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Butvar® B-76-Coated Japanese Tissues for Non-Aqueous Lining of Paper Documents

Butvar® B-76-beschichtetes Japanpapier für die nicht-wässrige Kaschierung von Papier

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Abstract: In this study, an alternative method for non-aqueous and non-alcoholic lining of paper documents is proposed, with Japanese tissue paper pre-coated with polyvinyl butyral (Butvar® B-76) adhesive used as the lining material. The adhesive layer is activated with a solvent mixture of dimethyl carbonate and *n*-hexane. The findings of the conducted tests indicate that the proposed method is safe with regard to the tested writing and printing media. Furthermore, it does not alter the paper structure or cause any deformation of the folios. In order to evaluate the effectiveness of the lining and the ageing characteristics of the pre-coated tissue, the mechanical properties of the lined samples, their colour stability, the pH values of the aqueous extracts and the removability of the lining tissue were tested both before and after accelerated degradation. The results were considered satisfactory.

Keywords: Butvar® B-76; coated Japanese tissue; non-aqueous paper lining

Zusammenfassung: In dieser Studie wird eine alternative Methode zur nicht-wässrigen und nicht-alkoholischen Kaschierung von Papier vorgeschlagen, bei der mit Polyvinylbutyral (Butvar® B-76) beschichtetes Japanpapier verwendet wird. Die Klebstoffschicht wird mit einem Lösungsmittelgemisch aus Dimethylcarbonat und *n*-Hexan aktiviert. Die Ergebnisse der durchgeführten Tests zeigen, dass die vorgeschlagene Methode die geprüften Schreib-und Druckmedien nicht verändert. Darüber hinaus bleibt auch die Papierstruktur ohne Verformungen der Blätter

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unverändert. Um Langzeiteffekte der Kaschierung und die Alterungseigenschaften der kaschierten Probepapiere zu bewerten, wurden mechanische Eigenschaften sowie Farbstabilität, pH-Wert der wässrigen Extrakte und Reversibilität sowohl vor als auch nach beschleunigter Alterung geprüft. Die Ergebnisse wurden als zufriedenstellend angesehen.

Schlüsselwörter: Butvar® B-76; beschichtetes Japanpapier; nicht-wässrige Kaschierung

1 Introduction

Large quantities of damaged paper documents, typically archival records, cannot be safely treated using traditional aqueous conservation methods. The most common causes are the presence of unstable writing or printing media, the risk of tidemarks, and paper deformation. A number of alternative, non-aqueous methods have been proposed, indicating not only the importance of the problem, but also the difficulty of solving it. Some of them use organic solvents or keep the amount of water used to a minimum (Ubbink and Partridge 2003; Pataki 2009; Titus et al. 2009; Anderson and Reidell 2009; Jacobi et al. 2011; Lechuga 2011; Lehovec 2013; Zervos and Alexopoulou 2015; Bedenikovic et al. 2018), while others choose to avoid solvents completely, preferring adhesives that can be activated by heat or pressure (Anderson and Reidell 2009; Sheesley 2011; Down et al. 2011; Hrbáčková 2011; Jamison 2013; Zervos and Alexopoulou 2015; Bedenikovic et al. 2018). Each of these approaches represents a different compromise.

Currently, the first group is mainly represented by the use of various self-prepared remoistenable tissues. The results are generally aesthetically satisfying, as these methods usually use very thin Japanese tissues, but sometimes unwanted gloss can be difficult to avoid. The pre-coating of the tissue can be a relatively time-consuming process that requires experience. During the application step, it is of utmost importance to ensure that an adequate amount of the activating solvent is evenly distributed, especially if water is used (Jacobi et al. 2011). This is not an easy task and is one of the main factors that limit the area which can be lined in this way. The most common non-aqueous solvent used is ethanol or isopropyl alcohol. However, even these dissolve many dyes and inks, which narrows the scope of the respective methods. The final adhesion of the remoistenable tissues is usually rather lower (Ubbink and Partridge 2003; Anderson and Reidell 2009; Pataki 2009; Titus et al. 2009; Lechuga 2011; Lehovec 2013).

Lining using thermoplastic adhesives inherently presuposses the thermal stability of the treated document. Given the short exposure time, this can be accepted in

many cases. However, the application of thermoplastic foils often changes the gloss of the original paper and its haptic properties. Gloss can be avoided, e.g., by using a thicker paper support, but at the cost of reducing the flexibility of the document and possibly reducing the legibility of the text. Removability of the lining is usually not possible without the use of organic solvents if it is to be complete. Also, many adhesives contain additives whose long-term stability has not been fully verified (Anderson and Reidell 2009; Down et al. 2011; Hrbáčková 2011; AIC 2025).

Pressure sensitive tapes are mainly used for local repairs, rather than routine lining purposes (Wächter 1988; Sheesley 2011; Neschen Coating 2025). The practical experience shows that the removability of adhesives used after long-term ageing may be difficult (Vávrová et al. 2015).

For bound material, most methods are suitable for local repairs only. Otherwise, their application is associated with the risk of dimensional changes and deformation or, conversely, unwanted flattening and altering the natural deformation of the paper.

The method proposed in this work can be classified as one of the methods that use pre-coated remoistenable tissues activated by a non-aqueous solvent. Although it does not address all the aforementioned shortcomings of related methods, the authors believe that it offers specific advantages that make it an interesting alternative.

