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# ASSESSMENT OF THE HYGROTHERMAL AIR CONDITIONS OF THE SCIENCE MUSEUM OF THE UNIVERSITY OF COIMBRA

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**ABSTRACT**

This paper presents the preliminary results of the study of the hygrothermal air conditions of the Science Museum of the University of Coimbra (UC), a XVI-XVIII century building. It is located in the historic centre of the UC, officially declared as a World Heritage in 2013 by UNESCO. Since then, the museum has been receiving an increasing number of visitors.

No previous studies on the environmental conditions of this museum were performed before. In face of this, the Rectorate of the University, who is concerned about the heritage preservation, started a research project focused on the thorough characterization of the hygrothermal air conditions within several museum rooms and on the assessment of risk situations, for both the heritage and human health issues.

Within this paper, some early results of more than one-year monitoring of the hygrothermal air conditions of two exhibition rooms of the Museum are presented and discussed.

Keywords: Microclimate / Conservation / Hygrothermal analysis / Heritage building

## 1 INTRODUCTION

In 2013, the buildings of 'University of Coimbra – Alta and Sofia' were declared a World Heritage Site by UNESCO (UNESCO 2013), turning Coimbra into part of an important tourist circuit in Portugal. The Science Museum of the University of Coimbra [*Museu da Ciência da Universidade de Coimbra* (MCUC)], a XVI-XVIII century building is located in 'Alta' and it is part of this tangible heritage. It allocates part of the scientific collections of the University, some of the oldest and most important of the country. Many of these objects date back from the Pombaline Reform of the University, which took place in the last quarter of the 18th century establishing the basis for modern teaching and scientific research in Portugal' (MUSEU DA CIÊNCIA 2017).

A review on indoor air quality is museums is presented in (Zorpas & Skouroupatis 2016). More recently, attention has been paid to sustainable retrofitting of cultural heritage buildings (Hernández 2014), (Zeno et al. 2014), (Troi & Sebastian 2014). In particular, emphasis has been given to the indoor environmental conditions in museum spaces and to the energy impact of 'ideal' conservation microclimates (Radon et al. 2013), (Ferdyn-Grygierek & Baranowski 2015), (Kramer et al. 2016), (Mueller 2013), (Hartman et al. 2013). A final version of the EN 16883:2015 draft is forthcoming (Conservation of cultural heritage — Guidelines for improving the energy performance

of historic buildings) (DIN EN 16883:2015-07 - Draft 2015).

Though energy conservation is presently a very important issue, in cases such as the MCUC, due to the absence of any heating, ventilation and air conditioning (HVAC) system, the main current concern is the general environmental condition and possible corresponding risks of damage of the collections. Moreover, this historic building has undergone different construction phases, and the envelope has different properties according to these construction periods.

Considering that the indoor conditions have a significant role in the protection of the tangible heritage of the MCUC (both the building and the exhibited material), promoting monitoring campaigns of the hygrothermal air conditions is fundamental to ascertain any risk conditions. Based on this concern, the MCUC personnel along with the Rectorate of the University has been carrying monitoring campaigns of these conditions in order to (i) assess the current hygrothermal air conditions of the MCUC, (ii) investigate the possible related risks to the tangible heritage, and (iii) determine actions and mitigating passive solutions.

Within the current paper, more than one-year monitoring of the indoor air temperature (T, ºC) and relative humidity (RH, %) of two exhibition rooms of the Museum are presented and discussed in the light of international guidelines.

## 2 METHODS

The Science Museum of the University of Coimbra (MCUC) was the first Portuguese university museum, and it is located at the ancient Jesus College, in the north-eastern area of the historic centre of the University of Coimbra (UC), as shown in Fig. 1. Currently it holds several collections, such as Physics, Astronomy, Chemistry and Natural History (MUSEU DA CIÊNCIA 2017). The scientific instruments of the eighteenth century belonging to the Physics Cabinet, as well as the ethnographic objects collected by Alexandre Rodrigues Ferreira in Brazil (between 1783 and 1792) are well known worldwide for their importance and rarity. The museum has also a very important collection (Natural History) of the former Portuguese Colonies in Africa.

In the spaces considered for this study the collections are very diverse. We can find skeletons, embalmed animals, insects, shells, minerals and rocks, fossils, books, watercolors, ceramics, ethnographic objects, among others. These objects are composed of many materials like leather, feathers, bone, ivory, wood, paper, several metals, glass, stone, etc.; some of which containing more than one type of material.

