	$524x10^{-3}$	$1.3x10^{-3}$	$0.9x10^{-3}$
Showcase nr.4 short side, closed window	158	$436x10^{-3}$	$2.8x10^{-3}$	$0.7x10^{-3}$
Showcase nr.5 long side, closed window	128	$487x10^{-3}$	$1.0x10^{-3}$	$1.1x10^{-3}$
Showcase nr.5 short side, closed window	158	$765x10^{-3}$	$6.7x10^{-3}$	$1.6x10^{-3}$
Showcase nr.5 lateral side	160	$948x10^{-3}$	$6.3x10^{-3}$	$1.8x10^{-3}$
Showcase nr 1 long side, open window	766	3.32	$120x10^{-3}$	$7.5x10^{-3}$
Showcase nr 1 short side, open window	610	2.50	$38.3x10^{-3}$	$5.1x10^{-3}$
Sacred Vestments room, n.2 long side, open window	554	2.59	$96.4x10^{-3}$	$5.5x10^{-3}$
Showcase nr.2 short side, open window	498	$926x10^{-3}$	$4.1x10^{-3}$	$1.5x10^{-3}$
Showcase nr.3 long side, open window	630	2.78	$35.2x10^{-3}$	$3.2x10^{-3}$
Showcase nr.3 short side, open window	425	1.98	$40.8x10^{-3}$	$3.2x10^{-3}$
Showcase nr.4 long side, open window	288	1.34	$37.8x10^{-3}$	$3.2x10^{-3}$
Showcase nr.4 short side, open window	180	$530x10^{-3}$	$2.8x10^{-3}$	$1.5x10^{-3}$
Showcase nr.5 long side, open window	171	$749x10^{-3}$	$1.9x10^{-3}$	$1.3x10^{-3}$
Showcase nr.5 short side, open window	165	$738x10^{-3}$	$6.4x10^{-3}$	$1.2x10^{-3}$
Showcase nr.5 lateral side, open window	170	$858x10^{-3}$	$5.8x10^{-3}$	$1.1x10^{-3}$

In August, all registered values fall outside the wellness area. However, most RH% values are within the range recommended by the law. The main problem, as has been seen for other months and particularly for the month of

August, is the strong fluctuation of values, above all relative humidity even on a daily basis (Figure 3).

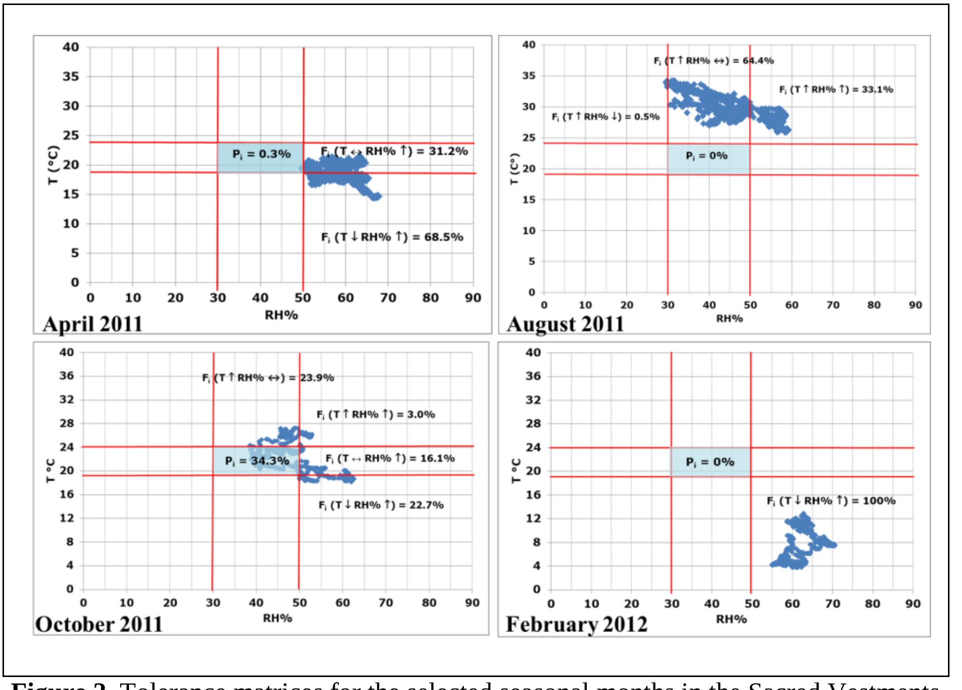

Figure 2. Tolerance matrices for the selected seasonal months in the Sacred Vestments room. P_i represents the performance index, i.e. the percentage of values falling in the tolerance area (correct values of RH% and T °C). F_i represents the failure index, i.e. the percentage of values falling out of the tolerance area.