2 Description of the Proposed Method

2.1 Solvent Selection

It is important for the intended use that the solvent used does not dissolve most writing and printing media. On the other hand, the solvent must be able to dissolve synthetic polymers that can act as adhesives. The solvent should have a relatively slow evaporation rate to facilitate pre-coated tissue preparation.

Following a comparison of the literature data on the physico-chemical and toxicological properties of selected groups of organic solvents (alcohols, ethers, ketones, esters, aromatic and aliphatic hydrocarbons), and the preliminary testing of their effect on selected writing and printing media, dimethyl carbonate (DMC, Carl Roth, Germany) was chosen as an acceptable compromise. Its boiling point is 90.1 °C at 101.3 kPa, vapour pressure 5.7 kPa at 20 °C (Zhou et al. 2011; Carl Roth 2024). The given vapour pressure value is similar to that of ethanol, suggesting its evaporation rate is comparable as well.

Although DMC is considered a low toxicity, “green” solvent, it is still an irritant and flammable liquid. When working, it is therefore necessary to use personal protection, such as respiratory protection and gloves, work in a well-ventilated area and follow the principles of safe work (Carl Roth 2024).

2.2 Paper Support Selection

As a support material, the readily available Japanese tissue RK-00 was chosen, which represents an acceptable compromise between strength and aesthetic unobtrusiveness of the lining (pH 6.8 ± 0.1, 100 % kozo, 3.6 g m^{-2}, Ceiba, Czech Republic).

2.3 Adhesive Selection

Based on compatibility with DMC, a series of tests and literature research, Butvar® B-76 (polyvinyl butyral, hydroxyl content 11.5–13.5 %, acetate content ≤ 2.5 %, butyryl content approx. 88 %, molecular weight 90,000–120,000, T_g = 62–72 °C, Eastman Chemical Company, U.S.) was selected as an adhesive (Eastman Chemical Company 2013).

In the context of this work, the poor solubility of Butvar® B-76 in DMC (Eastman Chemical Company 2012) is significant, as will be discussed below. Films prepared using ethanol solutions of Butvar® B-76 can exhibit a whitish haze, especially under humid conditions (Zhang et al. 2011). The DMC formulations of Butvar® B-76 are much less prone to this problem. Also favorable is the fact that its films show only a moderate gloss.

Polyvinyl butyrals (PVBs) form a broad group of materials. Some of them have been used for conservation purposes since the 1960s with more or less success as adhesives and consolidants for various materials including paper (Hayworth 1971; Höge and Hanzlová 1979; Wächter 1988; Feller et al. 2007; Horie 2013; Carrot et al. 2015; Zervos and Alexopoulou 2015). PVBs are generally considered stable materials, although they may show signs of photooxidation such as slight yellowing, chain scission, and crosslinking due to prolonged exposure to light (Hayworth 1971; Reinoehl et al. 1981; Wächter 1988; Feller et al. 2007; Feller 2008; Thomas et al. 2017). The ratio of chain scission and crosslinking during photooxidation depends on the exposure temperature and the wavelength of the radiation. While cleavage predominates at room temperature, shortwave radiation favours crosslinking (Spyridowicz et al. 2001; Feller et al. 2007; Feller 2008; Thomas et al. 2017).

According to some authors, PVB types with a high content of hydroxyl groups are more susceptible to crosslinking in the presence of acids and aldehydes than others (Horie 2013; Thomas et al. 2017). The yellowing and possible solubility changes of Butvar® B-76 during accelerated degradation were tested as part of this work.

2.4 Pre-Coating of Japanese Tissue

When pre-coating the Japanese tissue, great care must be taken when selecting a work support. It is very comfortable to work with, for example, stiff polypropylene

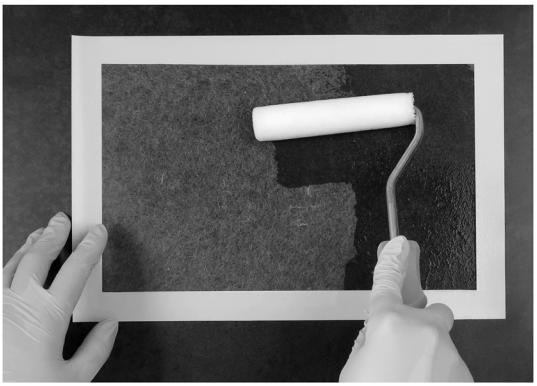

Figure 1: Application of adhesive solution on Japanese tissue, supported by a polypropylene frame.

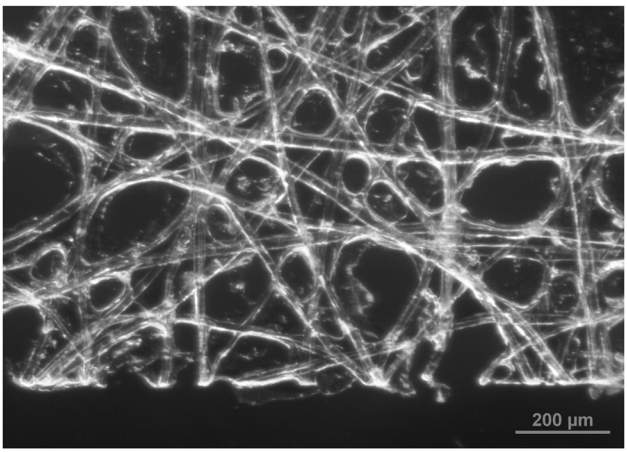

Figure 2: The edge of Butvar® B-76-coated Japanese tissue.

foils which are well wetted by the adhesive and the formed pre-coated tissue can be removed without difficulty at the same time. A frame, cut from a thinner polypropylene foil, is placed on the working support. This will later facilitate the removal and the manipulation of the pre-coated tissue. The Japanese tissue, the size of which slightly exceeds the window of the frame, is then placed on the top. Using a paint roller, a layer of adhesive solution (5 % Butvar® B-76 in DMC at approx. 23 °C, Figure 1) is applied to the Japanese tissue paper. The use of a roller eliminates the risk of tearing the thin Japanese tissue. Ideally, the adhesive should envelop the individual fibers of the Japanese tissue rather than form a continuous layer (Figure 2). The actual consumption of adhesive solution for film preparation is about 120 ml m^{-2}, the amount of adhesive applied is on average 4.4 g m^{-2}.

