Versión en INGLÉS

Application of capillarity systems to the graphic and documentary heritage conservation: A line of research at the Universidad de Granada

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Abstract
The study provides an overview of our research team's[1] experiences relating to the application of capillary systems in graphic works and documents conservation. The team employed such systems for the cleaning and deacidification of two collections: the School Maps Collection from the University Archive, and the Drawings Collection by Martín Morales, both property of the Peña de la Platería de Granada. We present the main results derived from the adaption and improvement of the capillary system methodology in its use as a vehicle for different solutions in treatments in which it has not been used until now. In the first intervention, the combination of capillary systems based on the communicating vessels and contact-absorption principles made it possible to treat structurally complex, large-scale documents comprising multiple supports and different material strata. This, while minimizing any physical and chemical risks and avoiding the need to disassemble the document and apply other treatments that can constitute potential stress factors for the document. In the second case, we experimented with the use of the capillary system as a vehicle for cleaning and deacidification solutions on works featuring graphic techniques that are highly sensitive to humidity, applying the solutions over several phases in a continuous and simultaneous process. We achieved optimal results that have now opened new lines of research.

Keywords
Cleaning; capillarity; communicating vessels; facing; documents; paper; textile; color.

[1] Those involved in the investigation were: Teresa Espejo Arias, Ana M. López Montes, M. Rosario Blanc García, Francisco José Collado Montero and Elena Esteban Garrido. The people who make up the conservation work teams are as follows: for the School Maps Collection: Teresa Espejo Arias, Ana Isabel Calero Castillo, Cecilia Lamolda, and the students of the Document Conservation and Restoration on Paper of the Degree in Cultural Property Conservation and Restoration of the courses from 2016 to 2020; for the Drawings Collection by Martín Morales: Ana López Montes, Elena Esteban Garrido, and Francisco José Collado Montero.

Capillarity is a physical property of fluids that depends on their surface tension and allows them to move inside a capillary tube. This principle is used in the field of document conservation and applied to cleaning systems and treatments. Its proven effectiveness, both in general interventions and in objects that, due to their material or formal characteristics or their advanced state of degradation, require extremely delicate actions, has replaced other risky conventional treatments –for example, cleaning by immersion in a bath– supporting its use, which has made possible the removal of unwanted elements through their solution and subsequent filtration. The fluid circulation principle through the capillary structures that compose the main supports of our documents also serves to introduce beneficial compounds into the paper or even trigger certain chemical reactions. These aspects –along with the optimization of the method and procedures– are currently one of the lines of research being developed in the Graphic Works and Documents Conservation Area of the Universidad de Granada, demonstrating the usefulness of the application of these systems in a broader framework of treatments.

Two methodological proposals: Case studies

Cleaning and deacidification are common treatments in the conservation of the cultural property on paper since they eliminate or neutralize degradation products, improve the aesthetic appearance of the work, and enable the introduction of beneficial products for its conservation. For the application of these treatments, the most common procedures are immersion and capillary suction, conduction, or absorption in which the main solvent is water.

Aqueous procedures are distinguished by their low toxicity and high effectiveness against hydrophilic degradation products. However, when applied to the item in a generalized way, they can cause serious damage such as bleeding or solubilization of the inks due to their chemical composition. They can also affect the condition of the pigments and binders which, even though they are hydrophobic, can be found disintegrated or powdery, causing their loss due to the mechanical action of the solvent. This leads to the usage of other procedures that use organic solvents, thus increasing the risk of chemical alteration of the materials and toxicity for the conservator, without being completely effective in most cases. The effects they produce on the substrates are also known, such as the physical damage due to support deformation or chemical damage due to the reaction of their components. These are the premises that have encouraged the search for safer and more sustainable methodological alternatives for the application of these treatments. In this regard, the experimental proposals presented below have been developed for the conservation of the following two collections.

Colección de mapas de la escuela. Archivo Universitario, Universidad de Granada

The Colección de mapas de la escuela of the Universidad de Granada is composed of 47 large-scale documents conceived as didactic material that replicate physical and political cartographies. They are printed on the paper, varnished, lining, laid down on wooden mouldings that allow them to be rolled up and hung on the wall.

