Modelling Diethyl Phthalate plasticiser loss from Cellulose acetate artefacts in closed museum storage. Transient diffusion and time-dependent emissions.

Argyro Gili, Luca Mazzei and Katherine Curran

Deterioration of a plastic artefact due to plasticiser loss can depend on museum storage conditions, such as ventilation or temperature. The aim of this work is to describe how mathematical modelling of plasticiser loss from plastic artefacts in a closed storage provides significant information about the artefact degradation process in a non-ventilated museum environment. This information, enhanced by a comparison of the degradation rates inside boxes of different volumes, could facilitate a connection between the degree of degradation of the artefact and the means used for preventing it. Storing plastic artefacts in closed boxes is a common tactic in museums for preventing degradation. This model could be therefore useful for implementing different preservation techniques to a variety of objects in a customized way.

Plasticisers are compounds used during manufacture to change polymer properties (decrease glass transition temperature and increase flexibility). Diethyl Phthalate (DEP) has been one of the most commonly used plasticisers for Cellulose Acetate artefacts. Plasticiser loss due to mass transfer from plastic artefacts in museums and collections leads to brittleness and the presence of sticky residues and crystals on the surface of objects, which significantly affects their aesthetic value. Therefore, it is crucial to prevent plasticiser loss and maintain artefacts value. Plasticiser loss and volatile emissions have been studied experimentally in the heritage sector, but mathematical modelling has been limited in the field. So, it would be valuable to develop a mathematical model as a tool for predicting plasticiser loss over time in different ventilation conditions.

In this work, the model is one-dimensional and assumes loss of DEP from a Cellulose Acetate slab of uniform initial DEP concentration. The transient diffusion of plasticizer within the Cellulose Acetate slab is predicted by solving the model with appropriate boundary conditions set at both surfaces of the sample. One surface of the slab is assumed to rest upon an impermeable solid surface inside a closed box; on it, the mass flux of plasticiser is set to zero. The other surface of the slab allows the DEP to freely diffuse out into the box containing the artefact; here, the mass flux of DEP is expressed in terms of an external mass transfer coefficient and the DEP concentration difference between the values at the object surface and in the bulk of the air present in the box. To determine the evolution of the latter, a DEP mass balance equation is solved for the box, which is assumed to be perfectly mixed, so that the concentration of plasticizer is uniform.

Predicting plasticiser loss over time, from samples inside closed storage of specific volumes, is important, as it indicates the degree to which degradation could be hindered with the use of specific storage boxes. Furthermore, predicting emissions of a plasticiser into closed storage could constitute an additional means of calculating loss. The proposed model could therefore be a promising tool to foresee degradation rates and suggest methods to prevent deterioration with the use of specific volume storage.