Reusing maintenance monitoring data on preventive conservation

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Abstract: The indoor climate of libraries and archives is determinant for the preservation of their collections, as temperature and relative humidity can trigger other damage factors. Standards and literature recommend to perform long term monitoring to understand the climatic history where the goods were kept, instead of follow rigid and arbitrary conditions. This trend is sustainable and environmentally friendly, but adds a new duty to the overloaded staff. We present two technical advices sustained in monitoring records produced to assess the HVAC equipment and reused to preservation purposes. The first is a library collection transferred from a historic building to a new building, and the second is a deposit room supplied with de-humidificators, where the analysis evidenced a very low humidity ratio. The main conclusion is that a synergetic use of monitoring data can improve the indoor climate of the collections and reduce the energy demand for preservation.

Keywords: preventive conservation, sustainability, indoor climate, environmental monitoring, cultural heritage

Reutilización de monitorización de mantenimiento para conservación preventiva

Resumen: El clima interior de bibliotecas y archivos es determinante para la preservación de sus colecciones, ya que la temperatura y la humedad relativa pueden desencadenar otros factores de daño. Las normas y la literatura recomiendan realizar un seguimiento a largo plazo para comprender el historial climático donde se mantuvieron los productos, en lugar de seguir condiciones rígidas y arbitrarias. Esta tendencia es sostenible y respetuosa con el medio ambiente, pero añade un nuevo deber al personal sobrecargado. Presentamos dos consejos técnicos sustentados en registros de seguimiento elaborados para evaluar los equipos HVAC y reutilizados con fines de conservación. El primero es un fondo de biblioteca trasladado de un edificio histórico a un edificio nuevo, y el segundo es una sala de depósito equipada con deshumidificadores, donde el análisis evidenció un índice de humedad muy bajo. La principal conclusión es que un uso sinérgico de los datos de monitoreo puede mejorar el clima interior de las colecciones y reducir la demanda de energía para la preservación.

Palabras clave: conservación preventiva, sostenibilidad, clima interior, vigilancia ambiental, patrimonio cultural

Reutilização de monitorização de manutenção sobre conservação preventiva

Resumo: O clima interior das bibliotecas e arquivos é determinante para a preservação das suas colecções, uma vez que a temperatura e a humidade relativa podem desencadear outros factores de dano. As normas e a literatura recomendam a monitorização a longo prazo para compreender a história climática onde se acondicionam os bens, em vez de seguir condições rígidas e arbitrárias. Esta tendência é sustentável e amiga do ambiente, mas acrescenta um novo dever ao pessoal sobrecarregado. Apresentamos dois conselhos técnicos sustentados em registos de monitorização produzidos para avaliar o equipamento HVAC e reutilizados para fins de preservação. O primeiro é uma colecção de biblioteca transferida de um edifício histórico para um novo edifício, e o segundo é uma sala de depósito com desumidificadores, onde a análise evidenciou uma humidade muito baixa. A principal conclusão é que uma utilização sinergética dos dados de monitorização pode melhorar o clima interior das colecções e reduzir a procura de energia destinada à conservação preventiva.

Palavras-chave: conservação preventiva, sustentabilidade, clima interior, monitorização ambiental, património cultural

Introducción

The preservation of collections housed in museums, archives and libraries is a challenge for conservators, registrars, engineers, librarians and designers, among other disciplines. In this sense, many institutions that preserve Cultural Heritage (CH) focus on improving the collection environment to the highest quality possible, while in turn need to reduce their operating and maintenance costs. This necessity is not exclusive to CH: countries in the European Union are encouraged to reduce carbon emissions as subscribers to global agreements. But it is not everything about energy efficiency and emissions: the preservation of valuable and irreplaceable collections is an intrinsically sustainable activity itself as we are caring historic goods for the enjoyment of future generations (Luciani and Del Curto 2018).