The original building (1541) housed the Society of Jesus and was reconstructed between 1773-1775, during the so-called Pombaline intervention, being adapted in order (i) to create ample rooms and with furniture suitable for storage and exhibition of the Natural History collections, and (ii) to became a university building, housing equipment for the experimental teaching of science. One great richness of this collection is the peculiarity of being preserved in the original spaces and in the cabinets that were built for the purpose (Isabel Carreira et al 2000).

The Museum is not provided with any air conditioned system. It is daily open, closing only on Mondays and other 5 holidays during the year. Between March 1$^{st}$ and September 30$^{th}$ it is open 7 days/week. The analysed exhibition rooms (1 & 2), located in the first floor of the building, are integrated in a carriage-type Gallery (Fig. 2a).

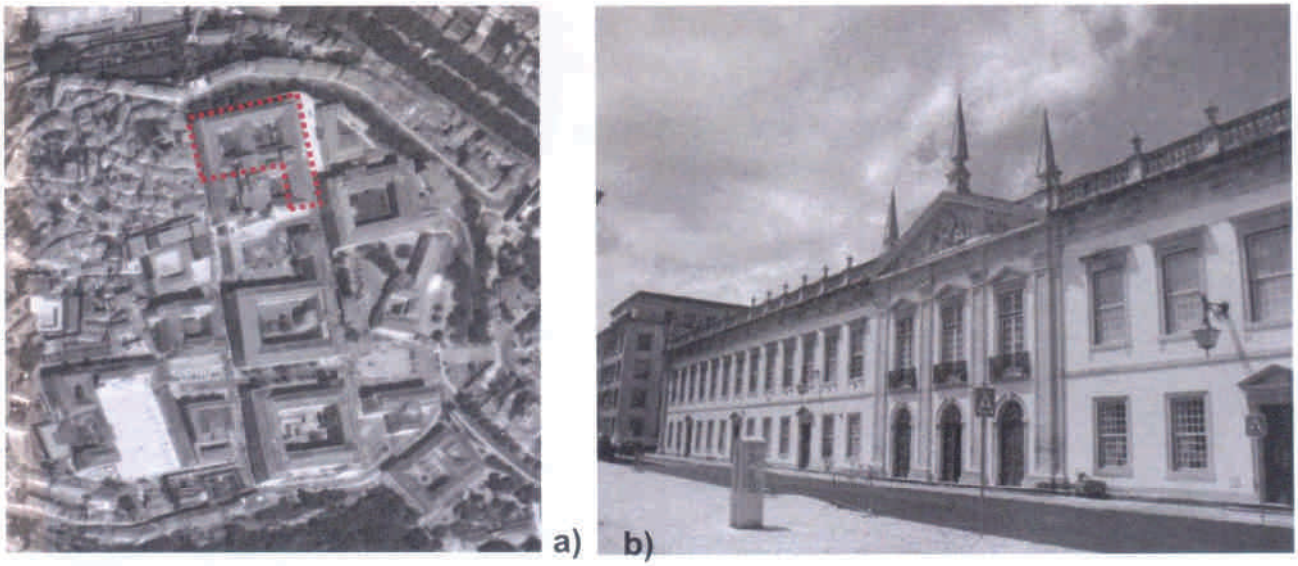

**Figure 1: *a)* Location of the Science Museum of the University of Coimbra (MCUC), [ArcGis (2017)]; *b)* external view of the Museum East façade**

## 2.1 THE MONITORING CAMPAIGNS

Indoor air temperature (Ta, ºC) and relative humidity (RH, %) were monitored for over one year, during several monitoring campaigns, namely: (1) 07/07/2015 to 07/12/2015; (2) 07/12/2016 to 28/04/2016; (3) 26/07/2016 to 07/12/2016. The parameters were registered every 15 minutes during all the campaigns using Tinytag View 2 (TV-4501) data loggers. *'The TV-4501 has an unobtrusive grey case and monitors temperatures from -25 to +50°C and relative humidity from 0 to 100% using built-in sensors. The coated RH sensor offers good resistance to moisture and condensation.'* This unit *'has a display providing a visual readout'* (Tinytag n.d.).

