CHAPTER

1.11 VENTILATION STRATEGIES FOR THE PREVENTIVE CONSERVATION OF MANUSCRIPTS IN THE NECIP PAŞA LIBRARY, İZMIR, TURKEY

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1. INTRODUCTION

Historic buildings are a significant part of the world's cultural heritage. Historic library buildings contain manuscripts, the preservation of which is vital for human culture. If a sufficient indoor microclimate is supplied in libraries, they may survive for centuries [1].

Insufficient indoor microclimate conditions in a historic building may cause mechanical, biological, and chemical degradation of cultural property. Therefore, approaches to conservation have been improved to avoid risks of degradation to cultural properties in historic buildings. Two types of approaches to conservation can be implemented: direct and indirect physical interventions. The former means physical reactions on the property, such as stabilization, consolidation, and disinfestations. Indirect intervention, on the other hand, is defined as preventive conservation, and mainly deals with environmental monitoring and control of storage areas, good housekeeping, pest management, and the education of staff [2]. The main objectives of this study were to examine the extant conservation conditions of manuscripts in the historic library and improve them from a "preventive" point of view.

In the literature, risks of mechanical, biological, and chemical degradation on paper-based collections were investigated from a preventive approach to conservation [2–4]. Fluctuations in temperature (T) and relative humidity (RH) are the main reasons for mechanical degradation that causes the dimensional alteration, shrinking, and swelling of manuscripts. The growth of mold, classified under biological degradation, may be seen on the surface of manuscripts, stimulated by optimal critical conditions of T, RH, and substrate over a certain time. The main reason behind chemical degradation is the high amount of moisture content in hygroscopic materials, which may result in the deterioration of text and discoloration of papers. These chemical processes slow down at a low RH and T. Thus storage conditions with lower microclimate values expand the lifetime of collections and archives [5,6].

There are several studies in historic buildings evaluating indoor thermo-hygrometric parameters with respect to the risk management of cultural properties. The degradation phenomenon was investigated with long-term monitoring in a historic church and a statistical risk-based evaluation of

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thermo-hygrometric parameters. The indoor climate was assessed according to European standards EN 15757, PAS 198 and the set points of 20°C and 50% RH [7]. Another study examined a climate risk assessment in museums based on the influence of set points for T and RH on the indoor microclimate by changing the values in the model [5]. Two museums in the United Kingdom were observed over a long period, and their microclimate was analyzed. The results conveyed the significance of ventilation and humidification for the indoor environment of museums to preserve collections [3].

The indoor microclimate must be controlled with respect to defined instructions to avoid mechanical, chemical, and biological degradation. The *American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook* (ASHRAE) Chapter 21 guidelines present six control classes to evaluate the degradation potential of paper-based collections in libraries, museums, and archives [8]. It simply states that properties should be stored either at set points (T between 15°C and 25°C and RH at 50%) or at the historic annual average value for permanent collections. The guidelines control indoor climate conditions by avoiding excessive daily T change or seasonal RH rises and drops. Moreover, indoor microclimate requirements define a set of ranges that may differ as a result of recommended seasonal and short time fluctuations.

Novel climate control systems are generally adapted to historic buildings to adjust the indoor environment in a preventive conservation manner. Studies conducted in historic libraries in the Mediterranean climate indicated that the free-floating hygrothermal behavior of historic buildings reasonably fulfills required indoor thermal conditions because of the choice of materials and high thermal mass specifications of the envelope, and low airtightness value of the buildings [4,9]. Hence, controlling the indoor microclimate with mechanical systems should be well scrutinized. The integration of active systems needs to be considered to satisfy requirements for preventive conservation [4].

The motivation of this chapter was to achieve a suitable indoor microclimate to preserve manuscripts in the Necip Paşa Library, Tire-İzmir, Turkey. There is no heating, ventilation, and air conditioning (HVAC) system in the Main Hall, and doors and windows are used to ventilate the building. A wooden octagonal cage-like structure where manuscripts are separately preserved was located in the middle of the Main Hall. Yet, a new conditioning system was planned for installation in the Main Hall without a detailed analysis of the current behavior of the building and its impact on the manuscripts. Preliminary results of the ongoing study in this library depicted that the indoor microclimate might cause a chemical degradation risk to the manuscripts, although there was no indication about mechanical and biological risks [10,11].

