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Comfort based investigation on historic libraries for user satisfaction and preservation of paper-based collections

C Turhan^{1,6}, C Topan², Z Durmus Arsan³, T Goksal Ozbalta⁴ and G Gokçen Akkurt⁵

¹ Department of Energy Systems Engineering, Atılım University, 06830 Incek, Ankara, Turkey

² Energy Engineering Programme, Izmir Institute of Technology, Gulbahce Campus, 35430 Urla, Izmir, Turkey

³ Department of Architecture, Izmir Institute of Technology, Gulbahce Campus, 35430 Urla, Izmir, Turkey

⁴ Department of Civil Engineering, Ege University, 35040 İzmir, Turkey

⁵ Department of Energy Systems Engineering, Izmir Institute of Technology, Gulbahce Campus, 35430 Urla, Izmir, Turkey

⁶ Corresponding author, cihan.turhan@atilim.edu.tr

Abstract. Historic libraries preserve cultural heritage values while housing rare manuscripts and paper-based collections. The collections in the libraries are deteriorated chemically, biologically and mechanically due to inappropriate indoor environment conditions such as temperature and relative humidity fluctuations and microbiological conditions. Apart from preserving vulnerable paper-based collections, accommodating of a considerable thermal comfort level for visitors is essential in historic libraries. The aim of this study is to analyse indoor environment of a historic library in terms of thermal comfort and preventive conservation of paper-based collections. Izmir National Library, built in 1933, is selected as a case study. Indoor air temperature, relative humidity and air velocity in the library were monitored with a one-year measurement campaign. Meanwhile, thermal comfort of the visitors was assessed with PMV/PPD indices and thermal sensation surveys. The results show that high chemical degradation risk is detected in the library while biological and mechanical degradations are in the low risk zone. On the other hand, 87% and 93% of the visitors feel thermally satisfied in heating and cooling seasons, respectively.

Keywords – Paper based collections; Preventive conservation; Thermal comfort; Historic libraries

1. Introduction

Historic libraries are the places where cultural assets are carried into the future generations via books, manuscripts, collections, documents, maps, artefacts, paintings and even sculptures [1]. It is well-known that paper-based collections can deteriorate where they are stored or exhibited [1-2]. Besides to external factors such as seepage and/or mechanical damage, inadequate indoor microclimate cause deterioration on paper-based collections [3]. Chemical, mechanical and biological degradation, which lead to shrinking, swelling, discoloration and mould growth on paper-based collections, are observed in historic libraries. The books and manuscripts could be conserved via curative or preventive conservation methods [4] that reduce damage and deterioration by improving their microclimate such as controlling temperature (T), relative humidity (RH) and pollutants. For instance; to prevent chemical deterioration, extreme values of T and RH should be avoided while fluctuations in T and RH are the main source for mechanical degradation. Biological degradation is also caused by extreme T and RH values, and substrates in the environment [5]. Adequate indoor microclimate values to prevent deterioration on paper

documents are described in the international standards such as the ASHRAE Chapter 21 [6] and ISO 11799 [7].

Apart from preventive conservation of paper-based collections, thermal comfort of visitors plays a vital role in order to satisfy healthy indoor environment in historic libraries [8]. ASHRAE 55 [9] defines thermal comfort as subjective sensation, which depends on four environmental parameters including indoor T and RH, mean radiant temperature (MRT) and air velocity (v), and two personal parameters which are clothing value (clo) and metabolic rate (met). Traditionally, thermal comfort is assessed by Fanger's Predicted Mean Vote (PMV) and Percentage of Predicted Dissatisfied (PPD) indices [10]. The PMV refers to a thermal scale where the value of zero PMV with a tolerance of ± 0.5 is considered as thermally comfortable while 10% of the occupants feels dissatisfied with the environment [9]. Therefore, investigation of the effect of microclimate data on paper-based collections and thermal comfort of the visitors is crucial in historic libraries. The aim of this paper is twofold: evaluate chemical, mechanical and biological degradation risks on the collections caused by microclimate data in a historic library and assess thermal comfort of the visitors by PMV/PPD data and thermal sensation surveys. The Izmir National Library in Izmir/Turkey is selected as a case study. A one-year measurement campaign was conducted to collect microclimate data (T, RH, v), and thermal comfort of the visitors was assessed by calculating PMV values and conducting surveys.