Preventive conservation is a discipline that acts on the context of the property to be preserved, it is concerned with creating adequate conditions in the direct environment of the elements so as to delay or prevent the natural aging that all materials suffer due to time effect (ICOMCC and ICOM-CC 2008). The main environmental factors affecting conservation are light, pollutants, temperature (T) and relative humidity (RH) (Daniel *et al.* 2000), but we are focusing on T and RH as it depends on those factors to trigger conditions of mechanical, chemical and biological risk like brittlement, foxing, moulds, pests, discoloration, yellowing .

State-of-the-art HVAC systems are capable enough to provide accurate T and RH conditions with high efficiency, with different costs depending on the outdoor climate and the performance of the envelope. But the set point configuration of the HVAC is seldom part of a conscious debate. Scientific evidence shows that, in addition to being sophisticated and expensive, maintaining stringent targets does not guarantee conservation, and can be unsustainable for the management of museums (Silva *et al.* 2016). Yet, they are still frequently used. The paradigm shift arises in 2010, admitting new safety parameters that allow mobile climatic intervals according to the proofed fluctuation that, as well as improving the conservation of property, are more economical in terms of energy since they contemplate previous climatic cycles (Padfield et al. 2014 ; Henry 2007 ; CEN 2011; ASHRAE 2019; Michalski 2007; UNI 1999; Pagliarino 2019; ICC and ICOM-CC 2014; Serota and Jones 2008).

The staff of the Institutions has now new tasks: to acquire instruments, to perform long term monitoring, and to analyze periodically the retrieved data. As material and human resources are always scarce, this is not easy. In our research path, studying the indoor climate for conservation, we run into the problem of missing T and RH data, and we were able to solve it thanks to the synergetic communication within the Institution: the library staff noticed us that there were dataloggers and who were they from.

The objective of this article is to present two technical advices related to the indoor climate of library rooms, sustained on the reuse of long term monitoring data, originally produced by the maintenance department with the aim of assessing the HVAC equipment.

The rest of the paper proceeds as follows. Section 2 presents background on indoor climate assessment, and related work in the area. Section 3 describes the case study institution and the general methodology performed to analyze monitoring data. Section 4 presents the results of the methodology applied to the climate data of both library rooms. Section 5 discusses the results obtained with the literature and the limits of our methodology, and section 6 presents the conclusions.

Background

Martens has already explained how poor definition of standards and a lack of understanding of the underlying physics lead to irrational, expensive and sometimes damaging distortion of the way museums are built and operated (Martens 2012). The average RH ideal value of 55% attributed to Thomson (1986) was deliberately chosen because early observations showed that fixing humidity on average levels of the cold northern-Europe winter would prevent the most evident damage (Brown and Rose 1996). But in cold climates, with low moisture content, winter heating will reduce ambient internal humidity to below 20%. To fix this issue, mechanical humidification can add moisture, but rising dew point promotes condensation or even dampness above the envelope of the building, meaning the constructive layer or set of layers of enclosure that separates the indoor rooms with the exterior. Wet layers may cause damage to the building itself.

In order to preserve collections and historic buildings as well the economy of CH institutions, that are struggled by the cost of maintaining stringent indoor conditions to reach literature and loan prescriptions, new research legitimate the paradigm shift: the ASHRAE Handbook (2011), PAS 198 (British Standards Institution. 2012), and European Standard UN 15757: 2010 (CEN 2011), that provide specifications for the control of T and HR in order to limit the mechanical damage induced by the climate to hygroscopic materials. This is called proofed fluctuation: when it has been proven that the microclimate is not harmful, the historical climate of the space where the object is preserved and adapted can be kept. It is based on the acclimatization concept that is the process in which materials exposed for prolonged periods to a given environment with fluctuations of T and RH accumulate sufficient internal stress as to produce breaks, and these breaks open and close as if they were expansion joints. The adaptation to the fluctuations should not be interpreted as a positive factor since these internal fissures in fact constitute a form of damage, so any variation of the oscillations entails a new acclimatization, and new damage. The procedure suggests climate bands instead of targets, with extra limits for daily and seasonal variations according the climate class the institution is applying. This is why it is convenient to know clearly where those limits are for each collection, to avoid wider excursions.