In this study, two control strategies, mechanical and natural ventilation, were proposed to reduce the risk of chemical degradation to manuscripts in the Necip Paşa Library with the help of a building energy performance (BEP) tool, DesignBuilder (Version 4.2.054) [12]. The study also aims to highlight the significance of quantitative research for any proposal that will be developed for the preventive conservation of manuscripts and other cultural properties in historic buildings. It anticipates contributing to the current literature in Turkey, in which the analysis of indoor environment and hygrothermal behavior of libraries, specifically those housing manuscripts, is limited.

2. NECIP PAŞA LIBRARY

The Necip Paşa Library is a 190-year-old, standalone, load-bearing building that functions to house manuscripts dating from the 12th to the 20th centuries in the west of Turkey, Tire-Izmir. It was built by Mehmet Necip Paşa to house his own collection, accumulated during his official service in several

FIGURE 1

South view of Necip Paşa Library, Tire-İzmir, Turkey.

places in the Ottoman Empire [13] (Fig. 1). The building housing one of the priceless manuscript collections in Turkey preserves 1156 manuscripts, 1312 books printed in the era of Ottoman Empire, and more than 9000 books in Latin letters, most of which were printed right after the foundation of the Republic of Turkey [13–15]. The library has undergone restoration work since July 2016 under the control and management of the Turkish Prime Ministry, Directorate General of Foundations.

The library lies on a south to north axis with three main zones: originally a portico (*Revak*), newly the Entrance Hall; an almost square planned Main Hall; and an octagonal cage-like Manuscript Zone located inside the Main Hall, respectively (Fig. 2). After the spatial intervention undertaken in 1930, the portico was converted into the Entrance Hall by wooden framed windows to create an office space for the library administrator and a reading hall for visitors. The cube-shaped Main Hall was enclosed by a lead-covered brickwork dome. It has nonhomogeneous high–thermal mass walls composed of rubble stone and brick. The thickness of the external walls is 1.08, 1.16, and 1.25 m for the eastern, western, and northern (and southern) walls, respectively. Seven windows on the Main Hall are single glazed with wooden frames and iron shuttered from inside. In addition, four fixed small windows on the drum of dome face the four main directions (Fig. 2). The only approach to the manuscripts is from a thick iron door between the Entrance and Main Halls. The manuscripts are separately preserved in a cage-like structure made of wood-framed glass shutters and fences, built in 1908 [16]. The openable shutters, fences, and a hole on top of the Manuscript Zone probably maintain air circulation.

A split-type air-conditioner is placed into the Entrance Hall for cooling and heating purposes, whereas there is no HVAC system in the Main Hall and Manuscript Zone. Therefore, the manuscripts are preserved in a free-floating microclimate [10]. The natural thermal behavior of the building is kept by opening the windows and door through natural ventilation on weekday mornings.

The Necip Paşa Library was purposefully elevated over an approximately 2-m-high podium to protect books and manuscripts against humidity from the rich groundwater of Tire. Yet, the authors

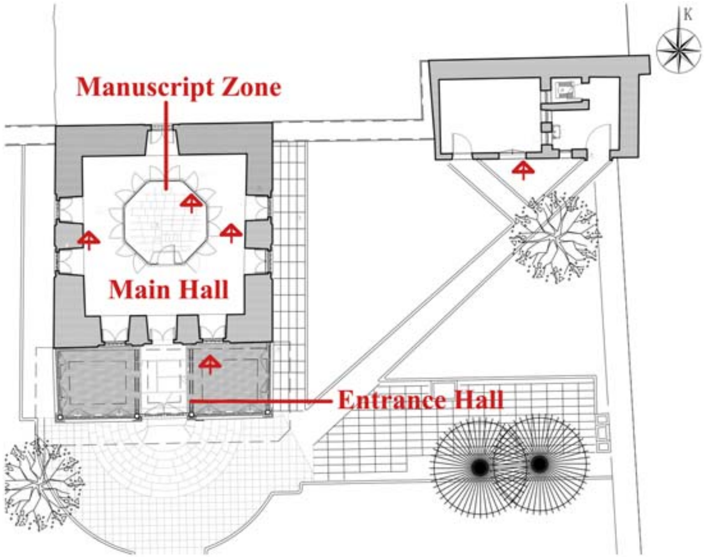

FIGURE 2

Schematic plan of Necip Paşa Library [17].

occasionally observed moisture from the ground surface that caused by condensation resulting from the T difference between the Main and Entrance Halls in winter. An interview with the administrator of the Library confirmed that the Library provided the desired indoor conditions, because most of the manuscripts were well preserved; in only few cases, such as the discoloration and embrittlement of pages, was observed due to misuse [18].

