

ANALYSIS OF DECAY RATES OF PAPER SAMPLES NATURALLY EXPOSED IN LIBRARY ENVIRONMENTS IN A SUBTROPICAL LOCATION

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RESULTS

The following table summarizes results of the monitoring period, which suffered seasonal variations (period's swing) and daily fluctuations of temperature (T) and relative humidity (RH), with a noticeable effect on TWPI values.

Table 1 - Summary of monitored data and TWPI obtained for each period

	Curitiba (library)	Curitiba (outdoors)	Curitiba (ΔT)	Caiobá (library)	Caiobá (outdoors)	Caiobá (ΔT)
T _{min} (°C)	12.8	2.6	10.2	14.6	7.8	6.8
T _{max} (°C)	32.9	35.3	-2.4	34.2	34.1	0.1
T _{avg} (°C)	23.2	19.2	4	24.4	20.9	3.5
Temp Swing (K)	20.1	32.7	-	19.6	26.3	-
RH _{avg} (%)	61	-	-	72	87	-
TWPI	Curitiba (library)	Curitiba (outdoors)	Relationship Indoor/Outdoor	Caiobá (library)	Caiobá (outdoors)	Relationship Indoor/Outdoor
After 12 months	0.38 (or years) 17	0.58 (or 26 years)	0.66	0.25 (or 11 years)	0.40 (or 18 years)	0.63
After 24 months	0.39 (or years) 18	0.59 (or 27 years)	0.66	0.26 (or 12 years)	0.40 (or 18 years)	0.65

With regard to local climatic conditions, Curitiba is situated approximately 910 meters above sea level, with a subtropical humid climate type according Köppen, whereas Caiobá, about 110 km from Curitiba, has a tropical wet climate type with lower temperature swing due to the proximity to the ocean and a high relative humidity throughout the year. The performance of both libraries can be expressed by the TWPI Relationship Indoor/Outdoor. Results suggest for measured conditions an inferior performance of indoor spaces relative to outdoor conditions.

Results of chemical testing on the samples before and after 12 and 24 months are presented in percentage changes over the control test, i.e. before natural exposure (only significant results are shown, i.e. variations which were higher than standard deviation obtained from each test run). Figure 2 shows the variation in dynamic viscosity after both periods of exposure, with a decrease in the initial value greater than 20% after twelve months in all cases. Such variations in viscosity result from the deterioration of cellulose chains. The largest changes were observed in samples exposed in Caiobá (at the coast), where the rate of reduction was 28% (outdoors) and 32% (indoors), both short-fiber samples.

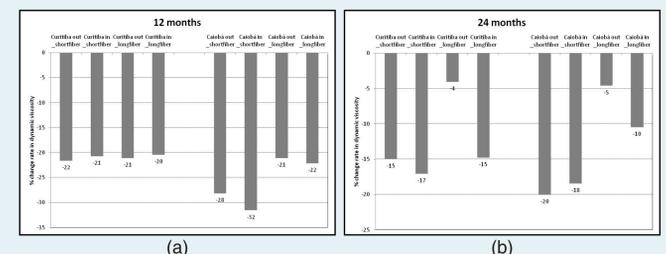


Figure 2 - Variation in Viscosity (%) after 12 (a) and 24 months (b)

ABSTRACT

Several factors affect paper degradation. Air temperature and humidity under inadequate conditions are among the most important ones. Such inadequate conditions will trigger biological, chemical and physical processes that may accelerate the deterioration process. In the present study, two types of paper were naturally exposed to different microclimate conditions, indoors and outdoors at two university libraries. One of the libraries is located in Curitiba (25° 30' S, 49° 20' W, 910m above sea level) and the other is situated in Caiobá (25° 49' 03" S, 48° 32' 34" W, on the sea coast). The aim of the study is to investigate how different, cyclical (24-hour cycles) and seasonal variations of humidity and temperature affect paper degradation, trying to determine under which climatic context larger paper decay rates take place. The theoretical indices PI (Permanence Index) and TWPI (Time Weighted Preservation Index), which quantify the effects of temperature and relative humidity on paper life expectancy, are used for comparison to observed decay rates in the lab. Chemical tests were performed, including viscosity and pH standard tests. The period of natural aging consisted of 24 months, with a mid-term data collection. The paper samples were placed in naturally ventilated acrylic boxes (41x41x16cm, 4mm thickness), which were coated with UV filter to block direct light and were provided with activated coal filters for pollutants control. The rationale was to allow almost exclusively only air temperature and humidity to have an impact on the paper samples. This box was used indoors as well as outdoors, whereas outdoors the box was placed in a Stevenson screen used in standard meteorological stations. Microclimatic data were recorded with data loggers in 1-h intervals; monitoring started in July 2010 through July 2012. The results of chemical tests correlated well with theoretical TWPI predictions.

METHOD

In this study, we adopted the natural exposure of paper samples (as opposed to 'accelerated aging' under lab conditions). The guiding hypothesis of the study is that the indoor microclimate can trigger chemical reactions promoting paper degradation, therefore reducing its permanence or longevity. Two types of paper were manufactured in the lab and naturally exposed to different microclimate conditions, indoors and outdoors at two university libraries. One of the libraries is located in Curitiba (25° 30' S, 49° 20' W, 910m above mean sea level) and the other is situated in Caiobá (25° 49' 03" S, 48° 32' 34" W, on the sea coast) (Figure 1).