Silva *et al.* (2014) pointed that when applying EN 15757 methodology in temperate climates, short-term fluctuations are limited too rigidly for buildings that do not usually have HVAC systems and interiors climates largely depend on the variations of the outdoor climate. The method described in EN 15757 assumes that the short-term fluctuations cause a higher risk, and limits their range significantly, therefore the authors considered that it is necessary to adapt this methodology to ensure a reliable application in temperate climates based on EN 15757, but influenced by ASHRAE specification and UNI 10829. They also propose a sequential process to determine an optimal indoor microclimate that reaches a balance between HVAC efficiency, conservation needs and thermal comfort of visitors. As a result, they propose seasonal T and RH ranges based on monitoring data collected ad hoc the precedent year in a national museum of Portugal (Silva *et al.* 2016).

Kramer et al. focus their study on obtaining a right setpoint configuration for the HVAC system of museums that contemplates T and RH for the comfort of the visitors and the needs of the collection. The algorithm is based on monitoring and dynamic simulation, and works for four different qualities of envelope, and all of the ASHRAE climates classes, assuming that however the envelope of the building may be, an efficient setpoint strategy is the first step for reducing the energy demand of the museum (Kramer, van Schijndel and Schellen 2017).

When a collection is in the same location through the years, it is natural that the climate band repeats itself as a pattern, but when a collection is going to be transferred, the climate history is a strong preservation argument to imitate the former climate in the new location, when the conservation state is good. This research presents an extra profit of performing indoor monitoring, using existing data available from the performance evaluation of HVAC system of an Institution. It consists on a decision tool applied on a case study, the library of the University of Seville, being transferred from a historic building to a new construction building. The use of this methodology, well supported by standards and recent literature, will permit a rational use of equipment and energy, by the adoption of a conscious and cost efficient determination of the climatic target (CT), understood as the safety interval of T and RH for each collection, and based on the historic climate of collections.

Figure 1.- Main facade of the Royal Tobacco Factory. The authors.

Materials and methods

— *Case study*

The Royal Tobacco Factory (Real Fábrica de Tabacos) is an industrial building from 1757, in a neoclassical baroque style, built by Sebastián Van der Borch, who was a military engineer in charge of the Royal Factory. It is one of the larger perimeter buildings in Spain: its rectangular plan has 147m. by 185m., with 42,000 sqm. It has two main levels, and a basement; the roof and mezzanine slab are performed by square-shaped spherical cap vaults of 5.87m side [Figure 1]. Each vault stands over four pillars of a cross-section sandstone. Facades are made of stone and bricks, and the same materials were used for the vaults and interior walls (González-García de Velasco and González Vilches 2013).

Since 1954 and thanks to a government donation, it is the house of the Rectorate of the University of Seville and the Faculty of Humanities and Philology, and it is a protected Cultural Heritage Monument since 1959 (Cano Arroyo 2014). In this magnificent building lied the Antonio Machado y Núñez Library, holding the historic archive and a valuable collection of medieval codices, manuscripts, incunabula and antique and rare books. In the basement level, the Faculty of Humanities has its periodicals deposit, and, likewise the rectorate Library, has a fabulous historic collection arriving up to the colonies period. The periodicals deposit is on the first basement. As it is vulnerable due to the damp foundations and possible flooding, it is fitted with dehumidifiers, that are activated at the discretion of the staff.

In 2017, the University of Seville inaugurated a new building for the Library, placed 1.7 km away from the Tobacco Factory. This new building complies all the Spanish regulations of the Technical Building Code and the European energy efficiency requirements. Regarding the microclimatic control for the conservation of all its collections, it is fitted with modern equipment that allows real-time monitoring of the climate in each library room from the maintenance offices of the University.