3. DESCRIPTION OF METHOD

The main purpose of this study was to decrease the risk of chemical degradation on manuscripts kept in the Necip Paşa Library by using natural and mechanical ventilation systems. Thus, the current condition of manuscripts was investigated via in situ monitoring. The proposed ventilation strategies was then assessed via a calibrated BEP model and simulations. The steps of the study are given in Fig. 3.

3.1 MEASUREMENTS

The indoor and outdoor microclimates of the Necip Paşa Library were monitored for 1 year by automatic sensors. Five data loggers, which recorded data with 10-min intervals, were used to measure T and RH from September 1, 2014 to August 31, 2015. Only one was placed outside; the others were placed inside. The locations of the data loggers are indicated in Fig. 2. In addition, a blower door test was carried out to measure the airtightness value of the library, which was found to be 0.52 air change rate (ACH). This indicated that roughly half of the air in the total volume (Main and Entrance Halls) changed over an hour.

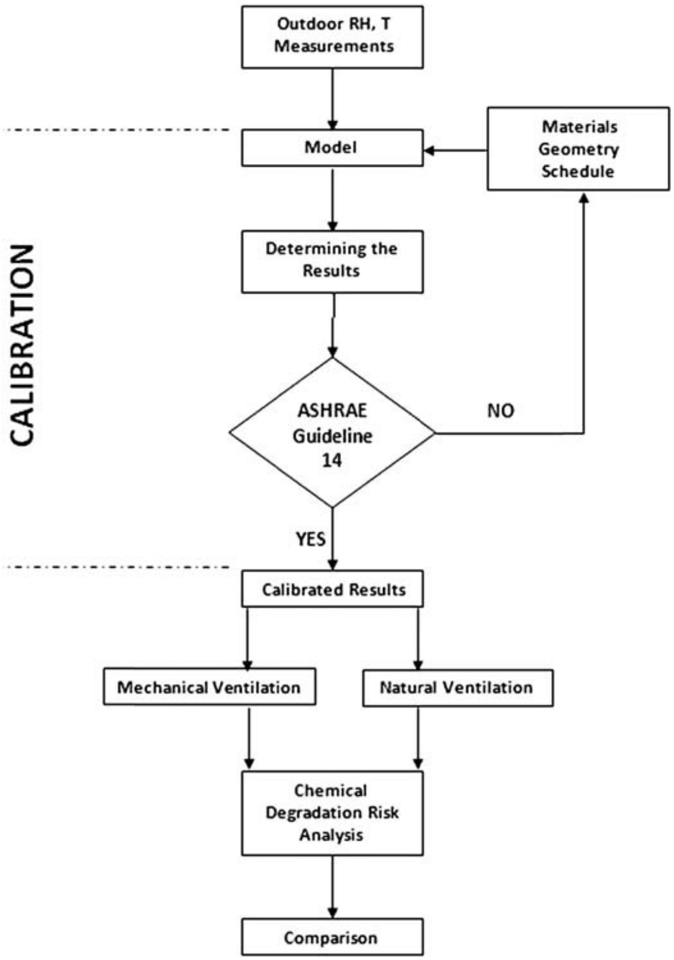

FIGURE 3

Methodology.

3.2 BUILDING ENERGY PERFORMANCE MODELING AND CALIBRATION

A BEP tool, DesignBuilder, was used to model the library [12]. The model was divided into three thermal zones: the Main Hall, Manuscript Zone, and Entrance Hall. Real physical features for each space were entered into the program. The overall heat transfer coefficients (U) of external walls made of limestone and brickwork were 1.64, 1.76, and 1.89 W/m^{2}K for the south/north, west, and east walls, respectively. The roof had a dome shape with a U value of 1.51 W/m^{2}K. All windows of the library were modeled as wooden frames with single glazing (U = 5.89 W/m2 K). The top surface material was the only difference between the ground floor sections of the Manuscript Zone (U = 1.24 W/m^2 K) and the Main Hall (U = 1.38 W/m^2 K). The internal loads including lighting, office equipment, and occupants, and operating schedules were specified based on site observations and interviews. Occupant density and schedule per space were determined.

Weather data (based on T and RH) that were integrated into the model were obtained from the 1-year outdoor measurements. Calibration of model was carried out with respect to the comparison of measurements (T and RH) and simulation results according to ASHRAE Guideline 14 [19]. Two dimensionless error indicators, the mean bias error (MBE) and the coefficient of variation of the root mean squared error [CV(RMSE)], were used as criteria for the calibration process and were calculated by Eqs. (1) and (2), respectively [20]:

$$\mathrm{MBE} = \frac{\sum_{i=1}^{N_i}(M_i - S_i)}{\sum_{i=1}^{N_i} M_i} \tag{1}$$

$$\mathrm{CV(RMSE)} = \frac{\left[\left[\frac{\sum_{i=1}^{N_i}\left[(M_i - S_i)^2\right]}{N_i}\right]\right]^{\frac{1}{2}}}{\frac{1}{N_i}\sum_{i=1}^{N_i} M_i} \tag{2}$$

The upper limit for the CV(RMSE) and MBE values were defined as 30% and ±10% for hourly measurements according to ASHRAE Guideline 14. If the calculated values were lower than the upper limits, the model was assumed to be calibrated.