2. Materials and methods

The methodology of the study is depicted in figure 1. Firstly, indoor and outdoor T and RH, and indoor v data are collected and recorded by sensors for one year. Then, degradation risk for paper-based collections are evaluated using the collected data. During the measurement campaign, the surveys are performed to evaluate the visitor's thermal sensation along with PMV and PPD calculations.

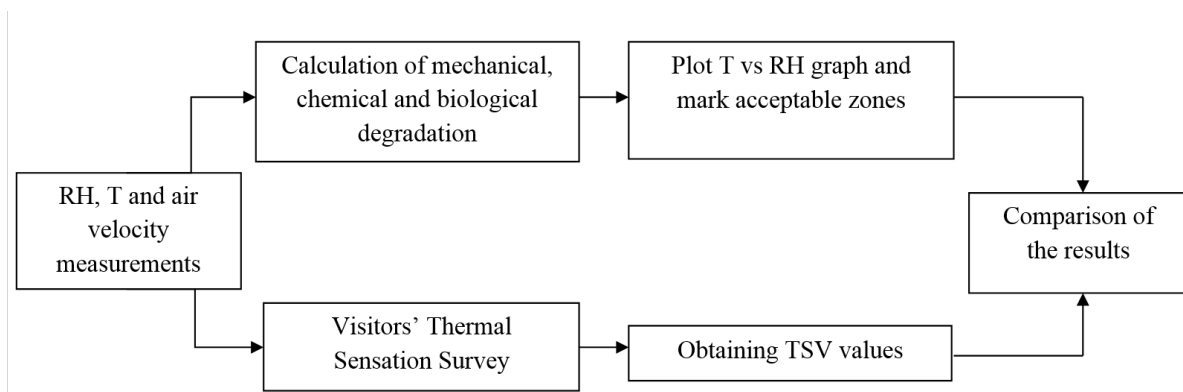


Figure 1. Flow diagram of the methodology

2.1. Case building

The Izmir National Library is located in the heart of the Izmir city, Turkey (38° 24' 52.1208" North, 27° 8' 38.8428" East). The climate zone of Izmir is Csa according to the Köppen-Geiger Climate Classification [11]. The location map and exterior view of the case building is shown on Figure 2.

The Izmir National Library, which was built in 1933, houses 290606 books, 3792 manuscripts, 44 stone mould printings, 9058 hard-covered and 950 uncovered newspapers, and 16238 hard covered journals. Furthermore, 4000 manuscripts written in Ottoman Arabic, Persian and Turkish from Seljuk and Ottoman Empire periods, are available in the library. The library is open to the visitors from 08.30 a.m. to 05.30 p.m. except Sunday. The library is a two-storey historic building with central atrium naturally lightened by coloured stained-glass at the ceiling and Marseille glass tiles at the roof. The atrium serves as the study hall with desks and seats for 52 visitors at the ground floor. It has a square plan with total area of 195 m² surrounded by archive storage rooms at both floors and a gallery at the second floor. The archive storage rooms cannot be accessible by the visitors. The load bearing walls are composed of

rubble stone and brick while the roof is composed of the lead covered dome over the main entrance and hipped roof with Marseille tiles. All exterior windows and doors are single glazed with wooden frames [12].

The library has a central heating plant with natural gas, distributed by hot water supplied radiators (Figure 2). Four boilers with 100 kW/each capacity are installed to the basement, operated during working hours. The cooling is provided by three air conditioning systems with a capacity of 19.6 kW/each (Figure 2). Five radiators are also located on the study hall. Moreover, there is no pre-defined set point temperature policy.



Figure 2. Air-conditioners and radiators used for the case building

2.2. Measurements

Microclimate data (T, RH and v) of the study hall and the first floor are collected with ten minute intervals by HOBO mini data loggers [13] from September 2016 to September 2017. List of data loggers is represented in table 1. The locations of data loggers are given in figure 3. In this study, the data loggers in the study hall and the first floor are used for evaluation.