### 2.1.1 Case studies description

Exhibition room nº1 (Fig. 2c), the Vandelli Hall – named after Domingos Vandelli (1730-1816), the first professor of Natural History and Chemistry at the UC – has samples of the oldest collections of the acquis. In this room the data logger was placed inside a relatively tight display case made of wood and glass, provided with LED lighting. Exhibition room nº2 (Fig. 2b) – the Portugal Hall – is dedicated to the fauna of the Iberian Peninsula. Herein, the data logger was placed above one of the display cases, about 3 meters high, in the centre of the room. The main data concerning the exhibition rooms' characteristics are presented in Table 1.

**Table 1: Room characteristics of case studies / Equipment (Nº and location)**

| | Floor surface ($m^2$) | Volume ($m^3$) | Window orientation | No. of windows | Equipment (No. & location) |
|---|---|---|---|---|---|
| Vandelli Hall | 118 | 888 | East | 4 | 01 \| inside a display case (± 0.80m from the floor) |
| Portugal Hall | 263 | 1645 | West | 6 | 01 \| above a display case (± 3.00 from the floor) |

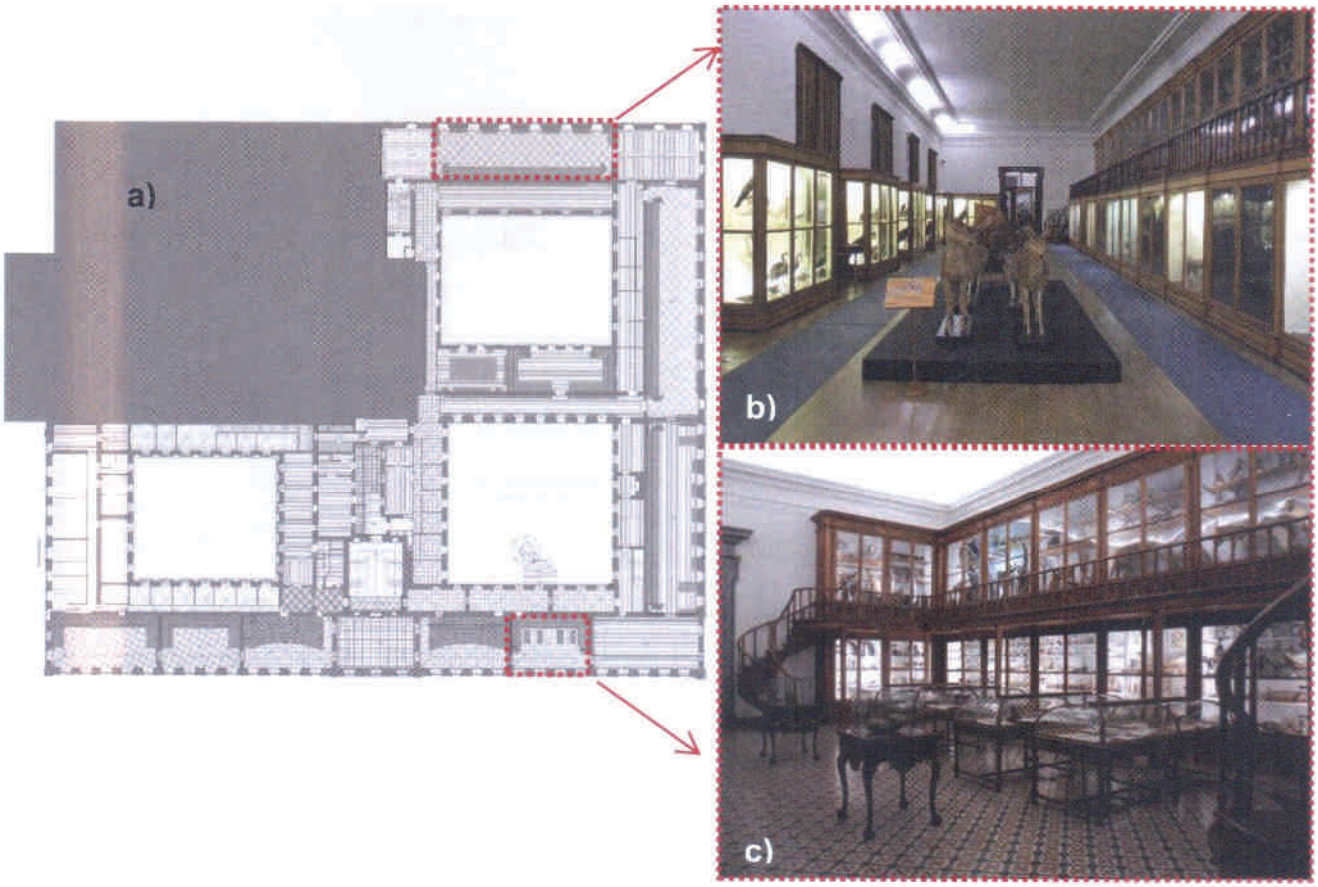


**Figure 2: *a)* Plan of the first floor of MCUC; *b)* Portugal Hall; *c)* Vandelli Hall**

## 3 RESULTS AND DISCUSSION

The following results were analysed according to the ASHRAE guidelines for indoor conditions of museum collections (ASHRAE 2015). As suggested by (Huijbregts et al. 2012), the potential damage risk of the collection was assessed framing the MCUC into Class B – appropriate for most historic buildings and presenting *'a very small risk for most artifacts'*. '*Classes B and C (...) are the best that can be done in most historic buildings'*, (ASHRAE 2015). Broadly, the following ranges are specified: 15 °C ≤ T ≤ 25 °C and 40 % ≤ RH ≤ 60 %.

### 3.1 HYGROTHERMAL DATA

The hygrothermal data measured in the investigated rooms of the museum are shown in Table 2, Figures 3 and 4, for the entire monitoring period. The outdoor climate data were obtained from one of the nearest meteorological stations, installed in the Laboratory of Industrial Aerodynamics (LIA)[†] in Coimbra, less than 3 km away from the MCUC.