3.3 ASSESSMENT OF CHEMICAL DEGRADATION RISK

Mechanical and natural ventilation systems were designed and introduced to the model to determine whether the manuscripts were risk of chemical degradation between the dates when the preliminary results exhibited such a risk [10,11]. The parameter called the lifetime multiplier (*LM*), which corresponds to the number of time spans an object remains unstable compared with an indoor climate of 20°C and 50% RH, was used to investigate the risk of chemical degradation for the manuscripts [5,7]. *LM* values below than 0.75 and greater than 1 are an indicator of high and low risk, respectively. Between these values is considered a medium risk level [5]. The equivalent lifetime multiplier (*eLM*) measures the annual response of objects with a unique value, enabling an evaluation of the annual impact. *LMx* and *eLM* values are calculated using Eqs. (3) and (4):

$$LMx = \left(\frac{50\%}{RH_x}\right)^{1.3} \times e^{\frac{E_a}{R}\left(\frac{1}{T_x+273.15} - \frac{1}{293.15}\right)} \tag{3}$$

$$eLM = \frac{1}{\frac{1}{n} \times \sum_{x=1}^{n} \frac{1}{\left(\frac{50\%}{RH_x}\right)^{1.3} \times e^{\frac{E_a}{R}\left(\frac{1}{T_x+273.15} - \frac{1}{293.15}\right)}}} \tag{4}$$

Table 1 Interpretation of Equivalent Lifetime Multiplier Values

	Ideal	Good	Some Risk	Potential Risk	High Risk
Equivalent lifetime multiplier	>2.2	[1.7–2.2]	[1–1.7]	[0.75–1]	<0.75

The risk levels for interpreting *eLM* values are given in Table 1. The lifetime of most objects duplicates every 5K decrement in T, which is around 20°C [21]. Thus, mechanical and natural ventilation systems were integrated into the model to provide *eLM* values within acceptable limits and reduce the risk of chemical degradation.

The indoor T and RH values of the Manuscript Zone were required to calculate the *LM* and *eLM* values. Hence both values were derived from in situ monitoring and BEP simulations were used and compared. General risk assessments for the indoor microclimate of the manuscripts zone were performed with respect to benchmarks defined by Martens [5], Silva and Henriques [7] and Kandil and Love [20].

4. RESULTS AND DISCUSSION

The impact of two different ventilation strategies, i.e., natural and mechanical systems, on reducing the risk of high chemical degradation on manuscripts stored in the unconditioned historic library is presented in this section. First, the outcomes of a yearlong monitoring campaign are depicted to clarify the risky times of the year. Then, the calibration results of digital model are given to ensure the accuracy of simulation model. T and RH differences between the monitored and simulated performances in the Manuscript Zone are indicated to demonstrate the similar thermal behavior of the historic library. The configuration and specifications of ventilation cases are explained in the next part. Finally, results of the simulation of the two cases are discussed to portray whether the proposals achieved eliminating the risk of chemical degradation.

4.1 RESULTS OF MEASUREMENTS

The yearly temperatures of the Manuscript Zone and outdoor environment are depicted in Fig. 4. Eq. (3) was used to calculate *LM* values for the Manuscript Zone. The horizontal blue dashed lines in Fig. 4 indicate the *LM* risk levels whereas the vertical gray line shows the beginning of restoration of the library in July 2015.

According to the results of the monitoring campaign, the manuscripts were under medium risk of chemical degradation in November 2014 and April 2015. The periods from September to November 2014 and May to September 2015 were the most critical for the life span of manuscripts, indicating high risk, whereas there was no risk from December 2014 until April 2015. The *eLM* value for the manuscripts was calculated to be 0.54, and they were under high risk according to Table 1.

Fig. 5 clearly conveys that T and *LM* values were inversely proportional. The highest value of *LM* was observed in January 2015, when the T of the Manuscript Zone was the lowest. RH values changed from the 40% to 70%, from September 2014 to July 2015. Therefore, the manuscripts were under the risk of chemical degradation when T exceeded 20°C.