The use of a relatively small amount of adhesive in relation to the grammage of Japanese tissue is recommended not only to reduce gloss but also to reduce consequences of possible degradation during ageing. However, for thicker Japanese tissues, the optimal proportion of the adhesive may be different, as more of the Butvar® B-76 solution is absorbed by the paper fibres.

Using a hair dryer, the pre-coated tissue can be dried in a few minutes. The foil frame then facilitates its safe removal from the work support. When removed in the above manner, the tissue is not prone to curling and can be stored for later use. The process is relatively simple and robust. This means that minor changes in the specified concentration or amount of adhesive applied can be tolerated.

2.5 Application of the Pre-coated Tissue

The paper to be lined should be placed on an impermeable solid support, which has to be sturdy but not necessarily strictly planar. The surface of the paper is covered with a pre-coated tissue so that it is in contact with the adhesive layer. The pre-coated tissue is strongly pressed against the treated paper using a paint roller slightly soaked in activating solution, i.e., a mixture of DMC (1 part by volume) and *n*-hexane (5 parts by volume). The reason for diluting the DMC with *n*-hexane is both to reduce the consumption of DMC and to further limit the dissolution of the Butvar® B-76 layer. The aim is to swell the adhesive, not to dissolve it, which could lead to its excessive absorption into the paper fibres. The dilution of DMC is not strictly necessary, but it allows relatively safe and generous work even when using larger tissue sizes. After drying, the other side of the paper can be lined in the same way.

During the review process of this study, it was suggested that *n*-hexane could be replaced by *n*-heptane as a part of the solvent activation mixture. The properties of *n*-heptane are very similar to those of *n*-hexane, but it is considered to be less toxic. In any case, it is still necessary to use the means of personal protection and to work in a well-ventilated area.

3 Properties of Pre-Coated Tissues and Linings – Methods and Materials

3.1 Stability of Writing Media and the Formation of Tidemarks

The stability of writing and printing media on different types of paper (Table 1) was tested by exposing them to both DMC and the activating solvent mixture. Various

Table 1: Papers used for test samples preparation.

Paper type	Specification	Manufacturer
Offset paper	Bleached chemical pulp, 80 g m^{-2}	Neograph, Czech Republic
Handmade graphic paper	Rag paper, 120 g m^{-2}	Velké Losiny, Czech Republic
Writing machine made paper	Mechanical and bleached sulfite chemical pulp, 70 g m^{-2}	Stráž, tisk. záv. n.p., Czech Republic

types of modern inks, stamp inks, copying pencils, black printing inks, and watercolours were tested. These represent some of the most problematic media with regard to their stability in water and alcohols. A blotting paper wetted with the solvent or solvent mixture was pressed against the paper containing the tested media for 20 s. This approximates the exposure time of the media to the activating solvent mixture. Both papers were then separated and allowed to dry freely. The stability of the media were evaluated by comparing samples before and after exposure to solvents under the microscope.

The tendency of water, ethanol, DMC, and the activation solvent mixture to form tidemarks when applied locally was assessed for all three types of paper. A 50 µl drop of each solvent was dispensed onto the paper surface, the samples were allowed to dry freely and visually inspected.

3.2 Reinforcement of Model Samples

The purpose of lining is to compensate for the deterioration of the mechanical properties of the treated paper. In the extreme cases of bridging cracks and tears, the lining substitutes the structural function of the paper completely.

The strength of such bridging was tested on samples prepared from stripes of offset paper of 15 × 100 mm (Table 1), which were cut transversally to simulate a "breakage" and joined again from one or both sides using the pre-coated tissues. The resulting samples were subjected to the tensile test based on ISO 1924-2:2008 standard (L&W Tensile tester, ABB, speed rate 100 mm min^{-1}, clamp distance 50 mm, machine direction). As reference samples, plain and pre-coated Japanese tissues, and a stripe of uncut offset paper were used. Ten samples were measured for each sample type.

The stability of the pre-coated tissue and lined offset paper samples was tested also under conditions of accelerated degradation, i.e. the combined exposure to heat and humidity in the climate chamber (Espec PR-2KP, 28 days at 55 °C and 65 %). These

parameters generally followed the recommendation of the ISO 5630-3:1996 standard. An exception was made for the temperature, which was chosen lower not to exceed the glass transition temperature of Butvar® B-76 polymer.

3.3 Adhesion

The samples of lined offset, handmade and writing paper (Table 1) were subjected to the peel test. Tested papers were covered by the pre-coated tissue. One half of the pre-coated tissue was adhered to the paper using the activating solvent mixture, the other half was left unadhered, but was reinforced using thin stiff paper to allow it to be firmly fixed in the test instrument. Figure 3. shows the test design with the prepared samples. From the samples prepared in the described way, test stripes of 15 × 150 mm were cut. An L&W Tensile Tester equipped with an extension made according to DIN 53357 standard was used as a test instrument (wheel diameter 90 mm, peel angle 90°, speed rate 100 mm min^{-1}, machine direction). The variable evaluated was the maximum peel force. Ten samples were measured for each paper support.