Table 1. Codes of data loggers

Item	Description
H1, H2, H3, H4, H5, H6, H7, H8	HOBO U12-012 T/RH/Light/External data logger
C1	HOBO MX Low Energy CO ₂ /T/RH data logger
V1	ONSET Air Velocity Sensor T-DCI-F900-S-O

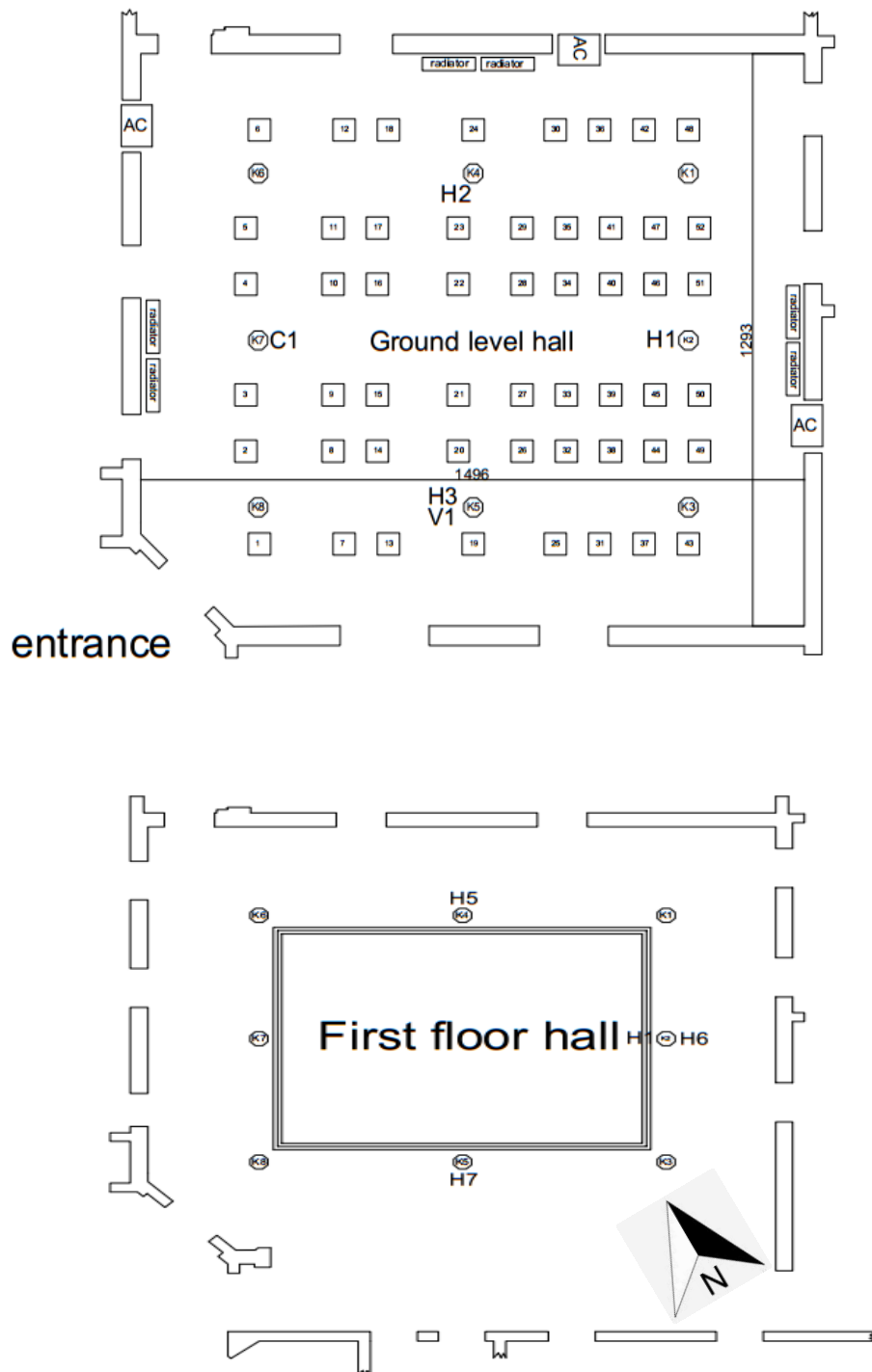


Figure 3. Location of the data loggers

2.3. Degradation risks

Chemical, mechanical and biological degradation risks are analysed based on collected microclimate data. The ASHRAE Chapter 21 [6] introduces control classes to assess the mechanical, chemical and biological degradation potential of paper-based collections in libraries, museums, art galleries and archives. Class A1 is chosen since it the allowed fluctuations are $\pm 5\%$ RH and $\pm 2\text{K}$. It allows seasonal

RH fluctuations of $\pm 10\%$ but minimum allowed T drop is 10 K. If 90% of the T and RH data is in abovementioned limits, the class A1 is satisfied. Below 25% and above 65% of RH values generally result with mechanical degradation [14].

