CHARACTERISATON OF THE INDOOR MICROCLIMATE WITHIN THE HISTORIC ARCHIVES OF A CULTURAL INSTITUTION IN THE MEGACITY OF SÃO PAULO (BRAZIL) IN THE PERSPECTIVE OF PREVENTIVE CONSERVATION

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Abstract : One of the reasons that explains the importance of developing research in the area of indoor microclimate is the concern with the conservation of cultural artefacts. This work presents and discusses the indoor microclimate of the archives of a cultural organisation located in the megacity of São Paulo, Brazil, as well as its links with the local outdoor climate. The results show that there are significant differences between the two monitored areas. The archive where a basic air-conditioning system is installed exhibits effective control on the temperature but with negative impacts on relative humidity, mainly in terms of short-term stability. The archive with no active control on T and RH displays a better performance with potentials for preventive conservation strategies aligned with the current trends toward sustainability.

Keywords: Indoor microclimate; Cultural heritage; Subtropical climate; Brazil.

Résumé : L'une des raisons de l'importance de développer la recherche dans le domaine du microclimat intérieur est le souci de la conservation des œuvres culturelles. Ce travail présente et discute le microclimat intérieur des archives d'un organisme culturel situé dans la mégalopole de São Paulo, au Brésil, ainsi que ses liens avec le climat local. Les résultats montrent qu'il existe des différences significatives entre les deux zones surveillées. L'archive où un simple système de climatisation est installé a un contrôle efficace de la température, mais avec des impacts négatifs sur l'humidité relative, principalement en termes de stabilité à court terme. L'archive sans contrôle actif sur T et RH montre une meilleure performance avec des potentiels pour des stratégies de préservation préventive conformes aux standards de durabilité.

Mots clés : Microclimat intérieur ; Patrimoine culturel ; Climat subtropical ; Brésil.

Introduction

The indoor microclimate has been the object of investigation for a long time. There are several reasons that explain the importance of developing research in this area, among which the predominant one is the promotion of the well-being of people, who spend a great deal of their time indoors (Nedel et al., 2015). However, the concern with environmental conditions for the conservation of cultural artefacts is also a particularly relevant question in museums, archives and, in general, all the institutions that deal with this kind of matter. The materials from which the material heritage is made undergo, like any other substance, gradual aging, a process that can be accelerated under the effect of environmental factors that affect the rate of chemical, mechanical and biological transformations (Thomson, 1986).

The need to minimize this effect, which is inherent to the nature of cultural heritage, has been the subject of debate for a long time and a vast literature has developed on the role of atmospheric pollutants (Hatchfield, 2002), of airborne biological agents (Allsopp et al., 2004; Skora et al., 2015) and light (Schaeffer, 2001), as well as air temperature and relative humidity (Bernardi, 2008). In particular, as far as the indoor microclimate is concerned, it must be stressed that both the levels of T and RH and their fluctuations over the short or the medium (i.e. seasonal) term are relevant from the point of view of heritage conservation. In fact, if on the one side air temperature and water vapour content are often decisive in determining the rate of chemical reactions involved with degradation (as well as in predisposing the development of living pests, thus promoting biodeterioration), on the other oscillations in T and RH govern the mechanical changes associated with moisture intake/release by materials (Camuffo, 2014). This is the reason why conservators have to be aware of the actual microclimate that characterise the areas where collections are sheltered, its dynamics and the several factors involved in it: mainly, local climate, architectonical aspects and forms of use and management of the spaces. In countries subject to tropical or subtropical climates, the issue becomes even more sensitive inasmuch as indoor microclimatic dynamics are, as a rule, strongly influenced by outdoor factors (Maekawa et al., 2001; Cavicchioli et al., 2017; Andrade & Cavicchioli, 2021).

The whole matter is even more pertinent if one considers that institutions of this sort are generally located in large cities that are increasingly exposed to exacerbation phenomena like heat islands and the incoming effects of climate change (Cassar, 2009). Furthermore, the discussion about the response strategies to be designed and implemented by conservators nowadays inevitably must take into account the current trend towards sustainability (Andrade & Cavicchioli, 2021). This work presents and discusses the indoor microclimate of the repository area of the headquarters of a cultural organization located in the megacity of São Paulo, Brazil, as well as its links with the local outdoor climate.