3.4 pH Values of Lined Papers

The pH values of the cold aqueous extracts were determined for both untreated and lined samples of offset, handmade and writing paper. Samples were measured before

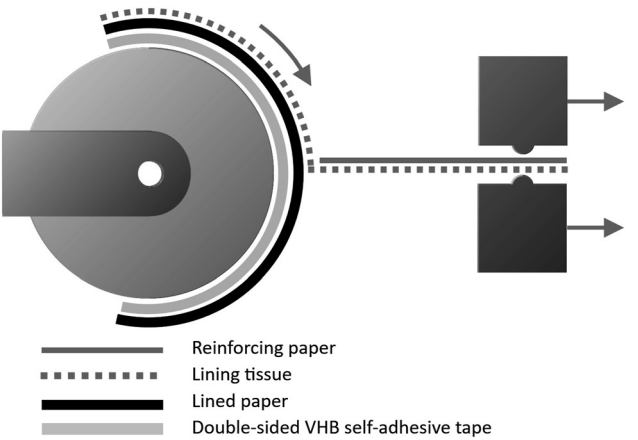

Figure 3: Peel test schematic.

and after accelerated degradation (55 °C, 65 % RH), as specified in Section 3.2. The procedure followed the recommendation of ISO 6588-1:2021 standard. Two grams of paper samples, torn into pieces, were extracted in 100 ml of demineralized water for 1 h. Subsequently, pH value of the decanted extract was measured (pHmeter Thermo Scientific OrionStar A211, electrode WTW SenTix Mic). Four samples were measured for each sample type.

3.5 Discoloration

Colour changes which took place as a consequence of lining and during accelerated ageing were determined for samples of offset, handmade and writing paper. The plain and pre-coated Japanese tissue samples were measured as well.

The colour changes were tested under two accelerated degradation conditions. The first method used the combined exposure to heat and humidity, as specified in Section 3.2, the second method was based on the samples' exposure to light (Q-Sun Xe-1, illuminance: 40 klx, total irradiance 20 W m^{-2}, wavelengths < 400 nm blocked using UV blocking X-10521 filter supplied by Q-Sun, isolated black panel temperature 26 °C, exposure duration 240 h). The illuminance value was derived from the recommendation of ISO 5630-7 standard, describing the estimation of paper colour stability. UV radiation was blocked, as it should be in study rooms, repositories and exhibition rooms.

Colour changes were expressed as differences of L^*, a^*, b^* parameters in CIELAB colour space and the total colour difference (ΔE^*) calculated on their basis. These parameters were measured using a Konica Minolta CM2600d spectrophotometer (illuminant D65, SCE mode, standard observer 10°, UV radiation excluded, aperture 8 mm).

3.6 Removability of the Pre-Coated Tissue

Lined offset, handmade and writing paper samples were used for removability tests. Additionally, untreated papers were used as reference samples for FTIR measurements. Removability was tested both immediately after the application of the pre-coated tissue and after accelerated degradation (28 days, 55 °C, 65 % RH).

The Japanese tissue was removed after wetting with the activating solvent mixture for several seconds. Subsequently, the residues of the swollen adhesive were wiped off using a cotton swab wetted with DMC. The work was carried out at

laboratory temperature (c. 23 °C). The success of the removal was evaluated visually and further analyzed by FTIR spectroscopy for residual adhesive.

The FTIR analysis was performed on a Nicolet iZ10 FTIR spectrometer in ATR mode (diamond crystal, number of spectrum accumulations 64, resolution 4 cm^{-1}, liquid nitrogen-cooled MCT-A detector). The interpretation of the results was based on the absorbance of the samples at 1,740 cm^{-1}. The corresponding band is generally well separated and can be attributed to the vibrational mode of acetate (carbonyl) groups of polyvinyl butyral polymer (Nikitakos et al. 2023). Five parallel measurements were carried out for each sample type.

4 Properties of Pre-Coated Tissues and Linings – Results and Discussion

4.1 Stability of Writing Media and the Formation of Tidemarks

As would be expected, many of the tested media were found to be unstable in water and ethanol. Typical examples included copying pencils, stamp inks, and fountain inks. In contrast, all of the tested media could be considered stable both in DMC and the activation solvent mixture under normal working conditions, regardless the type of paper used as a writing support. Selected results obtained for the writing paper are shown in Figure 4. Of course, it is still recommendable to carry out a preliminary test of the writing and printing media stability before conservation treatment.

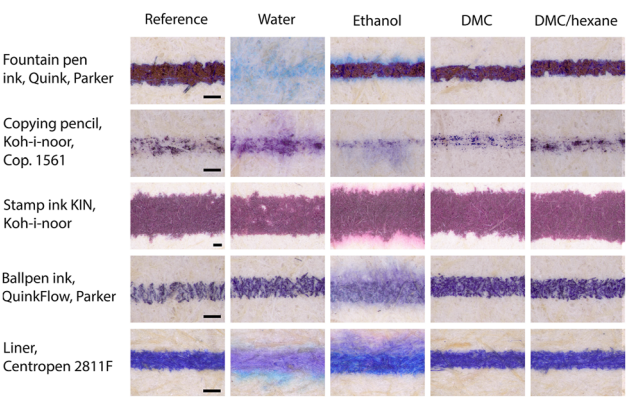

Figure 4: Several examples of stability test results for selected writing media on writing paper. The width of the scale bars represents 250 µm.