The maps' deplorable condition along with the growing interest in this type of document, has led those responsible for the University Archives to propose a global project for their recovery (figure 1). In general terms, they showed damp stains, oxidation, yellowing, cracking, and blanched in the varnish layer

because of their natural degradation and the humidity conditions to which they were exposed. In addition, the natural aging of the constituent materials facilitated the embrittlement of the cellulosic and textile supports. The documents had pronounced wrinkles, deformations, tears, and missing parts in the paper due to the differential movements of expansion/contraction between the paper and the fabric, and because of the usage and the numerous actions of rolling and unrolling. The current work began in 2016 and was carried out by a multidisciplinary team of professionals in different fields: such as chemists, opticians, archive technicians, historians, and conservators, and was done in a coordinated manner for its knowledge and conservation. An intervention protocol was established that included historical, material, and technical research, the analysis of its condition, the establishment of a diagnosis, and the application of an action protocol in which special attention was paid to cleaning treatments.

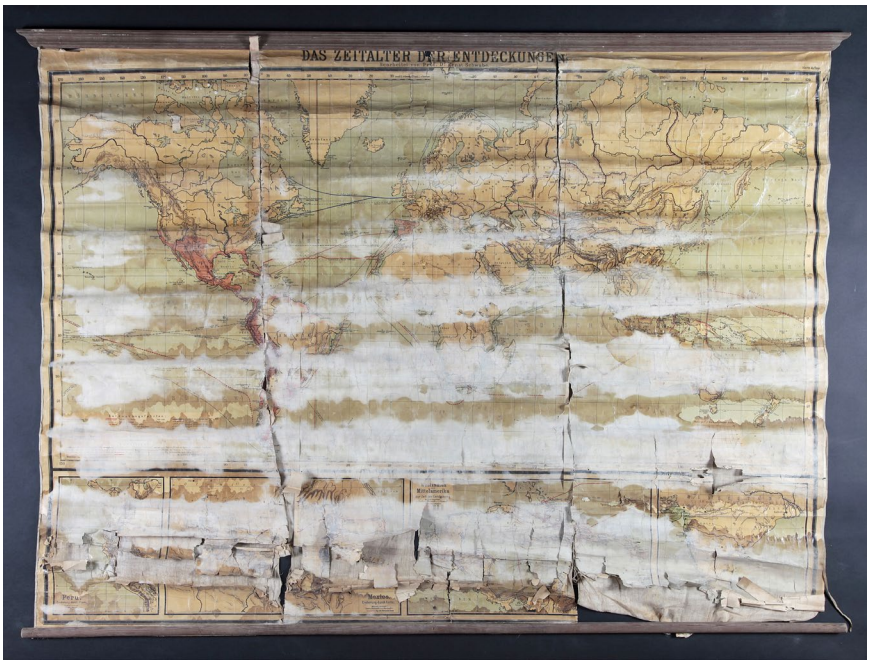

Figura 1. Map 00023, Professor Ernst Schwabe (ed.) (1858–1927) *Das zettalter der entdeckungen* (Age of discovery). Dimmensions: 1540 × 2115 mm. Before conservation. *Image: ©Domingo Campillo.*

The extreme fragmentation of the printed paper posed a significant risk of dissociation, preventing its dismantling. The separation of paper and fabric supports for the application of individualized treatments was therefore not possible.

In this circumstance, it was decided to intervene on the different supports simultaneously to avoid dismantling and stressful treatments for the document. It was decided to combine different capillary washing procedures adapted to each of the needs.

The capillarity system was the first cleaning phase and helped to remove oxidized varnishes. The solvent was applied using Sontara® (figure 2a) which, in direct contact with the map surface, absorbed and retained the dissolved varnish (figure 2b). Similarly, facing also acted as an absorption cleaning system. In this case, gelatin or starch –used as adhesives– worked as a means of extracting dirt and varnish residues when impregnating the medium-grammage Japanese papers or rayon used as absorption materials.