Materials and methods

The archives are located on the top floor of a four-storey building situated in the city centre. They consist of two rooms, of which one (archive A, 38 m^2) contains the historic collection whether the other (archive B, 24 m^2) stores administrative documents (Figure 1). Both rooms face south-west, are provided with windows (which are 6.3-m and 1.4-m long, respectively, and are obscured by shutters) and have a ceiling height of 2.9 m. In both archives, the ceiling is made of movable gypsum panels which create, underneath the zinc roof, of a void volume approximately 1.5-m high at the roof ridge.

Archive A is provided with an air-conditioning system set at 24.5 °C (with no humidity management), whereas the microclimate in archive B is not controlled by any mechanical device.

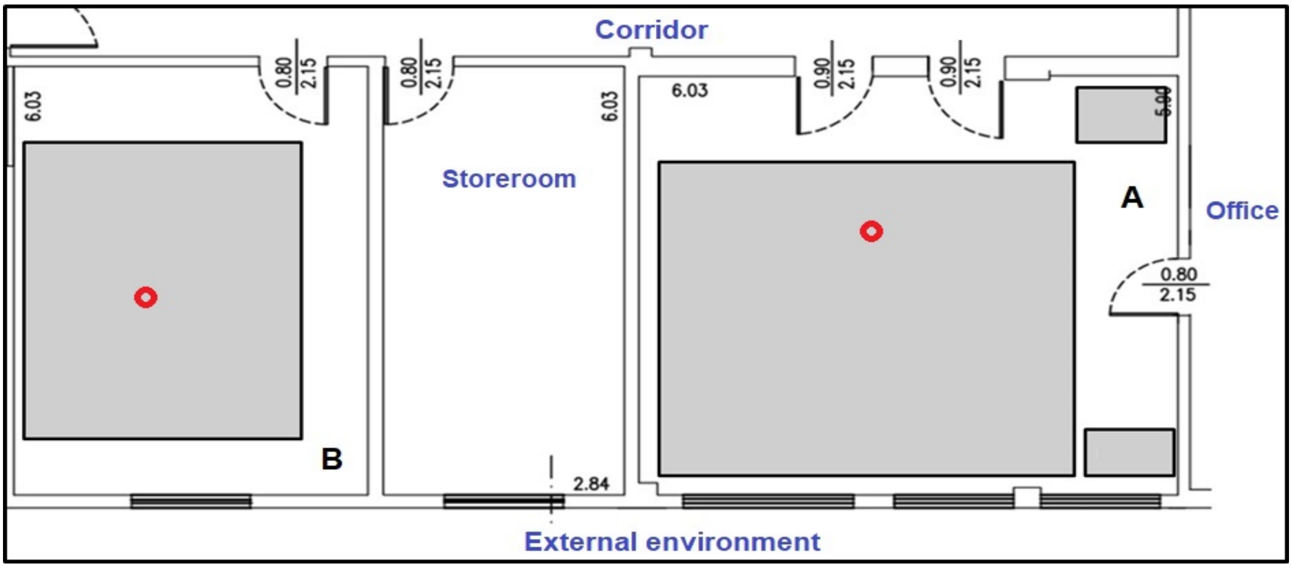

Figure 1. Plant of the archives of the institution that were investigated. A: historical archive, B: administration documents. The red circles indicate the position were the dataloggers were installed inside the sliding files.

The rooms are almost entirely occupied by sliding files where the actual collections are accommodated. Indoor microclimatic data (temperature and relative humidity) were collected at an hourly rate by means of dataloggers (Onset, USA) installed inside the files. The choice was made in order to get a real perception of the actual microclimate to which the artefacts are exposed. The outdoor data were measured by the same type of dataloggers installed in an external station located by the authors at a nearby site (with the exception of the pressure measurements that were retrieved from the databank of the national meteorological organization of Brazil - INMET). The water vapour mixing ratio values were calculated, as in Camuffo (2014) and Cavicchioli et al. (2017), using the empirical Magnus' formula.

It must be observed that the megacity of São Paulo has a humid subtropical climate (Cfa under the Köppen-Geiger climate classification, according to Dubreuil et al. (2015)), with an average temperature of 19.3 °C [1]. Two main seasons characterize the local climate: a rainy season (October to April, in summer the average temperature being 23 °C inside the city) and a dry one (May to September, in winter the average temperature being 17 °C).