Maintenance personnel collected monitoring data of the former building with the aim of observing if the climate is adequate to comfort conditions, and to check the correct performance of the HVAC equipment of the rooms, but any institution datalogging indoor climate can perform the proposed methodology.

— *General methodology*

The methodology is based on a European Standard (CEN 2011), and the procedure involves 5 stages: i) the analysis of the raw data from the datalogger, or data extraction; ii) the calculation of the mobile average with 30 days' period; iii) exclusion of the extreme values beyond the 7º and 93º percentile; iv) determination of the maximum and minimum limits of the band; v) selection of the climate target.

- Data extraction

Data is provided by the maintenance department, which practices long term monitoring of the historic building rooms to control the HVAC system performance. They use dataloggers Testo 175H1, logging T with a negative temperature coefficient (NTC) thermistor with a precision of ±0.4ºC; and capacitive sensor of RH with a precision of ±2%. The logging dataset includes T and RH from October 2015 to January 2016, and the moving average has a period of 30 days, meaning that the climate target corresponds to 15 days after the beginning (November 12nd) and 15 days before it ends (December 21st). The logging interval chosen by the maintenance office was one minute, so only a 16% of the records were kept and selected to obtain a five-minute interval sample.

- Mobile average

Seasonal variation is the mobile average of every record of the previous 15 days and following 15 days of each individual reading. Short-term fluctuations are the difference between a specific value and its 30-day moving average. In practice it is a simple procedure in Excel: in a 5 minute dataset, add a trend line to the RH series with "mobile average" format, and set a period of 8928, to include 288 registers a day (12*24) from the 15 previous and the 15 subsequent days. The result is a curve with softer edges, without any extreme peaks and valleys [Figure 2].

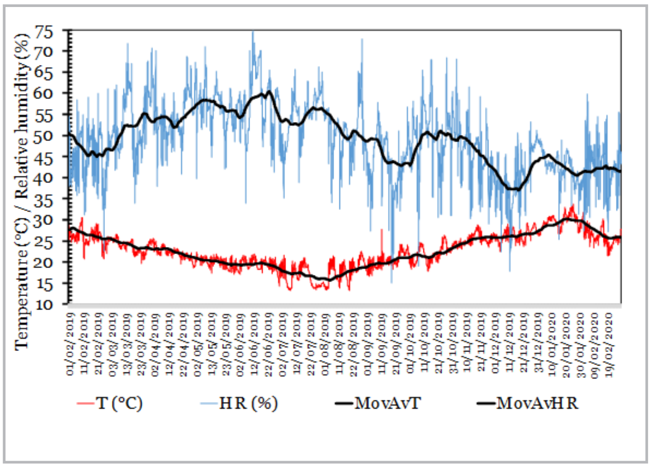

Figure 2.- Mobile average trend line example.

- Exclusion of the extreme values

According to EN 15757 the lower limit is given by the 7th percentile of differences between the moving average and the real records and the upper limit is given by the 93rd percentile of the difference between the record and the value that the moving average takes for that record. So, we exclude of the new safety band the highest 7% and the lowest 7% of the excursions to avoid the risks that imply the extreme peaks and troughs in the registries.

However, if the procedure indicates that fluctuations are less than 10%, it is considered unnecessary strict and negligible, and the 10% band can be accepted under a specialist supervision, like a conservator able to detect early signs of damage.

-Selecting limits to the band

To determine the final safety band [Figure 3], some other extra conditions are recommended: not to trespass certain values in spite of the historic climate. These limits are 40% as a minimum value for RH based on the risk of frailty, since the lack of humidity turns the paper brittle. The maximum value for RH is fixed in 60% (Bizot Group 2015). The development of bacteria usually requires higher RH (Pavlogeorgatos 2003). Low values of T are often safe over 16°C, excluding the risk of condensation -limited by humidity band- but beyond 25°C should be avoided as it accelerates chemical reactions, and desiccates the external layers of the exposed materials, raising the fragility level (Bizot Group 2015).

