Methods of Aqueous Treatments: The Last Resort for Badly Damaged Iron Gall Ink Manuscripts

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Methods of Aqueous Treatments
The Last Resort for Badly Damaged Iron Gall Ink Manuscripts*

The conservation of manuscripts damaged by iron gall inks remains a true challenge. Despite intensive research over the last two decades devoted to the development of treatments, the conservation community has so far adopted no universal solution, probably because the reality of collections is their diversity and so multiple criteria must be taken into account when choosing a conservation treatment.

Of all solutions investigated to delay iron gall ink corrosion, the calcium phytate treatment proposed in the 1990s (Neevel 1999; Reissland and Ligterink 2011) has been the most extensively tested: its safety regarding paper has been demonstrated (Botti et al. 2005) and its ability to limit the degradation of damaged paper has been measured several times on laboratory samples (Reissland and De Groot 1999; Neevel 2000; Kolar et al. 2000, 2005 and 2007; Zappala and Stefani 2005; Henniges and Potthast 2008; Orlandini 2009; Rouchon et al. 2011). The calcium phytate treatment involves immersing the object in several aqueous solutions for about one hour. The use of water as a solvent has pros and cons (Reissland 1999a, 1999b and 2000; Rouchon et al. 2008 and 2009); water helps to delay the paper deterioration because it enables the partial removal of iron, sulphates, acids and degradation by-products, while organic solvents do not. When other parameters are taken into account, such as the aesthetic aspect or the historical aspect of the paper composition, the use of water as a solvent produces negative effects: the dissolution of water-soluble products drastically modifies the chemical composition of the paper/ink and significantly changes the appearance of the object; the ink takes on a cooler colour and the paper lightens considerably. The calcium phytate treatment of objects of aesthetic value, such as drawings, is also not recommended.

These visual side effects may be acceptable on badly damaged manuscripts (e.g. Fig. 1), especially when the text forms the main value of the object. When the paper can no longer be handled, the text becomes inaccessible and the object is considered as lost. In these specific cases, it would be useful to apply the phytate treatment before consolidating the support by conventional treatments such as lining. But here another problem arises: the exposure of a highly brittle paper to different aqueous solutions is accompanied by a substantial risk of mechanical stress, which might create new splits and losses.

These arguments lead to a paradoxical situation: the calcium phytate treatment, whose effectiveness is established, is not used on highly damaged documents, but only on documents in a reasonable condition that can still be handled in aqueous solutions without major mechanical risk.

In view of these considerations, it seemed useful to investigate an appropriate methodology for the application of aqueous treatment to badly damaged documents. The use of non-woven viscose fabric combined with a floating process has been proposed to minimize the mechanical risk (Huhsmann 2007). This option was complemented by the proposal of a work stand-
ard for the treatment of damaged manuscripts (Huhsmann 2008). This very detailed work is illustrated by the treatment of a moderately damaged document, which is held sandwiched between two fabrics during treatment. The employment of this universal process on badly damaged pieces (Fig 1) remains questionable. Moreover, this process does not include lining, which is unavoidable for badly damaged papers.

This study was performed in a laboratory context but was motivated by the presence of badly damaged pieces in the collections of the French National Library, which are impossible to handle safely. The aim is to find a ‘last resort’ for the conservation of these objects.

In the initial phase of this project, an attempt was made to assess the mechanical risk as objectively as possible. A specific methodology using test samples was formulated in order to semi-quantitatively evaluate the mechanical damage induced by aqueous treatments. This determined the most hazardous treatment steps as well as the safest. These results were then used in the second phase for the development of a treatment procedure that could be employed on real objects.

**Methodology**

**Using Test Samples to Evaluate the Mechanical Risk**

Test samples were made of a sheet of approx. 10 x 10 cm Whatman paper (Whatman) with a deposit of a 0.1 mL drop of iron gall ink ([1] Fig 2a), resulting in an ink spot of approx. 3 cm in diameter. The samples were then artificially aged at 85°C and 65 % RH for 13 days. After ageing, the inked areas were very fragile whereas the blank area remained in good condition. When submitted to an aqueous bath without particular care, these samples split into pieces.