Results and discussion

In this work, the discussion was restricted to the results of the hottest and most humid season (summer), more specifically to the two-month interval between 11/12/2015 and 11/2/2016. For these three months, rainfall and temperature were above the average for December and February and below for January. This is the time of the year when the riskiest conditions for collections take place, thus deserving special attention by conservators.

The graph showing the temperature and relative humidity profiles in archive B is displayed in Figure 2. As far as the temperature is concerned (Figure 2A), the influence of the outdoor fluctuation on the indoor microclimate is evident, although there is a clear buffering effect determined by the building shell. Owing to this, the average indoor daily ΔT is just 1.7 °C (with a maximum of 3.4 °C) versus an outdoor average value of 8.7 °C (with a maximum of 13.6 °C), i.e. more than five times smaller inside the archive than in the external atmosphere. The buffering effect of the architectural structure is more efficient in reducing the cooling process at night than in mitigating the heating effect in the day. As a result, on average, the difference between T_{max} outdoors and T_{max} indoor (ΔT_{max} = 2.5 °C) is smaller than the differences between T_{min} (ΔT_{min} = 4.5 °C), a fact that explain why in the time interval that was monitored the average indoor temperature (26.4 °C) is higher than the average outdoor level of this parameter (24.5 °C). Such occurrence is connected with the fact that the heating rate is higher than the cooling rate in the indoor environment, a fact exemplified in Figure 3A for a sequence of four days with stable sunny weather. In that opportunity, the average morning heating rate amounted to 0.24 °C/h which was twice the average evening cooling rate (0.12 °C/h), thus leading to higher temperatures by the time a new heating cycle starts in the next early morning. The fact that the T measurements obtained in the same building during the same time interval at a lower level (third floor) resulted in a significantly reduced heating rate (0.10 °C/h) seems to indicate that the proximity of archive B to the zinc roof is an important factor in determining its thermal regime.

From the point of view of conservation goals, the good temperature stability is important inasmuch as it contribute to the mechanical stability of the artefacts, especially because it helps securing fluctuations in RH. On the other hand, the fact that the conservation space accumulates, in average terms, thermal energy might not be envisaged as a positive feature since it may enhance chemical degradation as well as biodeterioration. However, maintaining of a warmer indoor climate in the archives during the raining season could be a useful strategy to reduce too high levels of RH without the need of mechanical removal of excess of water vapour.

The RH profile of archive B is shown in Figure 2B. It can be noticed that RH was always maintained below the level of 70% which is considered the threshold above which biodeterioration promoted by microorganisms is likely to be trigged (Thomson, 1986). This happens despite the fact that outdoor RH_{max} systematically reaches values closer to 100% (as a rule, before dawn when temperature reaches the minimum value), also on account of the frequent and intense raining events.

