Supplementary Materials

Parchment Environmental Conditions

In connection with the storage, exhibition, and conservation/restoration of parchment objects, it is important to focus on factors and actions which can initiate or accelerate the deterioration of either text and paint layers or the parchment support. Light, heat and pollution may cause damage as does corrosion of iron gall inks or fading and colour changes to paints. However, in many cases damage to the text and paint layers is directly related to damage of the parchment structure (e.g., cracking, flaking etc.). Parchment degradation tends to develop from an intact fibre structure of high hydrothermal stability through different stages of fibre structure changes and decreasing physical and hydrothermal stability. The degradation may progress to a terminal stage with a considerable disintegrated fibre structure that is transformed into a gelatinous substance by contact with water or storage in moist conditions or into small fibre fragments without any detectable hydrothermal activity. At the macroscopic level these changes may be reflected in the characteristics like colour, stiffness, thickness, transmission of light etc. of the parchment.

The specific aged samples are grouped into four categories according to the measured or estimated degree of damage observed:

1. Undamaged: no or very small changes.
2. Slightly damaged: minor changes (may include shrinkage of a few fibres at room temperature).
3. Damaged: changes (may include fibres shrinking and/or gelatinising at room temperature).
4. Heavily damaged: major changes (may include partly or totally melting of fibres).

The definitions of damage set out above is primarily focused on the parchment structure at the macroscopic and microscopic level. Therefore, to be used as a damage assessment tool in conservation and restoration activities, it should be supplemented by an assessment protocol for text, illuminations etc. The IDAP assessment protocol is based on a general evaluation of the appearance and condition of the whole parchment (both sides of a single sheet) followed by a more intensive evaluation of selected specific areas of a well-defined circular size. The selection of the specific area depends on the interest of the study.

It is not possible to define a precise deterioration state of a single sheet or piece of parchment, the chemical and physical state, surface colour and other characteristics varies; the pattern of damage depends on the damage history which can be uneven distributed on a sheet of parchment. In general, uniform damage reflects, relatively speaking, the same influence from exposure to the environment or perhaps a conservation treatment covering the whole parchment area. Whereas a non-uniform damage picture reflects variations in environmental affects, or variations in exposure of different parts of the parchment area, for example the difference in damage of the back and hinges of the same bookbinding or of the edges and mid part of a parchment sheet in a book block.

A non-uniform damage picture also reflects exposure to different sources of deterioration in different areas of the parchment such as humidity, light, tear, human touching, local attacks from animals, insects' micro-organisms etc.). The deterioration can have a permanent progressing character caused by environmental factors such as pollution, heat, and moisture, or it may be occasional damage caused by human handling, fire, flood, insects etc. Occasional damage may stay in a relative fixed state of deterioration for a relative long period of time, however, when the damaged area is exposed to other damaging factors its deterioration may progress faster than the surrounding less damaged areas. In many cases the grain layer, may be more damaged than the corium part of the parchment structure, which is especially problematic in cases where the grain layer has been used for writing and illumination. Moreover, the damage may be superficial or penetrate part of or the whole structure from outside in.

Slightly damaged: minor changes may include shrinkage of a few fibres at room temperature

Parchment is extremely sensitive to changes in relative humidity and temperature. Even minor variation in these factors may cause changes in its dimensions (area and thickness) resulting in curling and waving of the structure. Moreover, dimensional changes of the parchment may cause damage to text and paint layers.

High relative humidity may accelerate chemical degradation and attack of micro biological attack of the parchment structure. In this damage category it may be expected that a few fibres are damaged to an extent that they may shrink irreversible at room temperature by exposure to a high relative humidity or moist treatment.

High temperature, light and electromagnetic radiation accelerates oxidative reactions leading to degradation of the parchment fibres, binding media, and pigment layers. High temperature may also dry out the parchment structure which may cause the parchment to stiffen.

Low temperature in combination with a high relative humidity may cause condensation of water on the surface of the parchment. Especially attention should be put to closed showcases where condensation may happen when the temperature in the surrounding drops. This situation may create an ideal microclimate for microorganisms and accelerate chemical reactions etc.

The following general precautions and recommendations are based on the present state of the art of knowledge and experience on the damage of parchment and the influence of damaging factors in the environment on or by treatment of parchment. New knowledge and experiences may therefore lead to detailing or modifications of the precautions and recommendations.

It is recommended to use the IDAP EWS parchment sensor system and data logger for measurement of relative humidity and temperature to control the environmental and warn against damaging factors in surroundings. This could with advance supplemented with other types of more specific sensors to early warning of damaging factors like acidic and oxidative pollutants.

In general, all parchment should be kept in a clean, dark and stable environment in protective boxes or other forms for protection from direct exposure to the environment of the storage room following the recommended parameters in the table below.

By exhibition, the parchment should be kept in showcases with clean stable environment secured from physical stress, pollution and a high light pressure.

ISO 11799 (2003) recommends temperatures between 2-18°C and RH between 50-60%. However, some micro-organisms thrive at 60 % RH. We therefore recommend not go higher than 55%. In mixed collections containing acid papers, it may be advisable to keep the RH as low as 45%.

Damaged: changes (may include fibres shrinking and/or gelatinising at room temperature)

Parchment is extremely sensitive to changes in relative humidity and temperature. Even minor variation in these factors may cause changes in its dimensions (area and thickness) resulting in curling and waving of the structure. Moreover, dimensional changes of the parchment may cause damage to text and paint layers.