The lifetime multiplier (LM), which is calculated from equation 1, evaluates chemical degradation risk.

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

E_a , R , T_x and RH_x in the Equation 1 are the activation energy (100 kJ/mol for degradation of cellulose), gas constant, indoor temperature and relative humidity, respectively. LM values and corresponding risk values are presented at table 2 [15].

Table 2. Critical LM values [16]

	Ideal	Good	Some risk	Potential risk	High risk
LM	>2.2	[1.7-2.2]	[1-1.7]	[0.75-1]	<0.75

Mould growth on the surface of the material is the indication for biological degradation. Prominent Aerofungi species in Izmir are Cladosporium, Altermaria, Penicillium, Phoma and Aspergillu. Hence, the lowest isopleth (limit curve) is given for Aspergillus Versicolor, which means the library is under high germination risk if the values are above the critical RH values [1].

2.4. Thermal comfort surveys

To obtain visitors thermal sensation, thermal comfort surveys are performed with library visitors at the study hall. Moreover, clothing value of the visitors is obtained from the surveys by selecting their garments in a clothing list. Thermal sensation vote (TSV) indicates perception of the occupants to the thermal surroundings and is calculated from the surveys, which uses seven-point thermal sensation scale as given in ASHRAE 55 [9]. Similar to the PMV, zero value of TSV is considered as neutral thermal comfort [3,9].

2.5. Thermal comfort analysis

Thermal comfort of the visitors is assessed by PMV/PPD indices by using CBE Thermal Comfort Tool [17]. T, RH and v are included for the calculation. Metabolic rate of the visitors is assumed as 1 met as given in ASHRAE 55 [9] for reading and writing activities.

3. Results and discussions

3.1. Measurements

The running averages of hourly T and RH data of the study hall and the first floor are calculated and given in figure 4. The figure also exhibits the allowable short-term fluctuations (blue lines) for T and RH based on class A1. In the study hall, 91.1% of the T and 83.3% of the RH is in the allowable range while in the first floor, class A1 is satisfied for T by 90.7% and RH by 87%. Satisfaction rate for the first floor is lower than the study hall especially in coldest (January and February) and hottest months (July and August). The reasons mainly are (i) the heat loss/gain through the stained glass ceiling and (ii) no radiator and air-conditioner installation on the first floor.