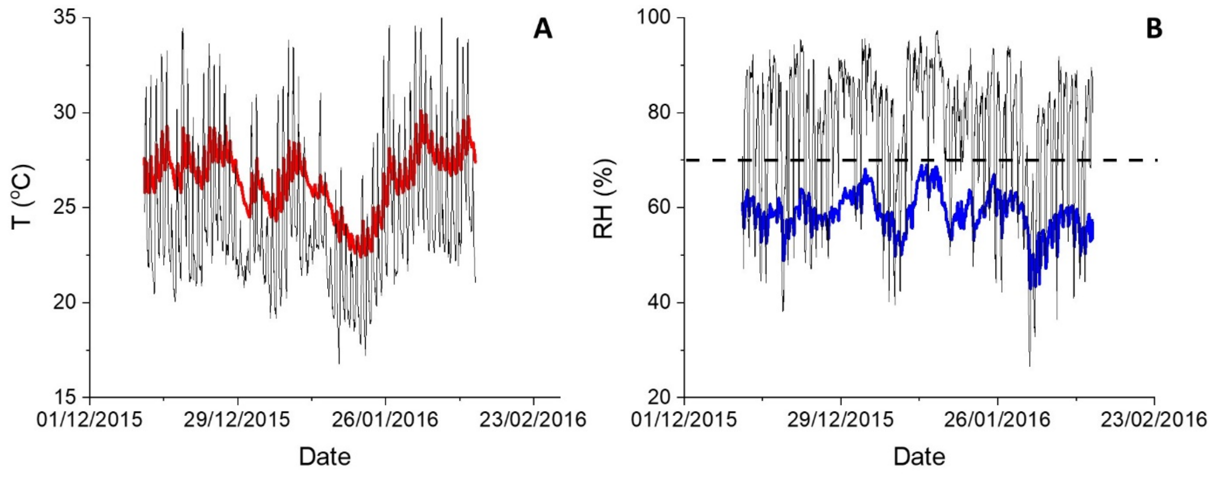

Figure 2. Plot of indoor (red) and outdoor (black) hourly temperature **(A)** and of indoor (blue) and outdoor (black) hourly relative humidity **(B)** data in archive B from 11/12/2015 to 11/02/2016. The dotted line indicates the safety threshold for the development of microorganisms.

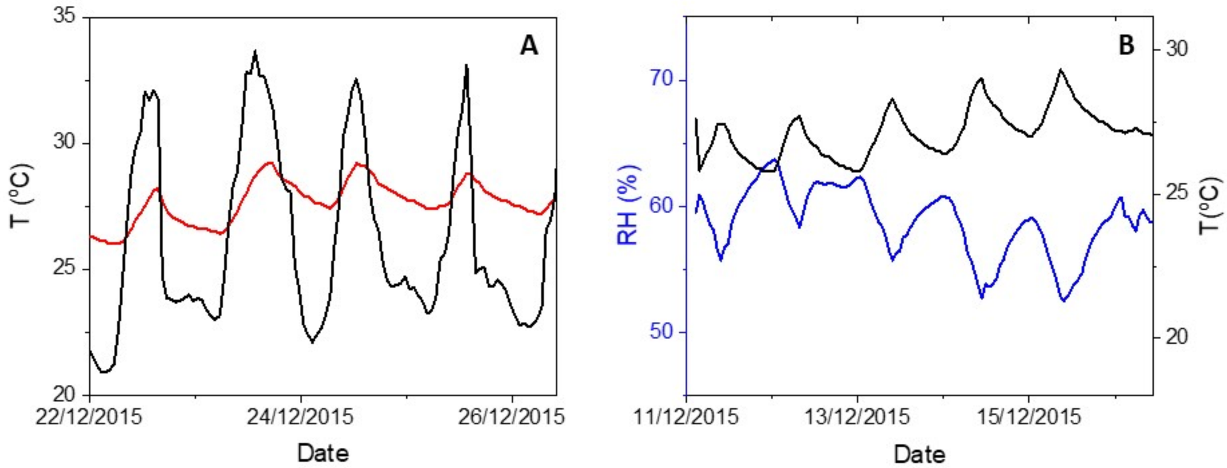

Figure 3. Plot of indoor (red) and outdoor (black) temperature **(A)** and of indoor temperature (black) and indoor RH (blue) **(B)** data in archive B in a sequence of four stable sunny weather days (22 to 26/12/2015).

Even though the absolute amount of water vapour (water mixing ratio, expressed in g/kg) is, indeed, lower inside the archive (Figure 4B), this kind of performance is mainly associated with the higher indoor temperature levels mentioned above. In particular, as a rough estimate, it was calculated that if the temperature was restrained to a maximum level of 24.0 °C by some sort of temperature control system, RH would have overcome the biodeterioration threshold almost half of the time (all other factors held constant).

The close dependency of RH from T is exemplified in the graph of Figure 3B. In particular, it should be emphasized again that the intensity fluctuations in RH are overwhelmingly controlled by temperature and that the reduced daily variations in RH recorded in archive B are, to a large extent, the consequence of the limited changes in temperature. The average ΔRH recorded during the monitored time interval was 6 %, with a ΔRH_{max} of 15 %.

Finally, it is interesting to have a look at the microclimatic situation in archive A, since the conservation area is managed with the use of a mechanical air-conditioning system (Figure 4A).