The paper samples were produced with unloaded long- and short-fiber cellulose, without adhesives (bleached pulp, softwood and hardwood, respectively, 120 samples of each type measuring 10 x 25 cm, with an approximate weight of 60g/m²) at Laboratório de Papel do Arquivo Nacional (RJ). The samples were placed in naturally ventilated acrylic boxes (41x41x16cm, 4mm thickness), which were coated with UV filter for blocking direct light and provided with activated coal filters for pollutants control. The rationale was to allow almost exclusively only air temperature and humidity to have an impact on the paper samples. This box was used indoors as well as outdoors, whereas outdoors the box was placed in a Stevenson screen used in standard meteorological stations. Microclimatic data were recorded with data loggers in 1-h intervals; monitoring started in July 2010 through July 2012, thus consisting of 24 months, with a mid-term data collection.

The Permanence Index (PI) (Sebera 1994) and the Time Weighted Preservation Index (TWPI) (Reilly et al. 1995) were adopted, which both give an estimate of the effect of storage conditions (from combined temperature and relative humidity monitoring data) on the paper samples. Additionally, the percentage of time above the reference temperature (20°C) and the percentage of time above the reference relative humidity (50%) were quantified.

Chemical tests included dynamic viscosity (mPa.s) and pH standard tests, which were carried out at Laboratório de Celulose e Papel - Instituto de Pesquisas Tecnológicas - IPT /São Paulo.

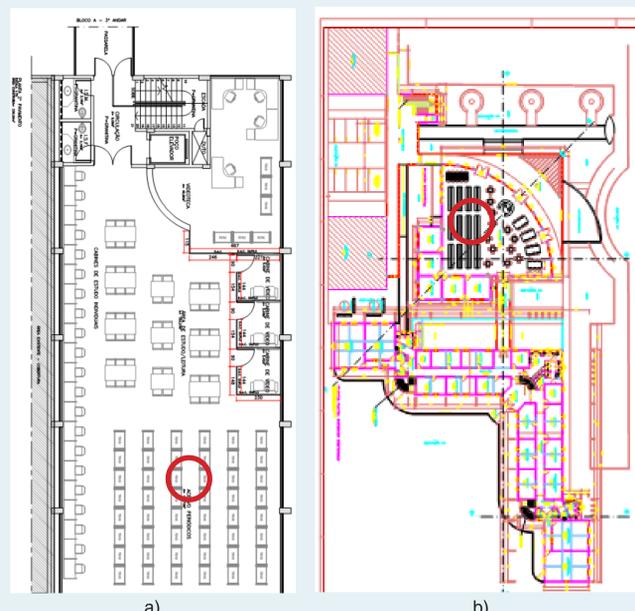


Figure 1 - a) Floor plan of the Journals Sector, Curitiba; b) Floor plan of the library at the coast (location of the samples highlighted)

INTRODUCTION

Cellulose-based materials stored in a given archive can undergo alterations with time, which may lead to degradation in three different manners: changes in dimensions, in chemical reactions and in biological degradation. The physical phenomena causing dimensional alterations are the expansion and contraction of organic materials, due to air temperature and humidity variations. Moisture absorbing materials, such as wood and parchment swell in high ambient relative humidity of the air and under low relative humidity such materials exhibit a contraction. The phenomena resulting from chemical reactions originate from elevated ambient temperature and moisture content, which may lead to discoloring, acid hydrolysis of cellulose in papers, weakening of textiles etc. Biological phenomena in turn affect all organic materials, generally associated with inadequate ventilation in high temperatures and moisture contents, whereas high humidity is likely to promote the growth of microorganisms.

Particularly temperature and humidity conditions have a direct effect on stored materials, requiring a set of actions to meet the collection's requirements, with the aim of preserving Cultural Heritage. Considering the high costs of permanently running HVAC systems, a viable and less costly alternative could be the implementation of passive strategies, eliminating or at least reducing the need of a permanent air-conditioning of the indoor space.

The purpose of this research is to evaluate two subtropical libraries in terms of well established standards from Preventive Conservation (ICOM-CC 2008, Thomson 1986, Guichen 1995) by means of continuous and concurrent indoor and outdoor ambient temperature and humidity monitoring. It is the aim of the study to verify whether for a limited monitoring period (two years) paper degradation could take place. The overall motivation for carrying out this research is to find possible ways to make international standards more flexible and suitable for libraries situated in tropical and subtropical regions.

CONCLUSIONS

From results obtained, correlations between observed paper decay rates (viscosity changes) and the calculated TWPI were somewhat higher than to other indicators (T, RH, Swing, percentage above recommended limits), but a cause for concern was the fact that reductions in viscosity were positively correlated with the longevity of the samples, expressed as TWPI. This is not to be expected. The distribution of fibers within each sample may have confounded results in this case. From TWPI data, it was concluded that paper permanence levels decrease indoors rather rapidly at both libraries.

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