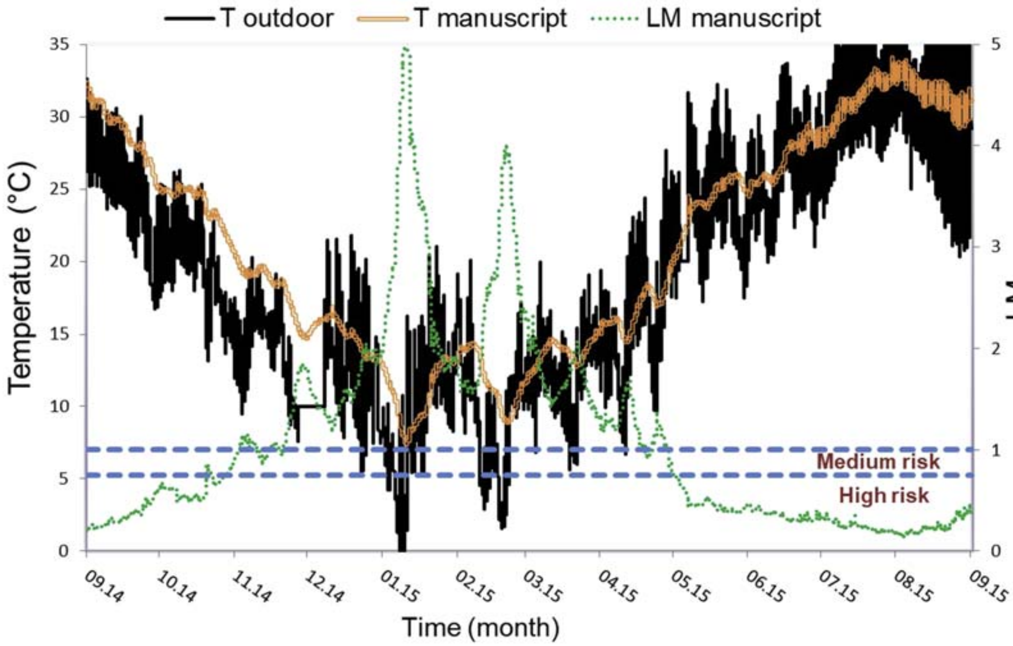

FIGURE 4

Results of the preliminary study indicating the monitoring period. *LM*, lifetime multiplier; *T*, temperature.

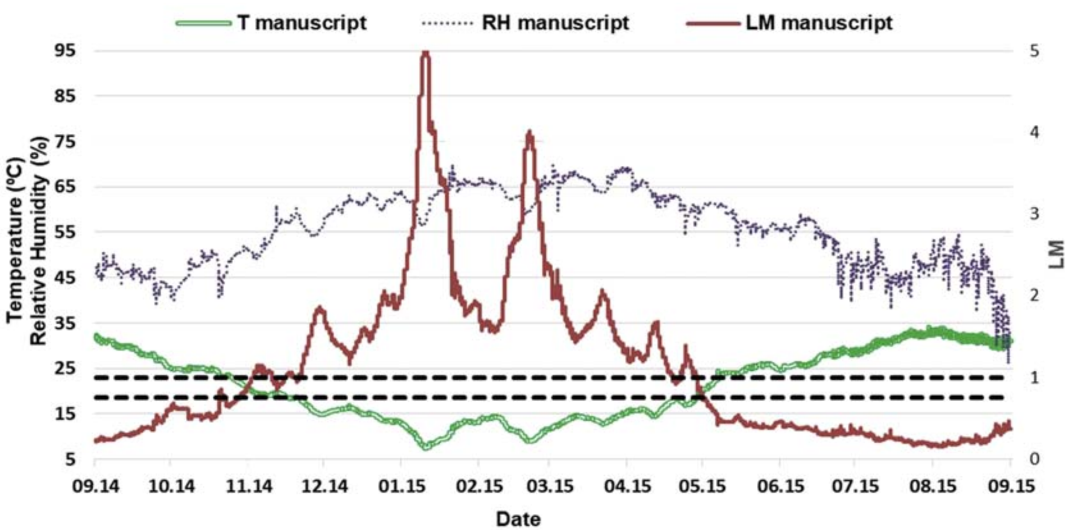

FIGURE 5

Change in lifetime multiplier (*LM*) values with respect to temperature (T) and relative humidity (RH) of the Manuscript Zone.