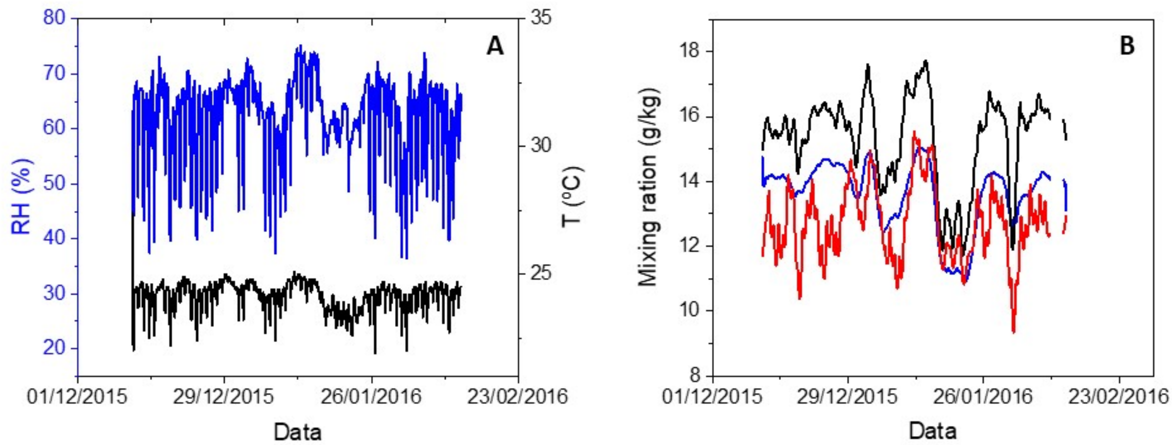

Figure 4. Plot of indoor relative humidity (blue) and temperature (black) data in archive A **(A)** and of water vapour mixing ratio in outdoor atmosphere (black) and in archive B (blue) and archive A (red) data **(B)** from 11/12/2015 to 11/02/2016. In graph (B), the curves were processed and smoothed using the adjacent averaging method.

It is quite evident that hindering the raise of air temperature results in mitigation of the overall thermal regime of the room, with an average level of 24.2 °C, more than 2 °C lower than archive B. However, some degree of temperature fluctuation is still in place owing to the fact that the thermostatic cooling device does not intervene in the night temperature drop, thus leading to an average ΔT of 1.2 °C (therefore, only 0.5 °C smaller than archive B). More important, though, is to note the average level of RH (62 %, higher than archive B where RH_{med} = 59 %) as well as the intensity of RH fluctuations (18 % versus 6 % recorded in archive B), an effect that is certainly associated with the condensation inside the cooler and its drainage outside the building. That being the case, the stored collection in archive A is exposed, in summer, to a higher average RH and to intense RH daily fluctuation, despite the use of a dedicated management device and the lower absolute amount of water vapour in the indoor atmosphere, as shown in Figure 4B (red line).

Conclusion

In tropical and subtropical areas, it is generally assumed that the priority in heritage conservation areas is the control of the surrounding air temperature. Although this is certainly a very relevant issue, this sort of approach tends to overlook the role of relative humidity in the degradation of materials. This is especially relevant in regions that are typically humid and warm for the most part of the year, since in such case biodeterioration became an important risk factor. Furthermore, as it was shown by this work, efforts made to actively improve the thermic conditions in conservation areas can worsen their performance in terms of relative humidity. This is particularly true when there is a lack of awareness of the effective microclimatic characteristics of spaces, shortage of technical staff and/or insufficient financial resources to acquire more sophisticated climate control systems. On the other hand, an indoor microenvironment that adapts itself to the outdoor climate with passive buffer elements might sometimes exhibit a better overall behaviour.

It must be observed that in this kind of climate mild temperatures and RH values are attained in winter, a condition which the conservator might profit from in order to compensate the increased degradation rate experienced in summer, again in the perspective of naturally controlled indoor microenvironment, as shown in an earlier work (Andrade & Cavicchioli, 2021).

In summary, it seems that museums, archives and conservation institutions in general located in tropical and subtropical zones present interesting potentials for the control of indoor conservation microenvironments that, apart from following the principles of preventive conservation, can also be aligned with the current trends towards sustainability and a reduced climatic footprint. Aspects that can be exploited in that direction include the maximization of passive control measures associated with architectonic elements (sometimes, present in historical buildings that were traditionally designed for hotter climates), optimisation of forms of access by staff and other users and the development of intelligent non-continuous microclimate adjustment, such as those described in Gonçalves (2013) in which natural ventilation and computational simulations play a predominant role.

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