Preserving the past through chemical engineering: Safe and sustainable applications in archives and libraries

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Archives and libraries are essential institutions for the preservation of cultural heritage, yet they remain highly vulnerable environments. Among the various risks they face, water damage, caused not only by natural disasters, but also by structural failures or human error, is a recurring threat. In such events, rapid and appropriate technological responses are crucial to halt degradation processes and restore affected materials to a usable condition.

In this framework, freeze-drying has proven to be an effective method for recovering water-damaged archival and library materials. This technique allows, in fact, for the controlled removal of water at very low temperature, thereby limiting further degradation and preserving the physical structure of documents. Another significant issue is microbial contamination, that exists in every Archive and that may affect documents even after the freeze-drying process posing risks to both stored materials and personnel. To address these threats effectively, a multidisciplinary approach that integrates chemical engineering with fields such as microbiology and conservation science is necessary. This perspective enables the development of safe, sustainable, and tailored solutions for cultural heritage protection.

In particular:

(i) The freeze-drying process has to be carefully designed in order to minimize the time needed to recover the flooded material, thus reducing the energy cost of the operation.

(ii) The microbial contamination can be mitigated using Essential Oils (EO) in the vapor phase, offering a natural, non-toxic alternative to conventional biocides, thus aligning with current demands for sustainable and health-conscious preservation practices. A recent experimental study, conducted by the Authors at the Archivio di Stato di Torino, has demonstrated the practical realization of EO treatment in vapour phase , proving it significantly reduced microbial load in indoor air, without compromising the integrity of the documents.

(iii) A system for risk-based decision making devoted to support the choice of the suitable preventive and protective measures to increase the resilience of the archives, based on relevant parameters - capital at risk, structural end environmental conditions - has been developed and validated.

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