

## DURABILITY OF PERMAMENT PAPER UNDER STORAGE CONDITIONS

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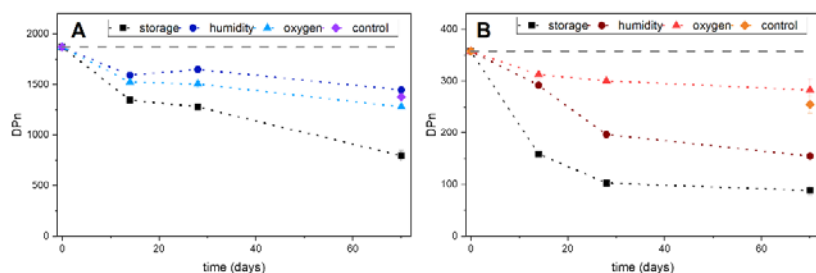
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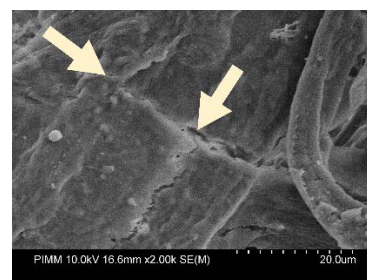
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Many printed documents from the 19<sup>th</sup> and 20<sup>th</sup> centuries are in a catastrophic degradation state, which is a major issue for libraries and archives. It is mainly due to the process that transforms wood into paper, which introduces acids that catalyze the hydrolysis of cellulose.<sup>1</sup> The standard for permanent paper (ISO 9706), which dates from the 1990s, addresses this major problem. It requires that an alkaline reserve such as calcium carbonate is used in the fabrication process, that aims at neutralizing the acidic compounds. Similarly, alkaline reserve deposition is required in deacidification treatments.<sup>2</sup> Another issue is the long-term preservation of data. Sensitive data, such as in nuclear waste archives, which report on the storage of radioactive waste, need to be accessible for five to six centuries with a limited cost. Estimating permanent paper lifetime would allow its use for such applications.

To estimate the kinetics of degradation, one needs first to identify the chemical mechanisms occurring during the ageing. In the case of paper, acid-catalyzed hydrolysis and oxidation are the two major causes. How these mechanisms interplay in the case of permanent paper is still not well understood. Accelerated ageing at 90°C in 4 different conditions was used to discriminate the parameters that influence the degradation of permanent paper: storage (in air at 50% relative humidity), humidity (under nitrogen, 50% RH), oxygen (air, 0% RH) and a negative control condition (nitrogen, 0% RH).



**Figure 1** – Evolution of DPn for permanent paper (a) and reference paper (b) over time under different ageing conditions



**Figure 2** – Permanent paper aged for 10 weeks under storage-like conditions after tensile stress test (SEM)

Size exclusion chromatography was used to determine the degree of polymerisation (DP) of the cellulose (**Figure 1**). The decrease of DP over time is slowed down for permanent paper compared to a reference paper (cotton paper Whatman n°40, acidic pH). We also show a synergistic effect between oxygen and water that we investigated measuring pH, alkaline reserve, and carrying out infrared spectroscopy of the paper. For permanent paper, no acidification is determined. This is consistent with the fact that alkaline reserve remains constant. However, a decrease of the DP was recorded. One hypothesis is that the permanent paper is more sensitive to oxidation from the oxygen in the air. Some mechanical properties such as strength and strain at break for tensile stress tests also decrease with ageing and can be correlated with the loss of DP. This can be explained by a decrease of the internal

strength of the fibres and by the breakage of interfibre bonds as observed by SEM (**Figure 2**). Chemical causes of degradation can be related to microstructural modifications of the fibres and its macroscopic consequences. Longer degradation times will be needed to make further conclusions about the mechanisms associated with the presence of alkaline reserve.

**References.**

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2. J. Baty, C. Maitland, W. Minter, M. Hubbe, S. Jordan-Mowery *BioResources* **2010**, *5*, 3.