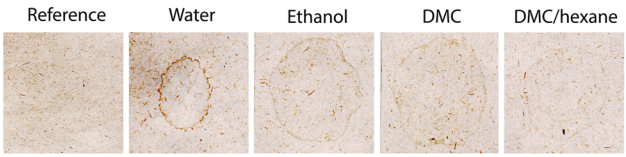

Figure 5: Tendency of selected solvents to the formation of the tidemarks on writing paper.

The tendency to the formation of tidemarks was generally negligible for all solvents. The exception was the writing paper, which was found to be the most sensitive in this respect. The tendency to form tidemarks on this type of paper decreased in the sequence of water, ethanol, DMC, activation solvent mixture (Figure 5). This should be considered in cases of local application of these solvents in paper conservation.

4.2 Reinforcement of Model Samples

The tensile strength of the bridging (cut and lined paper) was found to be approximately 24 and 46 % of the uncut offset paper in the case of single-sided and double-sided lining, respectively (Table 2). Its values exceeded those of the pre-coated tissue itself, because the effective length of the tested strip approached zero. In such conditions, the measured values primarily reflect the strength of Japanese tissue fibres themselves and therefore it was not considered necessary to repeat the test for handmade and writing paper. Subjectively, the bridging strength of the pre-

Table 2: Tensile strength of untreated, cut and lined paper samples, Japanese tissue and pre-coated tissue.

Sample	Treatment	Tensile strength/kN·m^{-1}	
		Accelerated degradation	
		None	55 °C, 65 % RH, 28 d
Offset paper	Untreated	5.17 ± 0.09	5.10 ± 0.13
	Cut and lined (single side)	1.23 ± 0.12	1.08 ± 0.27
	Cut and lined (both sides)	2.39 ± 0.11	2.48 ± 0.18
Japanese tissue	Untreated	0.08 ± 0.03	0.06 ± 0.02
	Pre-coated	0.25 ± 0.03	0.40 ± 0.09

coated tissue was considered sufficient for the safe handling of lined paper of the used types.

The stability of the pre-coated tissue and lined offset paper samples was tested also under conditions of accelerated degradation (28 days at 55 °C and 65 %).

The results suggested that during accelerated degradation values of tensile strength decreased with most of the samples (Table 2). However, these changes were not statistically significant (α = 0.05). The exceptions were the pre-coated tissue samples and possibly also the lined paper samples, where the opposite trend was observed, caused possibly by the hardening of the Butvar® B-76 film. Further research is needed to understand this phenomenon.

It can be concluded that the lining retains sufficient strength even under the conditions of the accelerated degradation.

It is also worth mentioning that the use of DMC or activation solvent mixture did not lead to any notable deformation of the lined paper, such as cockling or dimensional changes. On the other hand, no flattening of paper creases or folds is to be expected (please refer to the examples provided in the Appendix). Depending on the context of the conservation treatment, this can be viewed as either an advantage or a disadvantage. In any case, this represents a significant difference when compared to the results of the traditional lining methods using water-soluble adhesives.

4.3 Adhesion

The aim of the peel test was to evaluate the adhesion of the lining tissue to different types of paper. However, under specified conditions, the lining tissue always broke before it could be peeled off the lined paper. The length of the detached part reached only 4 ± 3 mm. Apparently, the force required to peel it off completely was greater than that required to break the pre-coated tissue itself (Table 3). Therefore the adhesion of the lining tissue was considered adequate in relation to the grammage of the Japanese tissue used for all types of paper tested.

4.4 pH Values of Lined Papers

The pH values obtained were found to be dependent on the types of papers lined. The observed variations can be attributed to the distinct fibre composition, used

Table 3: Maximum peel force measured during the peel test for different types of lined paper.

Sample	Treatment	Maximum peel force/N
Offset paper	Lined	1.2 ± 0.1
Handmade paper	Lined	1.3 ± 0.1
Writing paper	Lined	1.4 ± 0.2

additives and sizing of the tested papers. As a result of the accelerated degradation, a certain decrease of the pH values were recorded.

The contribution of the lining using the prepared tissue to these variations was negligible (Table 4), which is a important result. Polyvinyl butyrals always contain a certain proportion of acetate groups. These are a potential source of acetic acid which would contribute to the hydrolytical degradation of cellulose. The presented results indicate that the concentration of acetate groups in Butvar® B-76 and their contribution to paper acidity can be considered negligible. In fact, the low content of acetate groups in Butvar® B-76 was one of the reasons for the selection of this particular polyvinylbutyral type as the adhesive for this study.

4.5 Discoloration

The results confirmed that the most significant changes resulted from the lining itself. During subsequent accelerated degradation, the contribution of the lining

Table 4: pH values of lined papers before and after accelerated degradation.