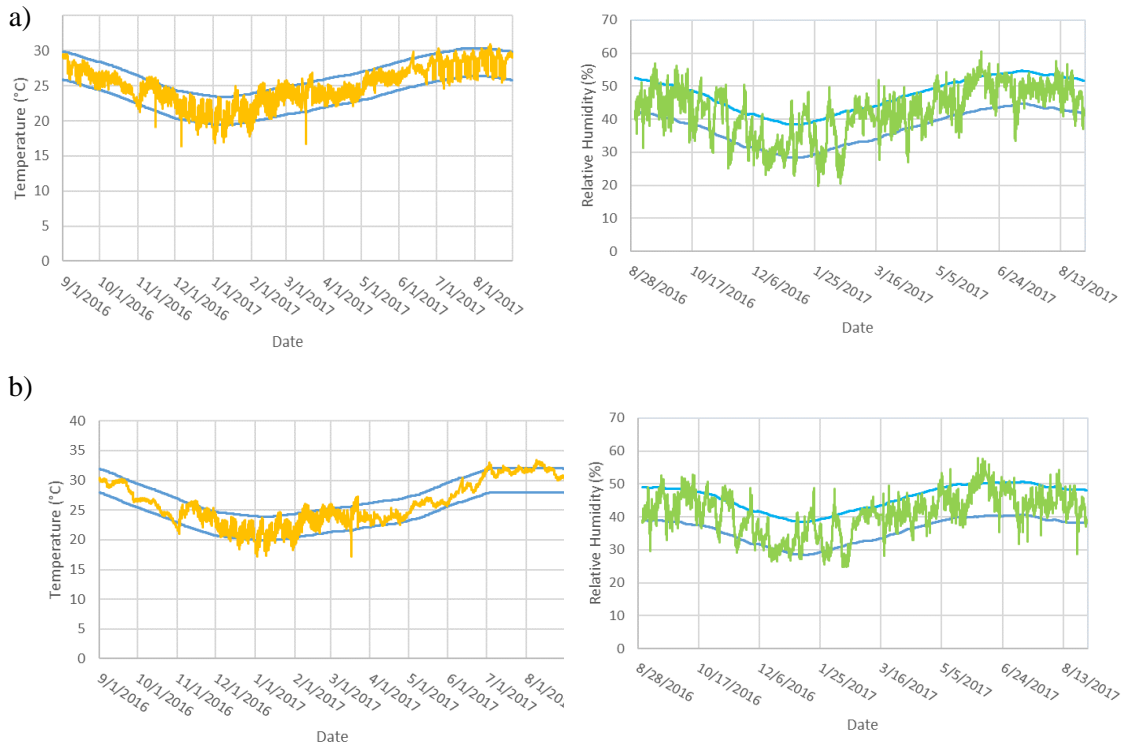


Figure 4. The running averages of T and RH data for a) the study hall and b) the first floor
 Note: Blue lines exhibit the allowable short-term fluctuations for T and RH on class A1

3.2. Degradation risks

Figure 5 depicts the biological degradation risks while figure 6 represents LM curve for the study hall and the first floor. Biological degradation risk was assessed with the help of isopleths. Assessment in both the study hall and the first floor were carried out based on superimposing the measured indoor climate data to limit curves (Figure 5). Figure 5 shows that the indoor climate of the library does not exceed the limit curve and stays in the safe region thus no risk of biological degradation exists. The figure 6 indicates that the LM values are between 0.75 and 1 for October 2016 and November 2016, which indicates that potential risk exists for chemical degradation. From May 2017 to October 2017, the LM data is below 0.75 which means that there is a high risk for chemical degradation. The reason of chemical degradation is high T and RH values. Mechanical degradation does not exist in the library according to the measurements.