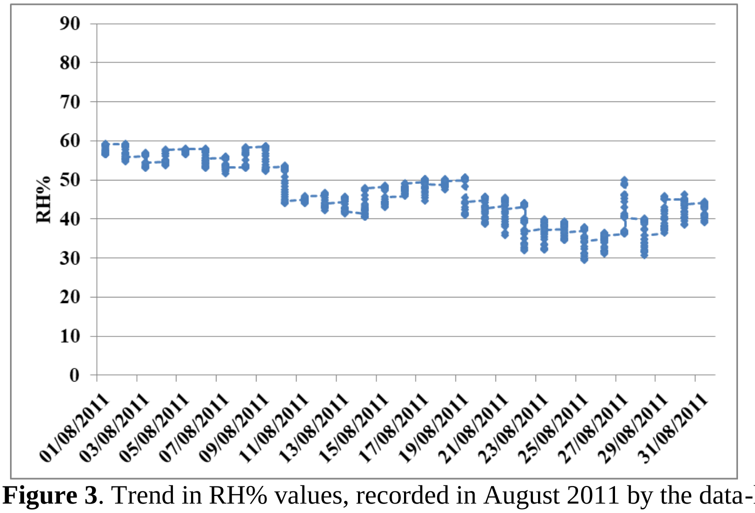

Figure 3. Trend in RH% values, recorded in August 2011 by the data-logger positioned above a window in the room of Sacred Vestments, as function of the days; the remarkable daily changes are the points aligned parallel to the ordinate axis.

The range between maximum and minimum monthly is in fact as much as 29.70%, the highest recorded by this data-logger. The temperatures are slightly more stable but they are very high because, since there are no air conditioning systems, the external climate determines the internal climate of the museum rooms.

As regards the month of October, chosen as an indication of the autumn season, a situation similar to that of the month of April or the spring season can be observed, although in October a higher percentage of values falls within the wellness area (34.3% as shown in Figure 2). Also in this case, the most important information that emerges from the reading of the RH% and T values is the considerable fluctuation of the values both on a monthly and on a daily basis due to the previously explained reason.

In the case of the winter season it is evident that the values recorded fall outside the wellness area. The temperature values are clearly below the threshold indicated by the legislation for textiles while the relative humidity values are clearly above. Also in this case the values of the thermo-hygrometric parameters are determined by the external climate which in February 2012 was particularly severe and snowy.

3.2. The room of the reliquary busts

The graphs of the tolerance matrices for the four months chosen as representative of the seasons are shown in Figure 4. Only the values recorded by the data-logger positioned above the window adjacent to the access corridor to the bust room are shown (Figure 5, datalogger nr. 2). Those recorded by the data-logger above the showcase inside the hall have the same trend. Therefore, the trends of T and RH% follow those observed for the Sacred Vestments room.

The most worrying datum concerns the oscillation of thermo-hygrometric parameters. Particularly the RH% on a daily basis also presents daily excursions of over 20% in the spring and autumn months, which partially is caused by the shape of the room (Figure 5). In fact, this a sort of corridor exposed to air currents and to effect of door opening/closing.

Also in this case, as for the hall of Sacred Vestments, the trends in the relative humidity and temperature values are determined by the external climatic conditions, not being active sources of conditioning of the environment.

3.3. The choir area in the Saint Lawrence Cathedral

The choir area is a confined space behind the current apse of the Cathedral of Saint Lawrence in the Papal Palace complex (Figure 6). It is the baroque remain of the cathedral that was closed to reconstruct the original medieval asset of the apse after the destruction in the Second World War. At present, the choir area is under the management of Colle del Duomo Museum.

Since there are no substantial differences between the values measured by the data-logger placed above the altar and that positioned above the choir, only the results measured by the latter are shown (Figure 7). In this case for spring May was chosen as reference month.