Table 2 presents a summary of the recorded data. As observed, during the winter period (December 2015 – March/April 2016), the average T values were below 15°C, reaching a minimum below 10°C in the Portugal Hall (PH). In contrast, during the last monitoring period, the highest T values were in both rooms much above the reference

[†] https://www.wunderground.com/personal-weather-station/dashboard?ID=ICOIMBRA14#history.

upper limits – both in terms of conservation of the exhibited objects and the visitors thermal comfort (ISO7730 2005), (CEN 2007).

**Table 2: Summary table of all registered values on the exhibition rooms**

| Space | Period | Parameter | Maximum value | Average value (average + St dev) | Minimum value |
|---|---|---|---|---|---|
| Vandelli Hall (VH) | 7 Jul – 7 Dec 2015 | T (ºC) | **26.4** | 21.7 ± 3.5 | **13.2** |
| | | RH (%) | **71.3** | 58.1 ± 2.4 | 53.8 |
| | **7 Dec - 8 Mar 2016** | T (ºC) | 18.1 | **13.3 ± 1.0** | **11.1** |
| | | RH (%) | **77.6** | **67.5 ± 2.4** | 52.0 |
| | 26 Jul – 7 Dec 2016 | T (ºC) | **29.3** | 22.6 ± 4.2 | **14.1** |
| | | RH (%) | 65.2 | 53.7 ± 2.3 | 50.1 |
| Portugal Hall (PH) | 7 Jul – 7 Dec 2015 | T (ºC) | **29.5** | 21.3 ± 3.7 | **11.2** |
| | | RH (%) | **82.0** | **63.1** ± 6.5 | 40.6 |
| | **7 Dec - 28 Apr 2016** | T (ºC) | 22.8 | **14.2 ± 2.1** | **9.2** |
| | | RH (%) | **91.9** | **72.8** ± 6.9 | 50.3 |
| | 26 Jul – 7 Dec 2016 | T (ºC) | **32.8** | 21.4 ± 4.3 | **11.4** |
| | | RH (%) | **85.1** | 61.8 ± 9.8 | **30.1** |

In addition to the reference range earlier specified, the ASHRAE guidelines and other international recommendations define acceptable 'short-term fluctuations'. Herein interpreted as daily fluctuations, i.e. the differences between the minimum and maximum of the T (ºC) and RH (%) data, namely 5 ºC (ΔT) and 10 % (ΔRH). Data registered in the exhibition rooms were processed and daily fluctuations were calculated every 24 hours during the whole period of the monitoring campaign.

From the analysis of all measured data, it can be stated that both exhibition rooms respected this sub-criterion almost entirely: $\Delta T \leq 5$ºC/day and $\Delta RH \leq 10$ %/day. In fact, in the Vandelli's Hall (VH) these were fulfilled (max $\Delta T_{VH}$ = 4.1 ºC and max $\Delta RH_{PH}$ = 6.1 %), except on the 7th December 2015, when $\Delta RH_{PH}$ = 19.4 %. Data were collected from the data loggers on this day; authors believe the exceptionally high ΔRH value was due to handling of the equipments.