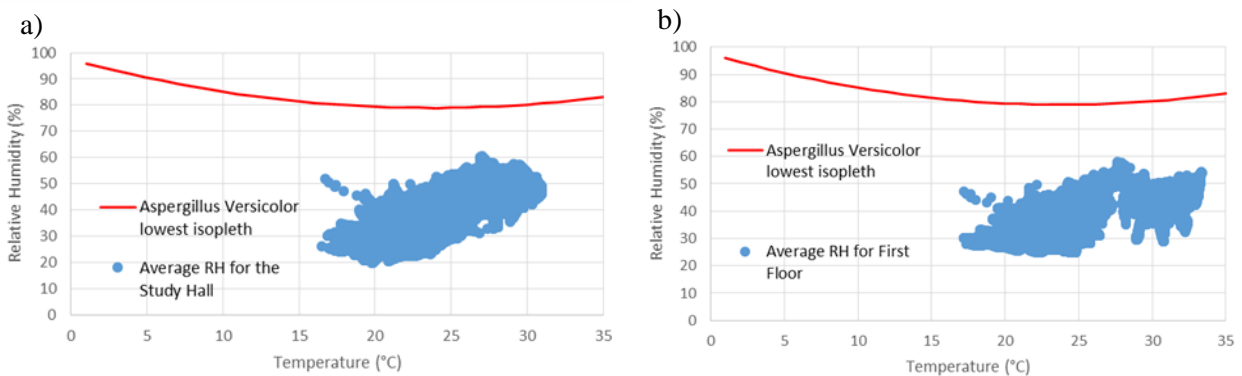


Figure 5. Biological degradation for a) study hall and b) the first floor

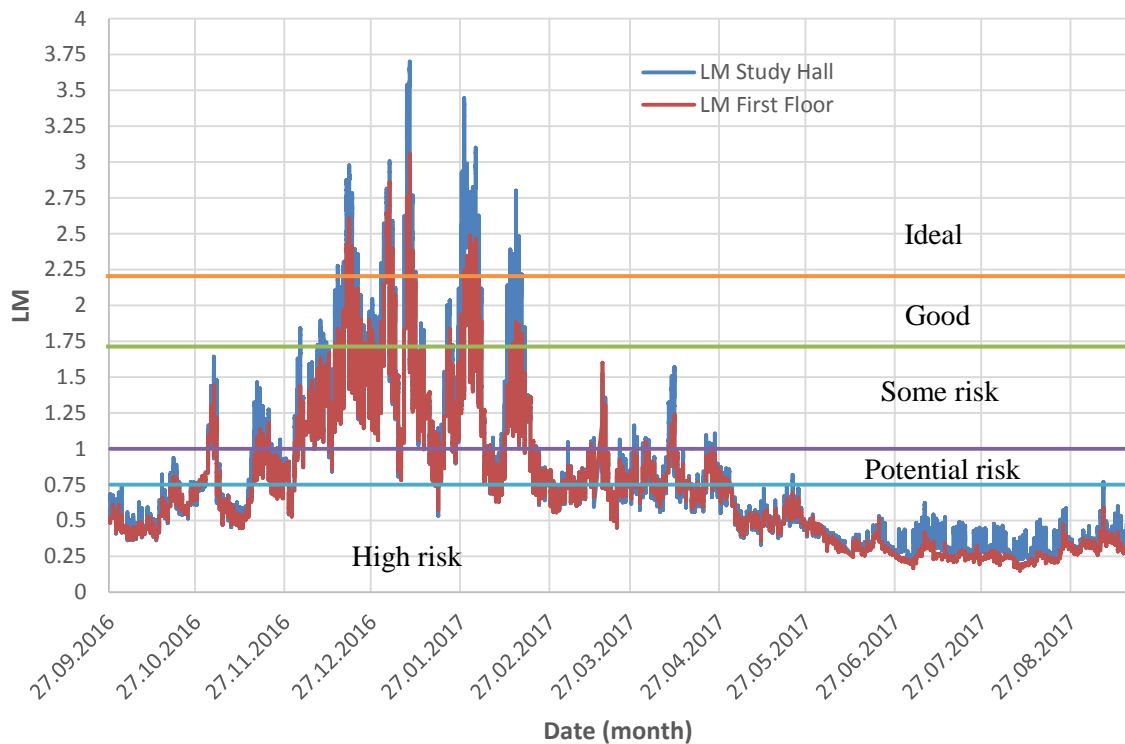


Figure 6. LM versus time for the study hall and the first floor

3.3. Thermal comfort surveys

Total of 340 surveys are conducted in order to evaluate thermal sensation of the visitors. 87% and 93% of the total votes are found as thermally acceptable for heating and cooling seasons, respectively. Predicted and preferred neutral operating temperatures for the heating season are calculated as 24.3°C and 23.9°C while the values are 26.2°C and 24.9°C for the cooling season. Both perceived neutral operating temperatures are in the limits of the recommended values by ASHRAE 55 and ISO 7730.

3.4. Thermal comfort analysis

The PMV and PPD values are calculated for heating and cooling seasons. PMV is obtained as +0.12 for heating season and +0.28 for cooling season while PPD values were 5% and 8%, respectively. The results indicate that visitors are satisfied with the thermal environment in the library.

4. Conclusions

Chemical, mechanical and biological degradation risks on the manuscripts and thermal comfort of visitors in a historic library, namely Izmir National Library, were investigated based on T and RH measurements. Based on the measured data, there were no mechanical and biological degradation risks on the manuscripts, while chemical degradation risk was observed due to the high indoor temperatures. The reason of high temperatures could be the shelves which behave like thermal buffer storage or high heating/cooling set point temperatures. In the library, as the surveys and PMV/PPD calculations indicated that heating/cooling system were operated based on thermal comfort of the visitors. However, the collections are under chemical degradation risk mostly in cooling season. Because of the stained-glass ceiling and glass tiles, the heat gains to the study hall and the first floor are high. Application of shading to the ceiling could have threefold advantage (i) reduce chemical degradation risk, (ii) increase comfort, (iii) reduce cooling need and thus enhance sustainability. Historic libraries are mostly lack of continuous monitoring system as Izmir National Library. For the preventive conservation of paper-based

collections, monitoring and control of the microclimate data based on the needs of the collections is essential.

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