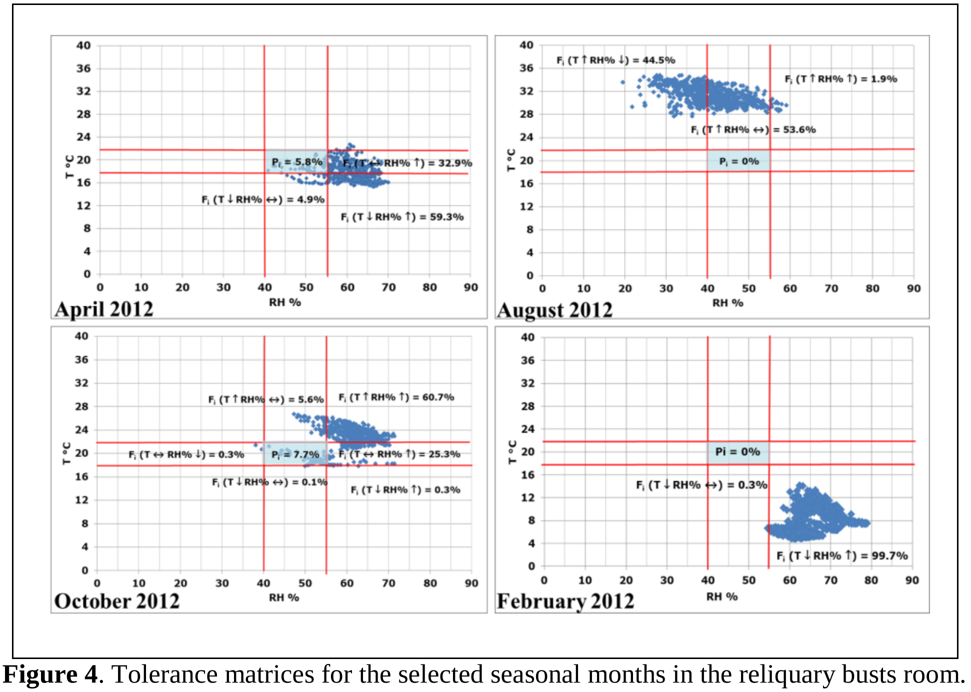

Figure 4. Tolerance matrices for the selected seasonal months in the reliquary busts room.

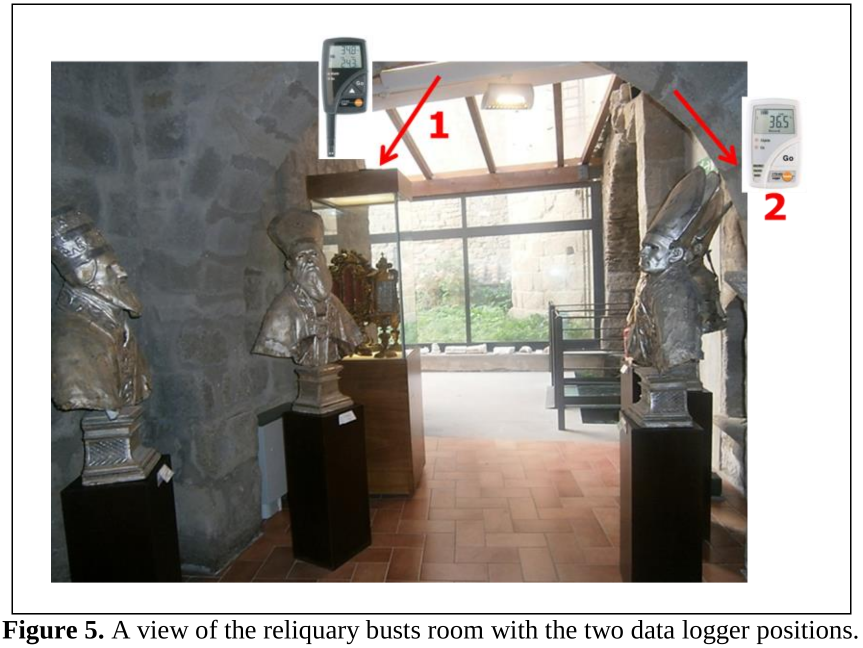

Figure 5. A view of the reliquary busts room with the two data logger positions.