Sample	Treatment	pH values	
		Accelerated degradation	
		None	55 °C, 65 % RH, 28 d
Offset paper	Untreated	9.0 ± 0.1	8.3 ± 0.1
	Lined (single side)	9.0 ± 0.1	8.1 ± 0.1
	Lined (both sides)	9.0 ± 0.1	8.9 ± 0.1
Handmade paper	Untreated	4.7 ± 0.2	4.4 ± 0.0
	Lined (single side)	4.6 ± 0.1	4.4 ± 0.1
	Lined (both sides)	4.7 ± 0.2	4.5 ± 0.1
Writing paper	Untreated	5.3 ± 0.1	5.2 ± 0.2
	Lined (single side)	5.5 ± 0.1	5.0 ± 0.1
	Lined (both sides)	5.8 ± 0.2	5.4 ± 0.2
Japanese tissue	Untreated	6.8 ± 0.1	6.6 ± 0.1
	Pre-coated	7.2 ± 0.1	7.4 ± 0.1

Table 5: Discoloration of untreated and lined samples, expressed by the difference of parameters L^*, a^*, b^*, ΔE^* in the CIELAB colour space. [a]Differences calculated relatively to untreated samples of the individual papers. [b]Differences calculated relatively to not degraded samples of the same type.

Sample type	Treatment	Differences of parameters L^*, a^*, b^*, E^*											
		Accelerated degradation											
		Not degraded[a]				55 °C, 65 % RH, 28 d[b]				40 klx, 26 °C, 240 h[b]			
		ΔL^*	Δa^*	Δb^*	ΔE^*	ΔL^*	Δa^*	Δb^*	ΔE^*	ΔL^*	Δa^*	Δb^*	ΔE^*
Offset paper	None	–	–	–	–	−0.6	0.0	1.3	1.4	0.0	0.2	−0.7	0.7
	Lined	−0.8	−0.1	1.0	1.3	−0.2	0.0	1.0	1.0	0.6	0.2	−1.1	1.2
Handmade paper	None	–	–	–	–	−1.0	0.4	1.8	2.1	0.7	0.3	−4.0	4.1
	Lined	−0.4	0.3	−0.7	0.8	−1.2	0.3	2.7	3.0	0.7	0.0	−2.8	2.9
Writing paper	None	–	–	–	–	−1.3	0.4	0.8	1.6	1.3	−0.8	−1.9	2.4
	Lined	0.5	−0.6	−1.5	1.6	−1.3	0.5	0.8	1.6	0.6	−0.1	−0.3	0.7
Japanese tissue	None	–	–	–	–	0.1	0.0	0.1	0.2	0.0	0.0	−0.2	0.2
	Coated	−0.2	0.0	0.3	0.3	−0.2	0.0	0.1	0.2	0.1	0.0	−0.4	0.4

tissue to the overall discolouration of the sample was insignificant (Table 5). The trends of colour changes were the same for the lined and reference samples. In case of the accelerated degradation at 55 °C, 65 % RH, a decrease in L^* (darkening) and an increase in b^* parameter (yellowing) was observed. In case of the accelerated degradation by the exposure to light, an increase in L^* (lightening or bleaching) and a decrease in b^* parameter (decrease in yellowing) was recorded.

Consequently, the contribution of the lining tissue to the overall discouloration of the sample is insignificant. This can be explained by the small thickness of the Japanese tissue used and the relatively small amount of adhesive used for its pre-coating.

4.6 Removability of the Pre-Coated Tissue

The activation of the adhesive by the activation solvent mixture facilitated the removal of the lining tissue without its excessive tearing. Following the removal of the residual adhesive using a cotton swab moistened with DMC, no traces of adhesive remained visible.

The FTIR measurements showed no evidence of residual adhesive in the offset and handmade paper samples after the removal of the pre-coated tissue (Figures 6 and 7). Although this does not necessarily mean that the adhesive has been removed

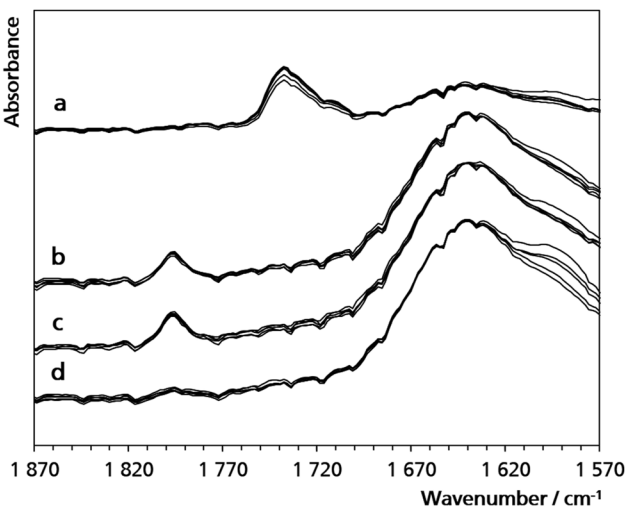

Figure 6: Comparison of the amount of Butvar® B-76 in the samples, proportional to absorbance at 1,740 cm^{-1} (detail of FTIR spectra). a: Lined offset paper, b: untreated offset paper, c: lined offset paper after the adhesive tissue removal, d: lined offset paper after the accelerated degradation (55 °C/65 % RH) and the adhesive tissue removal. Five spectra for each sample type are presented.