As the samples were not strictly identical, it was necessary to develop a semi-statistical approach [2], which required the manufacture of a large number of samples (Fig 2b). Each treatment was evaluated on the basis of a set of 30 samples. These were divided in 5 groups of 6 samples, which were treated simultaneously. The aqueous treatments were conducted in a transparent container placed on a light-table (Fig 3). Several photographs were taken of all samples at different steps of the treatment in order to identify the moments when the splits occurred (Fig 3b). A semi-quantitative evaluation could then be achieved by counting the number of splits occurring on the entire set.

For example, Fig 4 shows the average number of splits per sample occurring during a treatment performed in the same way on two sets of 30 samples. The results obtained on the two sets were very similar, showing that the methodology was satisfactorily reproducible.

**From Test Samples to Original Manuscripts**

The use of test samples for the evaluation of the mechanical risk is useful to achieve a general idea of the most promising directions to investigate but is obviously limited. The manufacture of test samples saves originals, but cannot reproduce their complexity. It was therefore decided to apply the general conclusions derived from the test samples to the treatment of originals. The second part of this project was performed on a few badly damaged sheets with iron gall ink and dating from the 18th century (Fig 1).

**Results**

**Evaluation of the Most Hazardous Sample Treatment Step**

It was initially expected that the immersion of the sample would be very problematic: the swelling of moderately damaged paper is often said to be very hazardous for damaged inked areas (Reissland 1999b and 2000; Huhsmann 2007) because it may induce excessive strain on the most brittle part of the paper. Nevertheless, this seemingly logical argument was not confirmed here [3], as the samples were very easy to immerse and could remain for hours in the bath (Fig 4) with no visible damage. However the removal of the samples from the bath was very delicate. When conducted with tweezers without any particular care, it led to...
approximately 1.5 splits per sample, meaning that almost all samples were split.

### Optimizing the Sample Removal Method from the Solutions

Several techniques were also investigated to handle the samples during their removal from the bath. These techniques (Tab 1) were not exhaustive, but aimed to span the most typical actions that could be employed on damaged paper: sandwiched between two rigid grids or two pieces of woven mesh, placed on a rigid support, or left to float without any constraints, and so on. As shown in Fig 5 most of these actions had damaging results. Sandwiching the document between two rigid grids was by far the worst option (Fig 5: rigid grid). Generally, any water flow on the paper surface induced damage. Even using a siphon to empty the bath was not effective in preventing splits (Fig 5: siphon). Letting the paper float freely on the solutions appeared to be the safest option (Fig 5: floating). The paper could then be carried from one bath to another by using a fine mesh stretched on a rigid frame, the latter being slightly immersed in the solution during treatment.

As we were at first reluctant to apply the treating solution to one side only, it was attempted to turn the samples between two baths. Here again, damaging results were obtained (Fig 5: floating RV1 and floating RV2). Inverting the sample means removing it from the support, which is very hazardous when the paper is moist. The only way to remove the support with less risk was to let the sample at least partially dry but this was not in-

<table>
<thead>
<tr>
<th>Gesture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tweezers</td>
<td>No specific care. Tweezers were used to hold the undamaged part of the sample during immersion and removal from the bath with tweezers.</td>
</tr>
<tr>
<td>rigid grid</td>
<td>The samples were first placed on a polyester woven mesh, 43T (A. Buisine), covered with 1.5 x 1.5 mm flexible plastic net (BHV), then placed between two rigid metallic grids (BHV); easy to handle during immersion and removal from the bath.</td>
</tr>
<tr>
<td>mesh</td>
<td>The samples were placed between two fine polyester woven meshes, 43T (A. Buisine) and immersed in the bath. The woven mesh could be easily handled during removal without touching the samples.</td>
</tr>
<tr>
<td>frame</td>
<td>A 1.5 x 1.5 mm flexible plastic net (BHV) stretched on a rigid plastic frame was first immersed. It was covered with a fine polyester woven mesh, 43T (A. Buisine). The samples were immersed with tweezers, then removed from the bath using the frame.</td>
</tr>
<tr>
<td>plexi</td>
<td>The samples were immersed in the bath using tweezers, then removed using a Plexiglas plate.</td>
</tr>
</tbody>
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<tr>
<th>Gesture</th>
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<tbody>
<tr>
<td>foam rubber</td>
<td>A foam rubber was first immersed. It was placed on a 1.5 x 1.5 mm flexible plastic net (BHV) which was stretched on a rigid plastic frame. This was covered with a fine polyester woven mesh, 43T (A. Buisine). The samples were immersed with tweezers and placed on the last layer. The frame was used for the removal of all layers.</td>
</tr>
<tr>
<td>siphon</td>
<td>Same as ‘frame’, but instead of removing the samples from the bath, the bath is emptied with a siphon.</td>
</tr>
<tr>
<td>floating</td>
<td>Same as ‘frame’, but instead of being immersed, the samples were simply floated on the solutions.</td>
</tr>
<tr>
<td>floating RV 1</td>
<td>Same as ‘floating’. After removal from the solution, the samples were covered with a second polyester woven mesh, 43T (A. Buisine), held with a second rigid frame and turned over. Then the first polyester woven mesh and the first frame were removed and the verso side of the samples were exposed to the solution in the same way as the recto.</td>
</tr>
<tr>
<td>floating RV 2</td>
<td>Same as ‘floating RV1’, but without removing the first polyester woven mesh.</td>
</tr>
</tbody>
</table>