The process to incorporate this condition in Excel is adding the "if" function, using as a logical test the premise of being inside the range of 40% and 60% for humidity, and being under 25°C for temperature. If the logical test is true, then the top limit value for the band is the mean average value plus the value of the 93rd percentile, and the lower limit of the band is the mean average value plus the value of the 7rd percentile (negative value). If the logical test is not true, then the limits are fixed by the range, 40-60% [Figure 3].

- Climate target

Once determined the safety band, it is necessary to select one value to set the HVAC equipment. The interval of time in which the thermostat is fixed (seasonally, monthly, or weekly) is related to the availability of staff to modify the thermostat, the capacity of the thermostat to save different set points, and the precision aspired. A monthly set point is more accurate than a seasonal set point, but a weekly set point is not recommended because outdoor weather is likely to change from one year to another. We propose to set a monthly setpoint value calculated as the average for each month of the mean average.

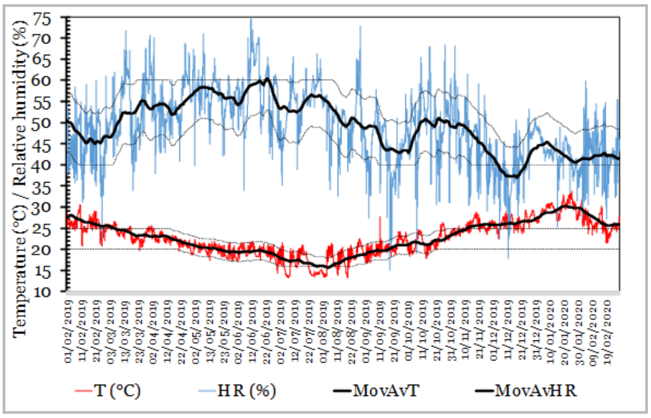

Figure 3.- Safety margins example.

Results

The results reflect the methodology applied on two rooms, with two different objectives: the relocation of the General Library of the University of Seville, and the need of dehumidification equipment in the deposit of the Philology Library of the University of Seville.

— *General Library*

From the original dataset, the first action is to filter and order the registers to obtain a logging interval of 5 minutes, which means 288 registers per day. The second stage of the methodology consists of calculating the mean average for each datum. That is the average of the 4320 previous and the 4320 subsequent values as it is shown on Figure 4.

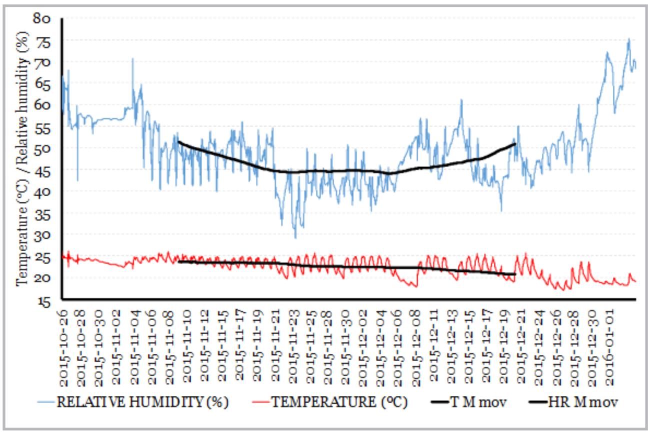

Figure 4.- Stage 2 of the methodology, determination of the mobile average of the General Library

In Figure 5, the mean average line for RH is drawn as a constant, and the Y axe represents the bias between the logged value and the mean average. The shadowed zone is for the excluded values, limited by the 93° and 7° percentile that, in this particular case, are values below -6.64 and above 7.45 using Excel function Percentil.exc. EN 15757 affirms that if the limit is smaller than 10%, the band will remain unnecessarily strict, so it can be set as 10%.