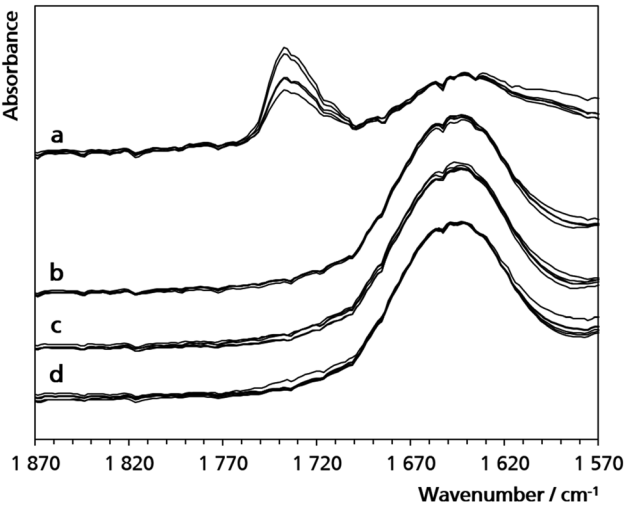

Figure 7: Comparison of the amount of Butvar® B-76 in the samples, proportional to absorbance at 1,740 cm^{-1} (detail of FTIR spectra). a: Lined handmade paper, b: untreated handmade paper, c: lined handmade paper after the adhesive tissue removal, d: lined handmade paper after the accelerated degradation (55 °C/65 % RH) and the adhesive tissue removal. Five spectra for each sample type are presented.

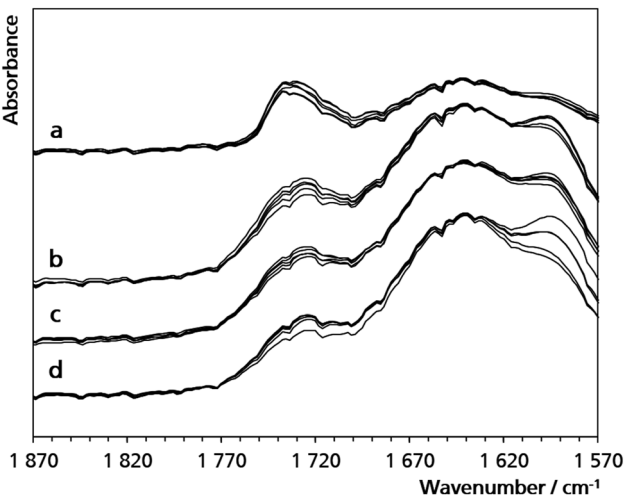

Figure 8: Comparison of the amount of Butvar® B-76 in the samples, proportional to absorbance at 1,740 cm^{-1} (detail of FTIR spectra). a: Lined writing paper, b: untreated writing paper, c: lined writing paper after the adhesive tissue removal, d: lined writing paper after the accelerated degradation (55 °C/65 % RH) and the adhesive tissue removal. Five spectra for each sample type are presented.

completely, it does indicate that its possible residual amount would be low from the practical point of view, i.e., would not affect significantly the paper properties or complicate any possible conservation treatment in the future. In case of writing paper, the spectra could not be reliably interpreted due to the overlapping absorption bands at 1740 cm^{-1} (Figure 8).

Pre-coated tissue remained conveniently removable by DMC without risk of damage to sensitive writing or printing media even after the accelerated degradation. Of course, it should be noted that more practical experience would be needed in order to verify the congruence of these results with the long-term natural ageing effects.

5 Conclusions

The method proposed in this work uses Japanese tissue pre-coated with Butvar® B-76 as the lining material. The adhesive is activated by a non-aqueous solvent mixture of dimethyl carbonate (1 part) and *n*-hexane (5 parts). Although the method cannot be considered universal, it offers specific advantages that make it an interesting alternative to traditional techniques.

The primary disadvantage associated with the proposed method is the need to use organic solvents. This requires the use of personal protective equipment and proper ventilation. Additionally, the cost of dimethyl carbonate may further complicate the implementation of the method on a large scale. The process of the pre-coating and the application of the lining tissue is relatively time consuming and therefore the method is probably more suitable for the conservation treatment of individual documents.

The reinforcement of the lined papers achieved using the pre-coated tissue was subjectively considered sufficient for the safe handling of lined paper of the used types. Also its adhesion was adequate; the force required to peel the lining tissue off was greater than that required to break the pre-coated tissue itself. The method is relatively robust and does not require extensive training or expensive equipment.

Both the process of lining and the possible removal of the lining tissue in the course of reconservation can be considered safe with regard to the writing and printing media tested. It is also worth mentioning that the use of DMC or activation solvent mixture do not lead to any notable deformation of the lined paper, such as cockling or dimensional changes. This is important especially when treating bound material. On the other hand, no flattening of paper creases or folds is to be expected. Depending on the context of the conservation treatment, this can be viewed as either an advantage or a disadvantage.

The ageing characteristics of Butvar® B-76 adhesive appear to be favourable. Under the specified conditions of the accelerated degradation, no negative effects were observed in terms of the loss of adhesion, discolouration, pH value of cold aqueous extracts or changes in solubility. Of course, more practical experience would be needed to verify the congruence of the accelerated degradation test results with the long-term natural ageing effects.

Appendix

Examples of practical application

After completing the aforementioned tests, the proposed method was used in the course of the conservation treatment of several archival records. The following are two examples of its application in different contexts.

Bound manuscript, dated 1777, National Archives in Prague.

The first example is a bound manuscript convolute dated in 1777 (Figure A1). The manuscript was written in iron gall ink on handmade paper. Its maximum dimensions were 240 × 345 × 160 mm.

The original binding structure itself was well preserved. Its opening was excellent as no spine lining was used. The quality of the paper and ink varied considerably within the manuscript. The folios showed characteristic deformation caused by the original folding of some of them and by the weight of the volume. Several folios showed advanced ink corrosion, resulting in cracks and minor losses of paper support.

Figure A1: Bound manuscript convolute, 240 × 345 × 160 mm, dated 1777, National Archives in Prague.