**Tab 1** Description of the tested actions.

4 Evaluation of the reproducibility of the experiment on two sets of 30 samples. During immersion and removal from the bath, the samples were manipulated with tweezers without any specific care (Tab 1: ‘tweezers’). They were dried in open air. The removal of the samples from the bath was the most delicate action.

5 Average number of splits appearing on the samples after removal from the bath. The tested actions are depicted in Tab 1.
vestigated. In conclusion, it was decided that the best way to proceed was to float the paper on one side only, and to increase the duration of the treatment.

Optimising the Drying Process

Drying is the second most hazardous step of an aqueous treatment: as the inked areas remain less flexible than blank areas, they may not follow the dimensional changes of the sheet during drying. As a result, new splits may appear or existing splits may become longer. Several ways of drying the paper were also tested (Tab 2). Here again, the worst results resulted from the application of constraint to the paper (Fig 6: under pressure) whereas the best results were obtained on the samples that were left to dry in the open air (Fig 6: air).

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>under pressure A</td>
<td>The samples were covered with a non-woven polyester film (Stouls) then placed between two blotting papers. The whole was held under pressure with a 2 kg weight.</td>
</tr>
<tr>
<td>under pressure B</td>
<td>The samples were immersed in ethanol before being dried in the same way as 'under pressure A'.</td>
</tr>
<tr>
<td>suction table</td>
<td>The samples were immersed in ethanol then placed overnight on a suction table.</td>
</tr>
<tr>
<td>air 1</td>
<td>The samples were immersed in ethanol then dried in open air on a rack.</td>
</tr>
<tr>
<td>air 2</td>
<td>The samples were dried in open air on a rack.</td>
</tr>
</tbody>
</table>

Investigating the Lining Process

Another important step of the universal treatment needed investigation: the phytate treatment delays the chemical degradation of the cellulose but does not reinforce the altered paper. It would seem necessary to consolidate a badly damaged document. Several types of lining were investigated: these treatments were performed using the same method [4] but with various types of adhesive (starch 4 % w/v, gelatine 4 % w/v, Tylose 4 % w/v and Klucel G in ethanol 4 % w/v). All adhesives led to an increase of approximately 0.2 to 0.4 splits per sample, showing that the composition of the adhesive is not a determinant factor for the risk of splits. The softness of the brush and the fluidity of the adhesive (which affects the ease of application) appeared to be more critical.

Use on Highly Damaged Originals

Some tests were made on original samples, which lead to the determination of five additional factors that are critical in mechanical risk management:

> The carrier should remain rigid while allowing water to permeate. A silkscreen (A. Buisine) constructed with a polyester woven mesh, 43 threads·cm⁻¹, stretched on an aluminium frame perfectly fits this criteria.

> The mesh should be positioned at the very surface of the bath so that with the weight of the paper, the application of a soft pressure on the mesh enables water to just permeate through the mesh. The water should come through the mesh ONLY underneath the document, not at the free margins of the screen (Fig 7).

> Bending the paper and touching its surface should absolutely be avoided during the treatment.

> Placing the document on a free mesh or sandwiched between two meshes during the floating process should be avoided. This seemed to have caused additional damage. It was decided to place the document directly on the silkscreen with no intermediate layers. It is then possible to undertake the lining in the meantime without waiting for the complete drying of the document. This point differs significantly from the previous recommendation (Huysmann 2008).

> It was not possible to perform the complete drying in open air.
because the blank paper tends to undulate, which enlarges existing splits or causes new ones. The weight of a 1 cm thick piece of wood and a couple of woollen felts is enough to keep the paper flat while enabling an even air exchange during drying.