Figure 6. Two views of the choir area with the two data logger positions. The beautiful wooden choir and the painting attributed to Romanelli are visible in the images.

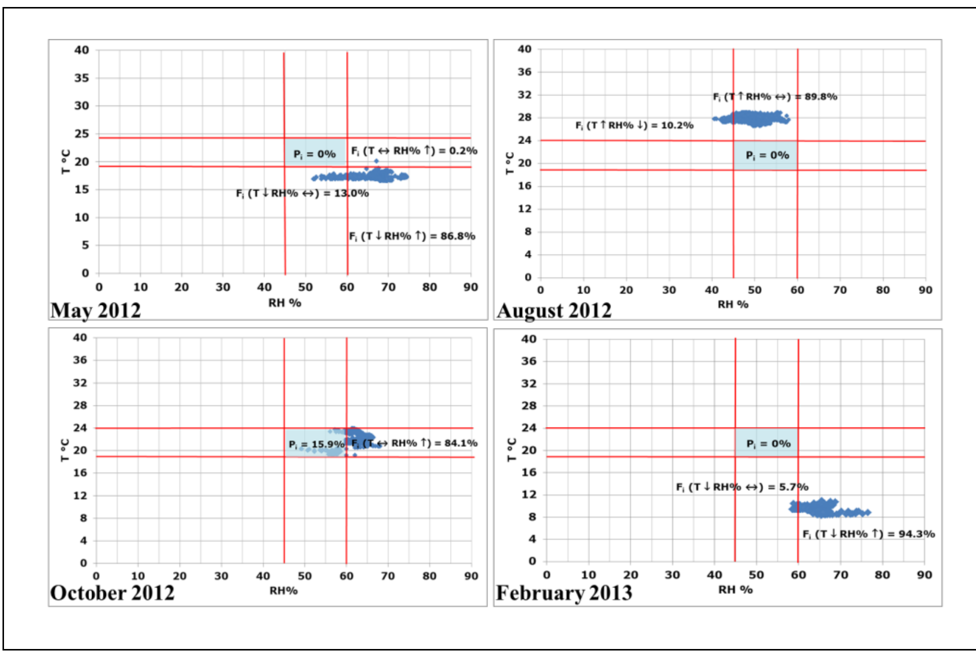

Figure 7. Tolerance matrices for the selected seasonal months in the choir area.

In this case, as for the room of Sacred Vestments and that of busts, there are trends in the relative humidity and temperature values following the external climatic conditions, as there are no active sources of environmental conditioning. Therefore, the trends of T and RH% follow those observed for the other two monitored environments in the museum.

In the case of the choir tribune, it should be emphasized that the relative humidity and temperature values are more stable and on a daily basis there are never so marked oscillations as shown in the museum rooms. The maximum daily RH% variations were recorded in August 2012 (Figure 7).

4. Conclusions

The results of the microclimatic monitoring in two rooms of the Museo del Colle del Duomo and in the choir area have shown that the recorded values are, in most cases, outside the areas defined by UNI10829 and that generally follow external weather trends typical of the Tuscia region. The most worrying figure is that related to the variation of the thermo-hygrometric parameters, above all on a daily basis with variations in relative humidity of over 20%. These strong excursions lead to the hypothesis that the works preserved within the study areas undergo considerable stress which, added over time, cause the degradation of the artefacts.

The data obtained from thermo-hygrometric monitoring must constitute a starting point for undertaking a reflection on any systems to be adopted to prevent the deterioration of the artefacts within the Museum's environments. The wish therefore is that the responsible of the Museum of Colle del Duomo could invest resources to protect and transmit to the future the cultural heritage preserved inside the expositive rooms.

Acknowledgment

This work was made possible thank to the Society Archeoares that runs the Museum of Colle del Duomo of Viterbo, and that gave us a great support in the organization of the microclimate monitoring.

The authors would like to thank the restorer Barbara De Dominicis for her collaboration to the thesis of Monica Pace and for having supported our work in the Sacred Vestments room.

This work was partially supported by the individual financial support to the basic research activities (FABR 2017 by Law 232/2016 to A. Lo Monaco and C. Pelosi).

It was partially supported by the Italian Ministry for education, University and Research (MIUR), Law 232/2016, 'Italian University Departments of excellence' UNITUS-DAFNE WP4.