As explained in section "*Selecting limits to the band*" besides the limits given by the 7th and 93rd percentile [Figure 5], to determine the climatic band we are introducing 3 extra conditions with the extreme limits that prevent also chemical and biological damage. The interval for the target band excludes:

- RH greater than 60%,
- RH lower than 40%;
- and T higher than 25° C

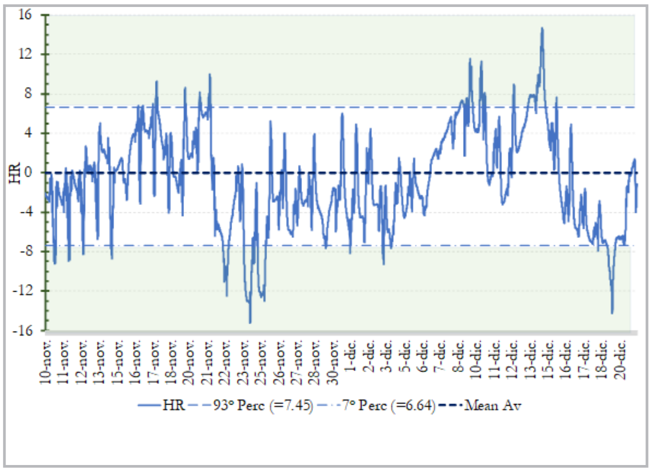

Figure 5.- Values corresponding the 7º and 93º percentile.

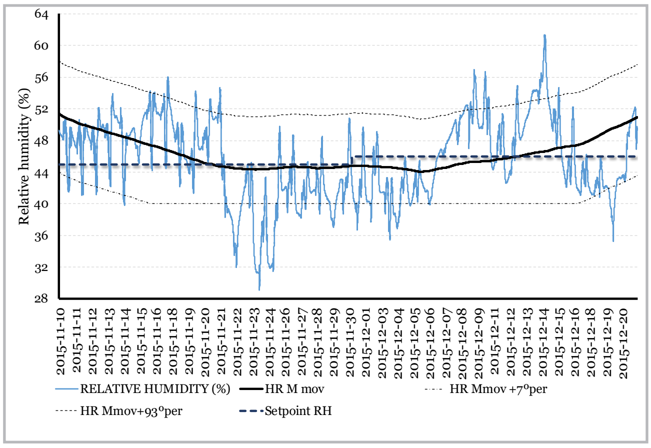

Figure 6a.- Target band and RH setpoint, excluding extreme values

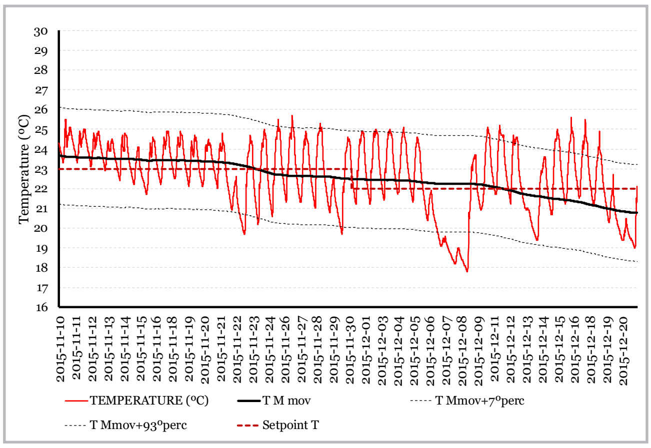

Figure 6b.- Target band and T setpoint, excluding extreme values.

As we are considering the heating period, it is noticeable that the HVAC turns the air too dry [Figure 7], below the limit of 40%, to fulfil the thermal comfort expectations for people reading seated (1.0 met) with winter clothing (1 Clo) (ASHRAE 2013) This is an issue useful to inform and amend in the new location in order to prevent future chemical damage and fracture risk of organic materials.