Table 2 Discrepancies Between Measurements and Simulation Results

Spaces	Temperature		Relative Humidity	
	MBE (%)	CV (RMSE) (%)	MBE (%)	CV (RMSE) (%)
Entrance Zone	−2.9	11.2	7.6	17.2
Main Hall	0.5	7.4	4.7	14.9
Manuscript Zone	−0.2	8.4	1.2	16.5
American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook Guideline 14 [19]	±10	30	±10	30

CV (RMSE), *coefficient of variation of the root mean squared error;* MBE, *mean bias error.*

4.2 RESULTS OF MODEL CALIBRATION

Through model calibration, three zones were evaluated with a full-year hourly T and RH comparison between the results of measurement and simulation. All error values given in Table 2 were below the threshold values and satisfied ASHRAE Guideline 14 based on MBE and CV (RMSE) calculations.

4.3 CONFIGURATION OF SIMULATION CASES

The cooling potentials of both systems were examined according to the assumptions defined in two BEP models.

4.3.1 Case 1: Mechanical Ventilation

A mechanical ventilation system was introduced to the Main Hall. The T of the Main Hall was set with respect to the outdoor T. Because *LM* calculations were based on the indoor climate of 20°C and 50% RH, the system became active when the outdoor T was below 20°C. The maximum airflow rate was selected to be 3 ACH for Case 1.

4.3.2 Case 2: Natural Ventilation

For natural ventilation, a daily schedule was introduced to the BEP model to reduce T in the Manuscript Zone. All windows and the door of the Main Hall were set to be open from 22:00 to 08:30. This ventilation scenario tested nighttime cooling without RH control.

4.4 DISCUSSION

The *LM* values for the mechanical and natural ventilation cases were calculated and the risk levels for chemical degradation are shown in Figs. 6 and 7, respectively. The restoration work of the Library started in July 2015, as represented by the solid gray line in both figures.

On a monthly basis, the *LM* values for ventilation strategies indicated that introducing the mechanical and natural ventilation systems to the model, slightly reduced the risk of chemical degradation on the manuscripts for critical months representing “high risk,” which were from September to

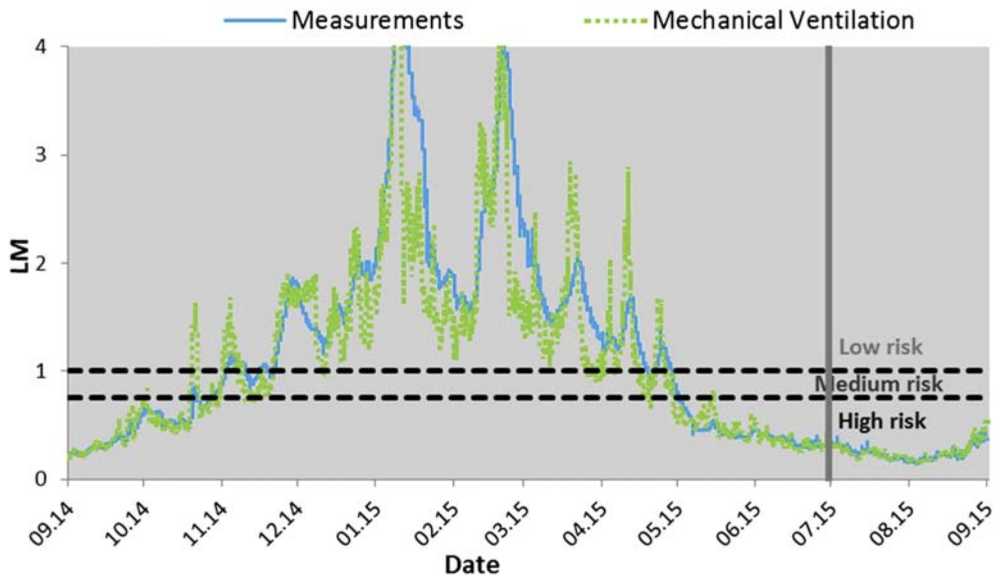

FIGURE 6

Comparison of measurements with mechanical ventilation system. *LM*, lifetime multiplier.