Portugal Hall (PH) performed slightly worse, as confirmed in Figure 3: $\Delta T \leq 5$ºC/day was achieved in 97% of the monitored days and $\Delta RH \leq 10$ %/day during 72% of the time (max $\Delta T_{PH}$ = 9.9 ºC and max $\Delta RH_{PH}$ = 41.4 %). The extreme values $\Delta T_{PH}$ = 15.4 ºC and $\Delta RH_{PH}$ = 48 % were registered on August 9th 2016, a day of very significant outdoor amplitudes (outdoor ΔT = 15.4 ºC and ΔRH = 48 %).

Moreover, when looking at the average of all the values: $T_{VH}$ = 20.0 ± 5.1 ºC, $RH_{VH}$ = 58.8 ± 5.8 % and $T_{PH}$ = 18.9 ± 4.8 ºC, $RH_{PH}$ = 65.9 ± 9.2 %, though RH average is distanced from the recommended value (50 %), these do not seem to be totally inadequate.

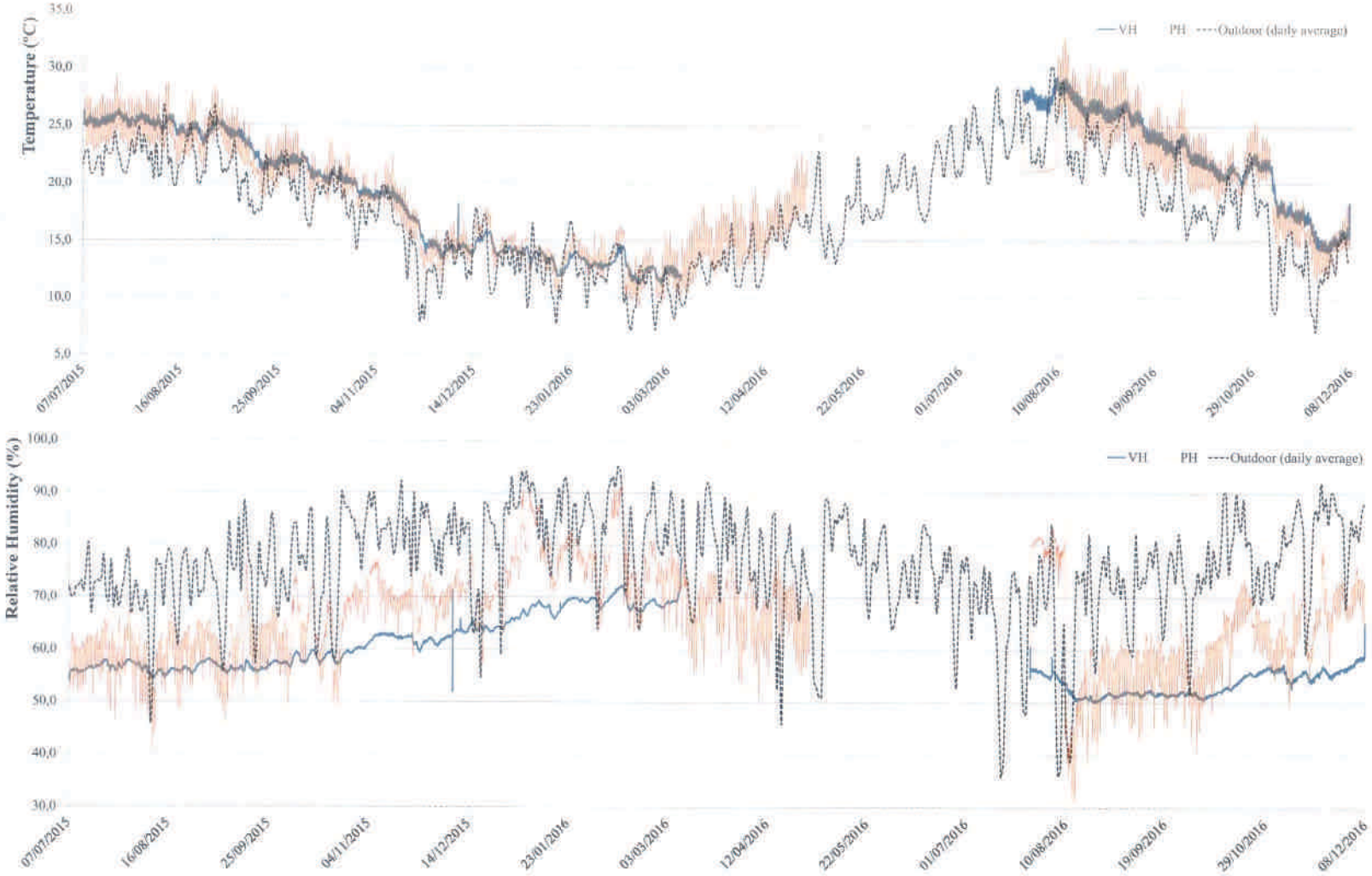


**Figure 3: Time variations of (a) temperature and (b) relative humidity during the entire monitoring period**

From the analysis of Fig. 3, other observations were drawn: (i) the Portugal Hall (PH) appears to be much more dependent on the outdoor conditions than the Vandelli Hall (VH), unveiling much stronger fluctuations of the monitored parameters; (ii) the registered relative humidity (RH) values were generically high (> 50%); (iii) RH values in the VH were generically lower than those registered in the PH; (iv) temperature (T) values were relatively satisfactory in both exhibition rooms during the 1st monitoring campaign, fitting the recommended interval (15-25ºC), unlike in the 2nd and 3rd campaigns when the T values were, respectively, too low (<15ºC) or too high (>25ºC); (v) even when temperatures were above 25ºC, RH values were broadly above 50%.

Complementing all the previous information, Fig. 4 allows 'a more visual' comparison between the exhibition rooms and between seasons/monitoring campaigns. Ideally, data recorded in both exhibition rooms should fit the intervals 15 – 25 °C (T) and 40 – 60 % (RH). As observed, either through the global data (on the right) or the data segmented by monitoring campaigns (on the left), both exhibition rooms present unsatisfying conditions regarding the conservation of the displayed heritage.