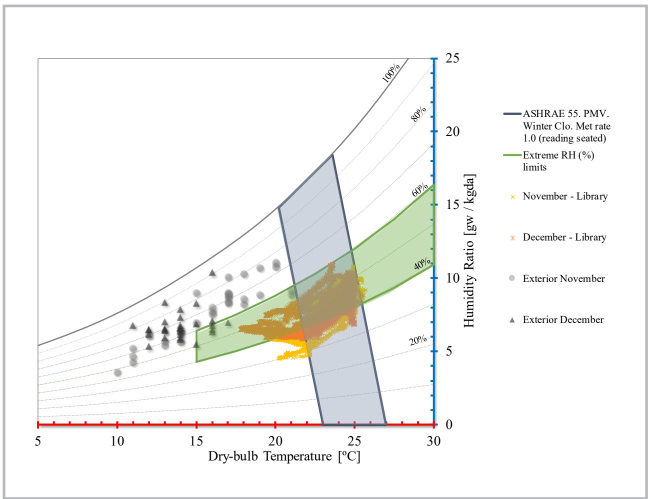

Figure 7.- Psychrometric chart. Comfort zone and ideal RH zone in the Library.

Finally, after the analysis, it is possible to determine the set point climate interval that the institution can manage. For the period analysed, the condition that contemplates mechanical risk based on the historic climate and biological and chemical damage based on extreme limits is 45% and 23ºC for November and 46% and 22ºC for December, showed in trimmed line in Figure 6. In November humidification is needed.

—*Periodicals deposit. Library – Faculty of Humanities*

The periodicals deposit, placed in the basement level of the Royal Tobacco Factory, is fitted with 2 de-humidificators manually activated. We are using the monitoring information to assess the indoor climate according to mechanical, chemical and biological damage, and to determine if the equipment is actually needed.

Figure 8 in the left shows a corridor of the periodicals deposit, with metal shelving and a clean and well organized collection. The picture in the right shows the instrument set by the maintenance staff to control the HVAC equipment: a Testo data logger displays the T and RH at the visit moment (may 22nd 2017, 11:00AM) 24.8ºC and 32.9%, a day where outdoor condition was 23° and 57%. The unusual value for a supposed "humid" room led us to dig into the long term monitoring. Figure 9 shows the trend for T and RH, and while T is constant and safe, RH is lower than literature suggests.

Figure 8.- Periodicals Deposit. Library of the Faculty of Humanities.