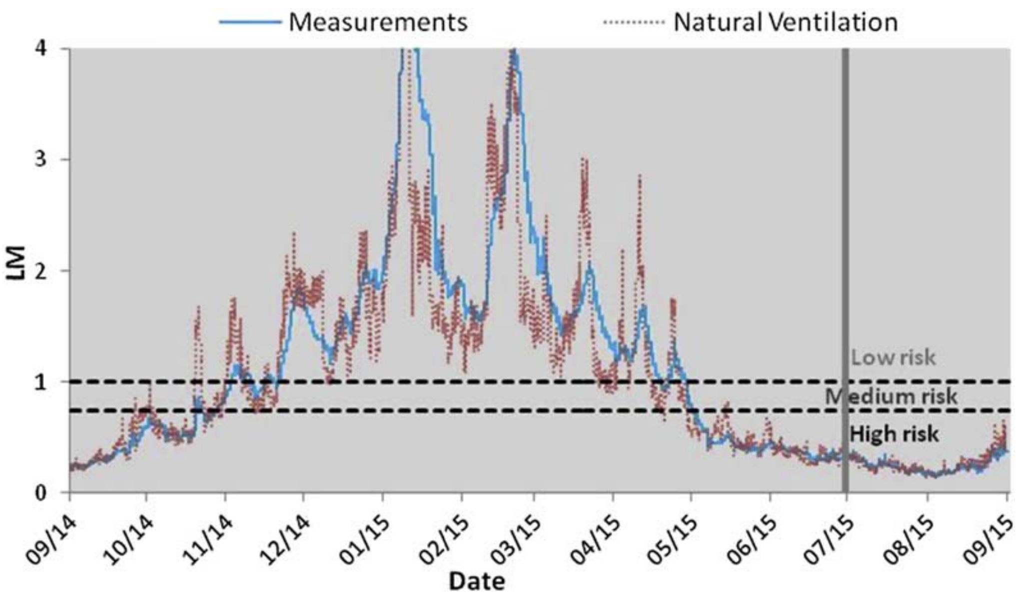

FIGURE 7

Comparison of measurements with natural ventilation system. *LM*, lifetime multiplier.

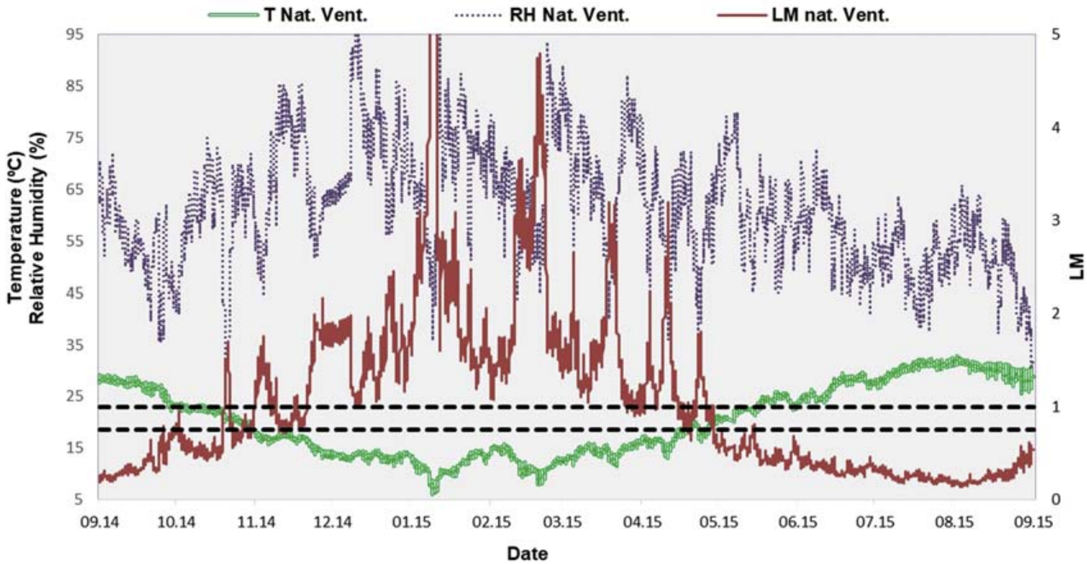

FIGURE 8

Change in lifetime multiplier (*LM*) values with respect to temperature (T) and relative humidity (RH) (for natural ventilation).

November 2014 and from May to September 2015. Yet, the risk for chemical degradation on manuscripts partly moved from the high risk to "medium risk" level after both strategies were implemented in October 2014 and May 2015 (Figs. 6 and 7).

In addition to the correlation between T and *LM* indicated in Fig. 5, the effect of RH on *LM* values is shown in Figs. 8 and 9. The sharp rises and drops in *LM* values can be observed with respect to RH values. In other words, RH and *LM* were inversely correlated.

On a yearly basis, after implementing the mechanical and natural ventilation to the model, the *eLM* values were calculated to be 0.53 and 0.55, respectively, whereas the *eLM* values for the measurements were calculated as 0.54. The cases did not assist in increasing the life span of the manuscripts and improve conservation conditions from the "preventive" point of view (Table 3). Because, as indicated in Fig. 4, the selected strategies were basically bound to the weather conditions of Tire-İzmir, where the outdoor Ts are mostly more than 20°C in the risky summer period. Therefore, both ventilation strategies did not qualify as good enough to cool down inner Ts in the Manuscripts Zone.