High relative humidity may speed up chemical degradation like hydrolysis of especially parchment acidified by pollution and other chemical reactions and attack of micro biological attack of the parchment structure. In this damage category it may be expected that several fibres are so damaged that they may shrink, gelatinise, melt and/or fragmentise irreversible at room temperature by exposure to a high relative humidity or moist treatment. In some cases, the fibre transformation may even take place at normal relative humidity conditions (50-55 %).

High temperature and light accelerate oxidative reactions leading to degradation of the parchment fibres, binding media and paint including fading of paint colours. High temperature may also dry out the parchment structure which will cause the parchment to stiffen.

Low temperature in combination with a high relative humidity may cause condensation of water on the surface of the parchment. Especially attention should be put to closed showcases where condensation may happen when the temperature in the surrounding drops. This situation may create an ideal microclimate for microorganisms and accelerate chemical reactions etc.

The general precautions and recommendations which follow are based on the current state of knowledge and experience on parchment and the influence of damaging environmental factors or by conservation treatments. New knowledge and experiences may therefore lead to detailing or modifications of the precautions and recommendations. In this connection we like to recommend trials to test and establish the optimum conditions with respect to relative humidity and temperature for storage of parchment in different stages of deterioration. This should include the effect of freezing heavily damaged parchment to stop the process of gelatinising.

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In general, all parchment should be kept in a clean, dark and stable environment in protective boxes or other forms for protection from direct exposure to the environment of the storage room following the recommended parameters in the table below. Parchment in this damage category should be kept cold in under very stable condition of temperature and relative humidity to avoid spontaneous shrinkage or gelatinisation.

Only short-term exhibition (e.g., or research purposes) in well regulated and controlled environment should be allowed for parchment in this damage category. Storage and exhibition conditions should be the same with respect temperature and relative humidity.

It is recommended to make safety copies of the parchment with text and illuminations for research and exhibition purposes. Take care not to expose the parchment to damaging conditions during the copying.

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Heavily damaged: major changes (may include partly or totally melting of fibres)

Parchment is extremely sensitive to changes in relative humidity and temperature. Even minor variation in these factors may cause changes in its dimensions (area and thickness) resulting in curling and waving of the structure. Moreover, dimensional changes of the parchment may cause damage to text and paint layers.

High relative humidity may speed up chemical degradation like hydrolysis of especially parchment acidified by pollution and other chemical reactions and attack of micro biological attack of the parchment structure. In this damage category it may be expected that several fibres are so damaged that they may shrink, gelatinise, melt and/or fragmentise irreversible at room temperature by exposure to a high relative humidity or moist treatment. In some cases, the fibre transformation may even take place at normal relative humidity conditions (50-55 %).

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The general precautions and recommendations which follow are based on the current state of knowledge and experience on parchment and the influence of damaging environmental factors or by conservation treatments. New knowledge and experiences may therefore lead to detailing or modifications of the precautions and recommendations. In this connection we like to recommend trials to test and establish the optimum conditions with respect to relative humidity and temperature for storage of parchment in different stages of deterioration. This should include the effect of freezing heavily damaged parchment to stop the process of gelatinising.

It is recommended to use the IDAP EWS parchment sensor system and data logger for measurement of relative humidity and temperature to control the environmental and warn against damaging factors in surroundings. This could with advance supplemented with other types of more specific sensors to early warning of damaging factors like acidic and oxidative pollutants.

In general, all parchment should be kept in a clean, dark and stable environment in protective boxes or other forms for protection from direct exposure to the environment of the storage room following the recommended parameters in the table below. Parchment in this damage category should be kept cold or frozen (in case gelatinisation of the parchment takes place below room temperature) under very stable condition of temperature and relative humidity.

Only the most necessary short-term exhibition (e.g. or research purposes) in well regulated and controlled environment should be allowed for parchment in this damage category. Storage and exhibition conditions should be the same with respect temperature and relative humidity.

It is recommended to make safety copies of the parchment with text and illuminations for research and exhibition purposes. Take care not to expose the parchment to damaging conditions during the copying.

Information on Dynamic Mechanic Analysis with controlled relative humidity (DMA-RH)

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DMA measures the mechanical response of materials to the application of a sinusoidal stress or strain. The sample is clamped and a sinusoidal (1Hz in this instance) stress applied. Dynamic force is applied to achieve the dynamic strain specified in the method (0.1%) and the static force is automatically adjusted from the magnitude of the dynamic force to ensure that the sample remains in tension and does not buckle. As sample is humidified and modulus changes this will alter the static displacement (labelled as D% in the main text) under the applied static force. The change in dimension, strain is measured. In this work the RH around the sample is controlled accurately and differences in response at different RH values determined. Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. The component of each can be determined from processing DMA data.

Atomic Force Microscopy (AFM)

AFM is a very high resolution imaging technique mapping the interaction of a sharp tip with the surface. AA cantilever with a sharp tip (usually silicon or silicon nitride~10 nm in radius) at its end is raster-scanned on a surface, providing information to re-create a 3-D contour image. It can measure the contours of a sample by keeping the force between the sample and tip constant with a feedback loop. Most atomic force microscopes use an optical cantilever system for force feedback [550]. A laser beam is directed at the back of the cantilever and reflected onto a photodetector that is divided in four segments. The signals from the four segments are used to calculate the vertical and lateral deflection of the probe. The deflection is used by a feedback loop to keep the force between the probe and the sample constant by adjusting the cantilever height with a piezo crystal [505].