As part of the conservation treatment, an "*in-situ*" lining of the folios damaged by iron-gall ink corrosion was proposed. It was not possible to use a water-based method, because of the risk of migration of ferrous ions within the paper and also because of the risk of the undesirable changes in the deformation and dimensions of the treated folios. It was therefore decided to use Butvar® B-76 pre-coated tissues. Several folios were lined from one side only, most from both sides using the method described in Section 2. The lining provided sufficient reinforcement for the folios without significantly altering the characteristic structure and deformation of the folios (Figure A2a and b).

Hand-drawn map, 17th century, National Archives in Prague.

The second example is a lining of a hand-drawn map from the collection of the National Archives in Prague (Figure A3). The dimensions of the map were 431 × 349 mm. The map was drawn on handmade paper with iron-gall ink and

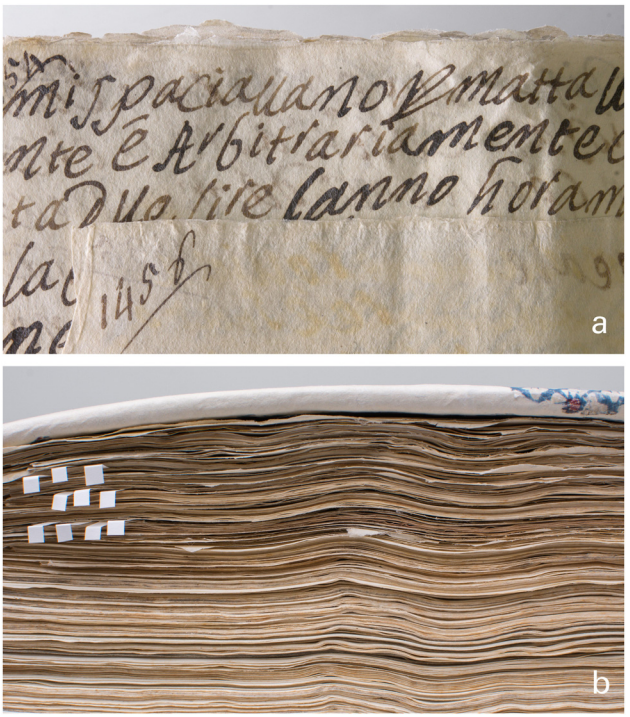

Figure A2: Manuscript folios lined with Butvar® B-76 pre-coated tissues. The characteristic paper structure (a) and the deformation of the folios (b) were not visibly altered. The white "bookmarks" in the picture (b) indicate the individual lined folios.

Figure A3: Hand-drawn map, 426 × 345 mm, 17th century, National Archives in Prague. Condition before the conservation treatment.

completed with watercolours. Iron-gall ink corrosion caused cracks and minor losses in several places on the map. There was a red stamp and several annotations in water and ethanol soluble ink in the lower right corner.

As part of the conservation treatment, the reinforcement of paper support was suggested. For this purpose, the use of Butvar® B-76 pre-coated tissue from the verso side seemed a reasonable choice due to the presence of soluble media. The process was carried out as described in Section 2. The dimensions of the map necessitated the use of two sheets of the lining tissue, which were applied side by side on the verso side of the map. The result was considered satisfactory. The paper support was strengthened and the writing media exhibited no visible changes such as bleeding, attenuation or seepage to the opposite side of the paper, as demonstrated in Figure A4.

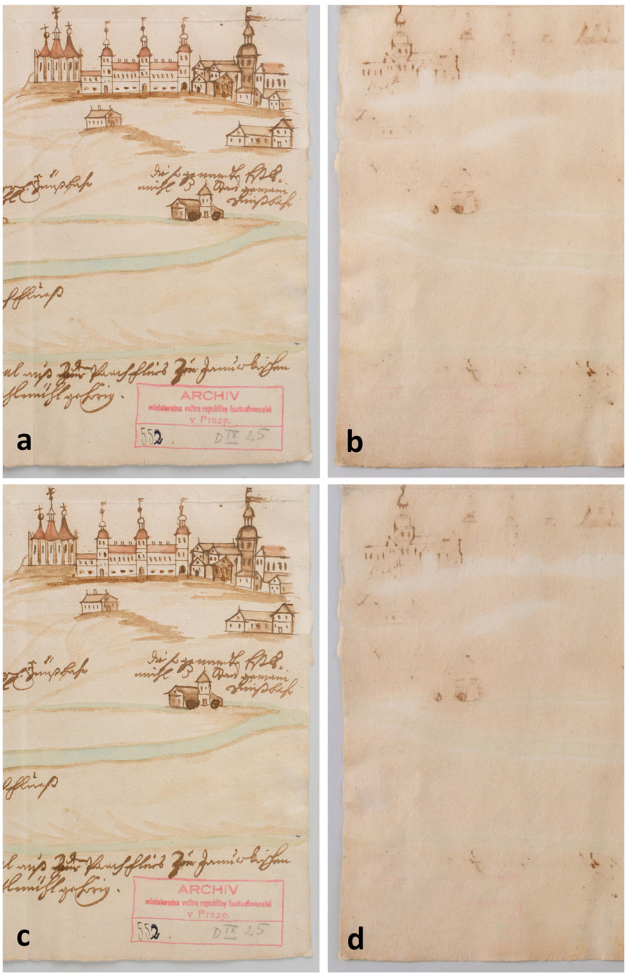

Figure A4: Detail of recto and verso of the coloured map marked with a stamp and writing ink before (a, b) and after lining (c, d). Colour layer and inks remained unchanged after the application of the pre-coated tissue from the verso side (d).

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