Finally, the risk of chemical degradation on the manuscripts could be totally reduced by controlling T and RH together in the Library. To achieve this goal, T and RH in the Main Hall need to be controlled by an HVAC system. However, historic buildings should be treated differently from contemporary ones. Therefore, interventions on a historic building, e.g., integration of an HVAC system, require attention, a multidisciplinary viewpoint, and more qualitative research. The awareness of the academic and administrative authorities should be increased on this issue.

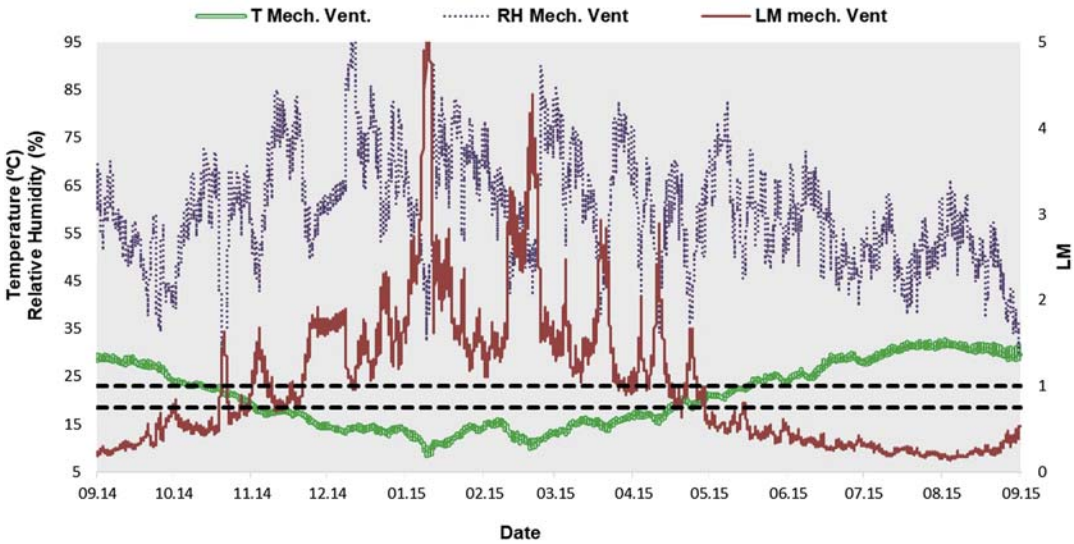

FIGURE 9

Change in lifetime multiplier (*LM*) values with respect to temperature (T) and relative humidity (RH) (for mechanical ventilation).

Table 3 Comparison of Equivalent Lifetime Multiplier Values

	Natural Behavior	Natural Ventilation	Mechanical Ventilation
Equivalent lifetime multiplier	0.54	0.55	0.53
Improvement (%)	–	−1.9	1.9
Region	High risk	High risk	High risk

5. CONCLUSIONS

The indoor microclimate of a historic library is evaluated in this chapter. According to preliminary results, manuscripts in the Library were at risk of chemical degradation owing to high indoor Ts during summer months, although there were no biological and mechanical degradation risk. Mechanical and natural ventilation systems were integrated into the historic library and tested via a BEP model to use the cooling potential of both systems on the indoor environment. Before doing that, the BEP model was calibrated hourly by tuning the parameters that affected by hygrothermal conditions.

The BEP models revealed that the risk of chemical degradation on the manuscripts continued after the integration of ventilation strategies. Neither nighttime natural ventilation nor the circulation of outdoor air via a mechanical system was enough to eliminate the risk on the manuscripts.

The lifetime of the manuscripts is shown by *eLM* values. The annual impact of both cases is encountered as minor: The natural and mechanical ventilation has a slight negative and positive impact on the life span of the manuscripts, respectively.

NOMENCLATURE

ACH	Air change rate
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEP	Building energy performance
CV (RMSE)	Coefficient of variation of the root mean squared error
E_a	Activation energy (100 kJ/mol for degradation of cellulose)
eLM	Equivalent lifetime multiplier
EN	European standard
HVAC	Heating, ventilation, and air-conditioning
i	Data point in the data range
MBE	Mean bias error
n	Number of data points
PAS	Publicly available specification
R	Gas constant (8.314 J/mol K)
RH	Relative humidity (%)
T	Temperature (°C, K)
x	Data point in data series

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