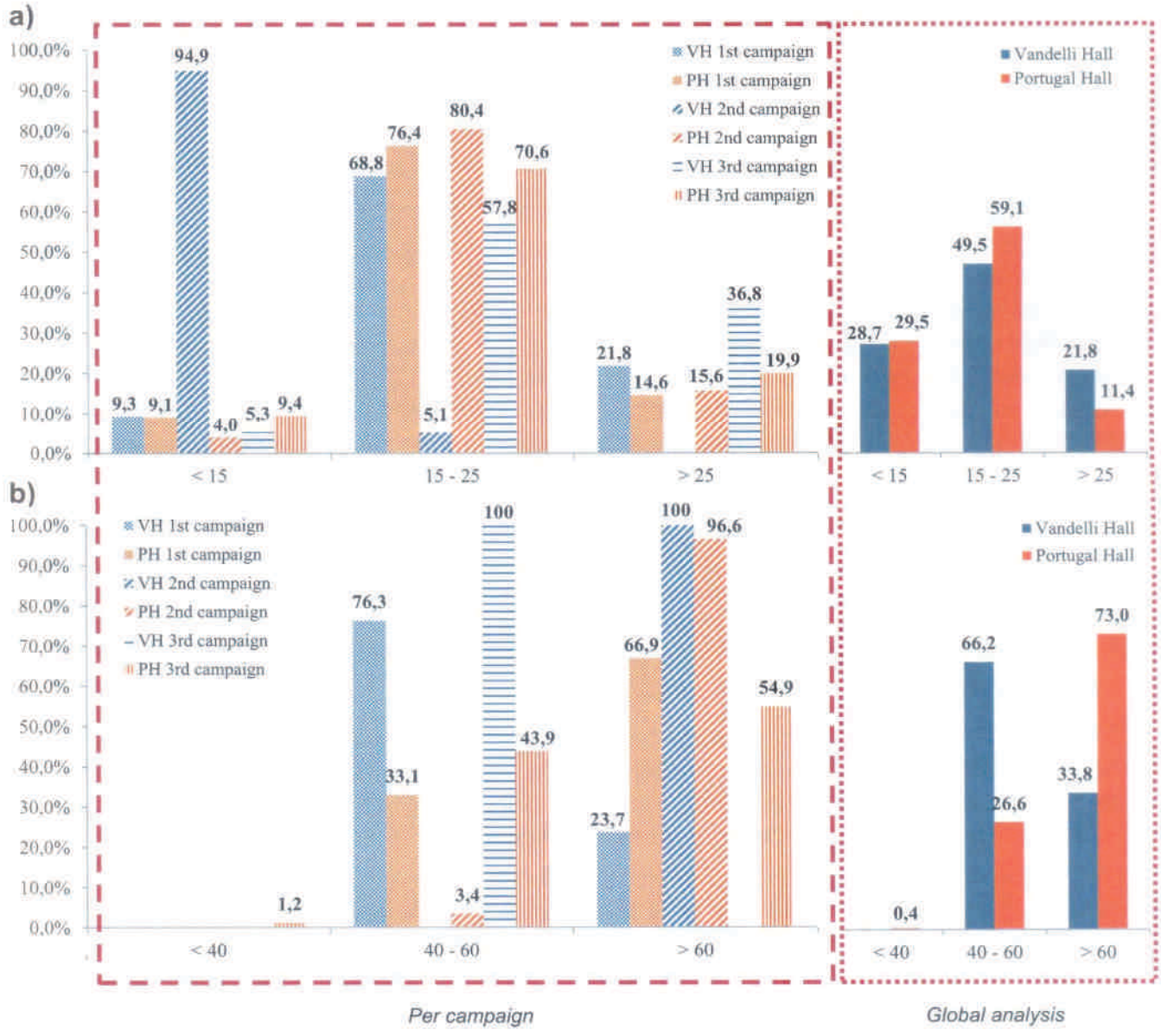


**Figure 4: Distribution (%) of the monitored data according to the ASHRAE recommended intervals for conservation categorie B: (a) Temperature and (b) Relative Humidity. (VH - Vandelli Hall; PH - Portugal Hall)**

In terms of temperature – Fig. 4.a), the Vandelli Hall (VH) with an east-oriented façade, performed the worst during the 2nd monitoring campaign (winter/early spring period), with too low T values. It is worth mentioning that this monitoring campaign was longer in PH, for which the spring values might help justifying the significant difference between data in both rooms. Generally, both rooms performed poorly: less than 60% of all data fitted the recommended range and, in the case of the VH, this value is actually below 50%.

Concerning the relative humidity, the VH performed better (Fig. 4.b), right side). The values registered in the Portugal Hall (PH) unveiled worrying marks – over 70% of the values were above 60% RH. It should be remarked that a peak value of RH = 91.9 % was registered in the 2nd monitoring period (Table 2). It is remarkable that during this campaign, T < 15ºC more than 94% of the time, and still during this entire period, RH values were higher than 60%.

## 4 CONCLUSIONS

The existence of different materials in the same space makes it difficult to establish the ideal environment conditions (either temperature, relative humidity or illuminance levels). Low HR conditions may be suitable for metals but not for woods, for example. Appropriate levels should be adopted for the most sensitive component. Within the present study the hygrothermal air conditions were assessed according to ASHRAE guidelines for indoor conditions of museum collections (ASHRAE 2015).