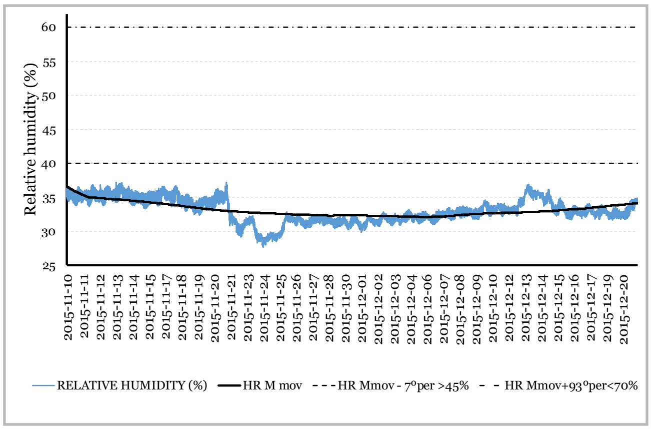

Figure 9a.- Mobile average and target band of RH for Periodicals Deposit

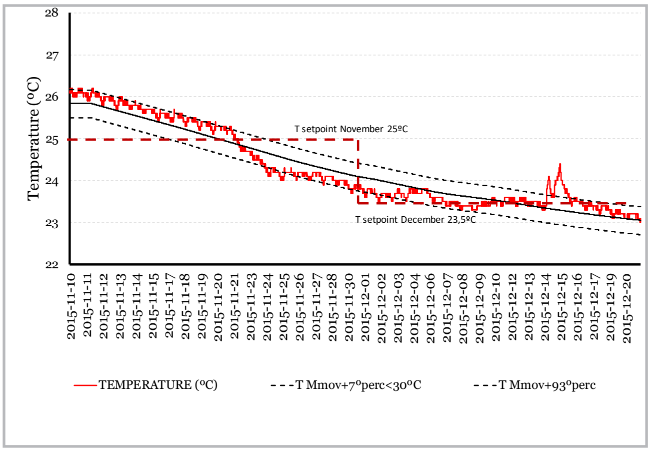

Figure 9b.- Mobile average and target band of T for Periodicals Deposit

Discontinuing the intermittent use of dehumidifiers will reduce the energy demand of the equipment, release the staff of emptying the buckets, and avoid the chemical risk that an extreme dry environment triggers in the collection. If dehumidifiers are to be used, they should be humidistatically controlled based on RH sensors, connected to the drainage system.

The detention of the de-humidificators will increase of the absolute humidity in the air, and is going to approach the T and RH to preservation conditions (green), and comfort conditions (blue) as it is shown in Figure 10.

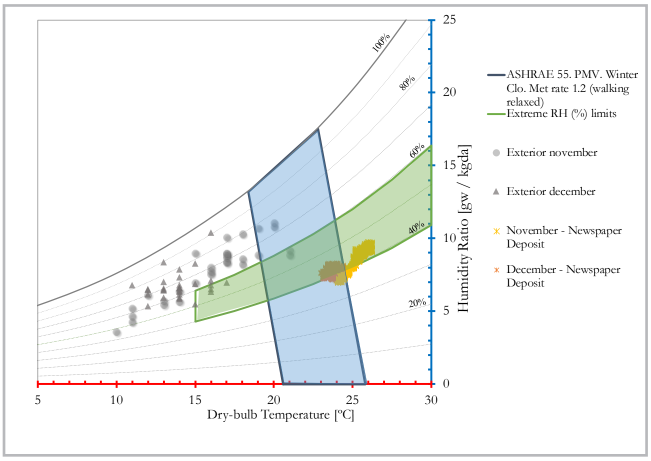

Figure 10.- Psychrometric chart. Comfort zone and ideal RH zone in the periodicals deposit.

Discussion

Before the implementation of this procedure, the set point for T and RH in the new Rector Machado Library would follow instructions from literature, but would ignore the historic climate of the collection, at the risk of new mechanical damage. Besides the prescription of the 15757 standard, the methodology also contemplates the extreme limits of RH and the maximum level of T to prevent biological and chemical degradation.

Silva (2015) agrees on the fact that 15757 standard is suitable for cold climates, permitting larger long term variations and smaller daily oscillations, but not for temperate climates as Seville and Lisbon: not needing permanent climate control, indoor climate suffers wider short term fluctuation. This is why some extra limitations are included.

For the determination of the full climatic band, the data set should include, at least, 13 months of monitoring information, but ideally, to have a consistent idea of the historic climate of the collection, the data set should include more than two years to perform a more complete report, but that is a subject of further studies. As in this case the monitoring was performed from October to January, the climate band was calculated to assess only two months of the period: November and December. But the problems that the present assessment evidenced will not change even under a longer dataset.

Conclusions

The monitoring campaign was performed with maintenance scope, and it was reused in order to obtain two main advices related to conservation.

The first is the ideal set point configuration for the heating of the General Library Collection in its new building, in the months of November and December based on the climatic history of the goods preserved in each room, therefore, in compliance with the new literature agreement to prevent new mechanical damage. With this information, the conservation responsible can consciously decide the T and RH set point for the brand new building.

The second technical advice alerts the staff to inappropiate use of mechanical de-humidificators in the periodicals deposit, because the RH is already too low and may provoke damage to the collection, like drying and brittleness to paper. Another suggestion would be to install humidistically-controlled dehumidifiers with automatic drainage.

This conservation improvements are environmentally friendly and also money-saving measures. They are based on T and RH data, and this article is not only an additional proof of the convenience of performing long term monitoring for conservation porpoises, but an idea for other institutions willing to improve their conservation climate.

Finally, the main conclusion is that a synergetic communication within an Institution is helpful to release the staff of extra tasks, save money, and operate in a sustainable way.

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