Finally a method of handling the paper sheet from beginning to end of the conservation treatment was developed. This process, illustrated in (Fig 7) and fully described in the ‘Instructions’ section of this issue, enables the treatment of a paper that is so brittle that manipulation is almost impossible. In Fig 8 for example, such a paper was treated without resulting in any substantial mechanical damage. This is particularly clear when examining the sample on a light table (Fig 9). No new splits could be found. Some existing splits were slightly enlarged (Fig 9: yellow arrow) while some others were no longer visible (Fig 9: red arrows), probably because the two edges of the split rejoined.

An initial concern was that a floating process would make the treatment less efficient because the chemical exchanges between paper and solution could be limited to one side only. The final colour of the paper (Figs 8, 10) indicates that this is not the case: the paper lightens significantly on both sides and turns a cooler hue similar to an immersion result. It would appear that the floating process does allow chemical exchange between the paper and the solution and does not jeopardize the overall efficiency of the treatment. It is however advised to extend the duration of the treatment (compared with immersion treatments) since the floating process may delay chemical exchanges.

Loss of legibility is the main drawback of the method, mainly due to the slight opacity of the Japanese paper. This aspect may not be noticed with a first impression of the document (Fig 8), but becomes obvious when focussing on details (Fig 10). Dyeing the Japanese paper with diluted acrylic colours was attempted with encouraging results (not shown): further development in that direction requires an investigation into the reliability of the dye when in close contact with the manuscript.

**Conclusion**

This work aimed to formulate a treatment of badly damaged papers embrittled by iron gall ink corrosion. Firstly the most damaging steps, the removal of the paper from the baths and its drying, were determined using test samples. Several methods were attempted to reduce the mechanical risk: letting the paper float on the solution was by far the best option and the best way to dry the paper was to apply a minimal constraint. These approaches were adapted to the treatment of badly damaged original documents, which led to the development of a treatment protocol. It is hoped that this protocol will allow a more specific use of the calcium phytate treatment, which remains to date the most widely documented of anti-oxidant treatments. Obviously this method is not suitable to treat kilometres of documents. It was designed in a laboratory context to address hopeless documents that can no longer be manipulated, even with the greatest of care. The method is time consuming (probably more than one hour per sheet) and is also restricted to some specific cases where no additional split is acceptable and where the time spent corresponds to the value of the object.

**Acknowledgements**

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**Endnotes**


[1] Composition of the ink: iron II sulphate heptahydrate (11.6 g.L⁻¹), gallic acid (1.5 g.L⁻¹), gum arabic (34.1 g.L⁻¹; all Sigma-Aldrich).

[2] A full statistical approach would require a sampling of more than 100 test samples per treatment which would be much too time consuming. We opted for a semi-statistical approach and sampled approximately 30 laboratory tests per treatment. This lead to what was considered to be a satisfactory reproducibility. The ex-
After the flotation, the samples remained on the same carrier water-permeable on their whole surface whereas highly damaged originals are often less permeable on inked areas than on blank areas.

References


Suppliers

A. Buisine, 78 rue Felix Faure, 92700 Colombes, France, Tel +33-141-192970, Fax +33-147-858210, serigraphie-boutique.fr (polyester woven mesh, 43 threads-cm², silkscreen fabric).


BHV, 52 rue de Riviére, 75 189 Paris Cedex 4, France, Tel +33-977-401400, Fax +33-142-749679, www.bhv.fr (1 x 1.5 mm flexible plastic net; 1 x 1 cm rigid metal grid)

Sigma-Aldrich Chemie S.a.r.l., 80 rue Luizais, 38070 Saint-Quentin Fallavier, France, Tel +33-474-822888, Fax +33-474-956808, www.sigmaaldrich.com (gallic acid monohydrate, 398225; iron Il sulphate heptahydrate, 215422; gum arabic, G9752)

Stouls, 9-11 rue de l’Orme Saint-Germain, 91165 Champlan Cedex, France, Tel +33-1-69101-070, Fax +33-1-69101-079, www.stouls.com (Tylose MH300P, Reemay 17g. m-2; 1.5 x 1.5 mm flexible plastic net; 1 x 1 cm rigid metal grid)

Whatman plc, Springfield Mill, James Whatman Way, Maidstone, Kent ME1 2LE, United Kingdom, Tel +44-1622-676670, Fax +44-1622-691425, www.whatman.com (Whatman No 1).

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