The recorded data showed that the indoor hygrothermal air conditions of the exhibitions rooms in this Museum were strongly influenced by the outdoor environmental conditions. Moreover, either in terms of conservation and/or thermal comfort of the occupants, the registered values of temperature and relative humidity were many times out of the reference ranges (ASHRAE 2015). Both rooms performed worse in terms of relative humidity rather than temperature, though it is worse mentioning that in one of the exhibition rooms, air temperature surpassed 30 ºC (ASHRAE 2015). The monitored peak relative humidity values clearly suggest the need to control the environment and to protect the exhibited collections.

It was observed that indoor hygrothermal air conditions achieved more extreme values on Portugal Hall than in Vandelli Hall (VH). Since these results can be due to the location of the sensor in VH – inside the display case, therefore further investigation on this issue is suggested. Notwithstanding the sensors location, in Portugal Hall the RH peak values were alarming and need attention.

Future research will also include other exhibition rooms in the museum and data analysis according other norms, such as EN 15757, e.g. analyses of seasonal cycles and the calculation of the central moving average (MA). Including a more cautions analysis, framing data to the 'real season' effects.

Lastly, the suggested environment protection should be explored through passive building measures, namely through the investigation of the integrity of the building envelope, e.g. wall and window inspection, window curtain protection, etc.

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