References

[1] N. Stolow, *Conservation standards for works of art in transit and on exhibition*, UNESCO, Paris, 1979.
[2] G. De Guichen, *Climate in Museums Measurement*, ICCROM, Roma, 1984.
[3] A. Bernardi, *Conservare opere d'arte. Il microclima negli ambienti museali*, Il Prato, Padova, 2003.

[4] D. Camuffo, V. Fassina and J. Havermans (eds.), *Basic Environmental Mechanisms. Affecting Cultural Heritage*, Nardini Editore, Firenze, 2010.

[5] A. Luciani and D. Del Curto, *Monitorare il microclima negli edifici storici. Una pratica preventiva come strumento di conoscenza*, Atti del Convegno di Studi: Pensare la prevenzione, G. Biscontin & G. Driussi (eds.), Arcadia Ricerche, Venezia, 2010, 203-212.

[6] R. Cosenza and C. Pelosi, *La prevenzione nell'arte contemporanea. Ferro bifrontale arancione e plastico in ferro di Pietro Consagra*, Atti del Convegno di Studi: Pensare la prevenzione, G. Biscontin & G. Driussi (eds.), Arcadia Ricerche, Venezia, 2010, 301-309.

[7] ***, *UNI 10829, Works of art of historical importance - Ambient conditions or the conservation - Measurement and analysis*, UNI. Ente Italiano di Normazione, Milano, 1999, 1-24.

[8] ***, *EN 15757, Conservation of Cultural Property - Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials*, CEN. European Committee for Standardization, Brussels, 2010, 1-18.

[9] ***, *EN 15758, Conservation of Cultural Property - Procedures and instruments for measuring temperatures of air and the surfaces of objects*, CEN. European Committee for Standardization, Brussels, 2010, 1-18.

[10] ***, *EN 16141, Conservation of cultural heritage - Guidelines for management of environmental conditions - Open storage facilities: definitions and characteristics of collection centres dedicated to preservation and management of cultural heritage*, CEN. European Committee for Standardization, Brussels, 2013, 1-16.

[11] ***, *EN 15759-1, Conservation of cultural property - Indoor climate - Part 1: Guidelines for heating churches, chapels and other places of worship*, CEN. European Committee for Standardization, Brussels, 2011, 1-26.

[12] ***, *EN 16242, Conservation of cultural heritage - Procedures and instruments for measuring humidity in air and moisture exchanges between air and cultural property*, CEN. European Committee for Standardization, Brussels, 2012, 1-16.

[13] ***, *CEN/TS 16163, Conservation of Cultural Heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions*, CEN. European Committee for Standardization, Brussels, 2014, 1-36.

[14] ***, *EN 15759-2, Conservation of cultural heritage - Indoor climate - Part 2: Ventilation management for the protection of cultural heritage buildings and collections*, CEN. European Committee for Standardization, Brussels, 2018, 1-26.

[15] C. Pelosi, *Il controllo del microclima negli ambienti confinati. Con quali strumenti?*, in *In viaggio con le muse. Spazi e modelli del museo*, M.C. Mazzi (ed.), Edifir, Firenze, 2005, 309-310.

[16] A. Lo Monaco, M. Marabelli, C. Pelosi and M. Salvo, Chem. Cent. J., **6** (2012) 47.

[17] D. Gallo, P. Zander and C. Pelosi, Eur. J. Sci. Theol., **14(2)** (2018) 131-140.

[18] G. Agresti, G. Genco, C. Giagnacovo, C. Pelosi, A. Lo Monaco and R. Castorina, Acta Horticulturae, **866** (2010) 51-57.

[19] L. Lanteri, C. Pelosi and A. Lo Monaco, *Microclimate monitoring in the Museum of Colle del Duomo in Viterbo (Italy)*, Proc. of the 11th European Symposium on Religious Art, Restoration & Conservation, M.L. Vázquez de Ágredos-Pascual, I. Rusu, C. Pelosi, L. Lanteri, A. Lo Monaco & N. Apostolescu (eds.), Lexis Compagnia Editoriale in Torino srl , Torino, 2019, 108-112.

[20] S.P. Corgnati and M. Filippi, J. Cult. Herit., **11(3)** (2010) 345-349.