Figure 2. Map 0021, José Paluzie Lucena (1905) *Physical Europe. a)* Detail of solvent application through the Sontara®. *b)* Detail of the absorbed varnish once the solvent has evaporated. *Image: ©Teresa Espejo.*

The cleaning system based on the principle of communicating vessels was used for the general and simultaneous cleaning of the primary and secondary supports. The physical characteristics of the documents, their format, and condition entailed optimizing the system (Garrido *et al.*, 2014) based on the Schalkx (2011) models, so methodological improvements adaptable to different documentary typologies were developed (figure 3).

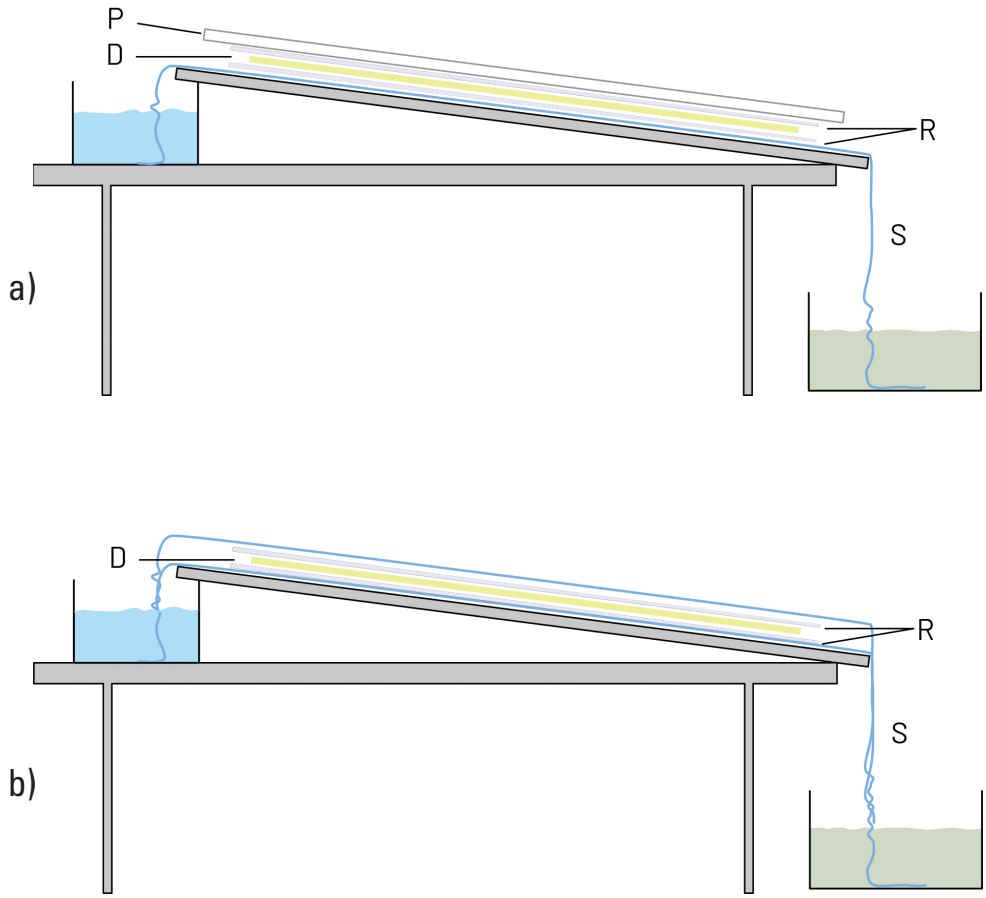

Figure 3. Variants of the capillary washing method using the communicating vessels system. *a)* applicable system to simple documents, formed by single paper support. *b)* Useful system for documents composed of several supports and materials. Caption: D: document, R: Reemay®; S: Sontara®; P: controlled and homogeneous weight.
Image: ©Teresa Espejo.

The most noteworthy results can be summarized as follows:

- The document must be kept in permanent contact with the absorbent base material. It is necessary to avoid the appearance of bulges, creases, or deformations that act as a barrier to the passage of water and cause dirt deposits that, when dry, resulting in stains and haloes. Placing a soft weight on the document solves the problem and maintains the humidity, preventing evaporation and making the treatment more effective.

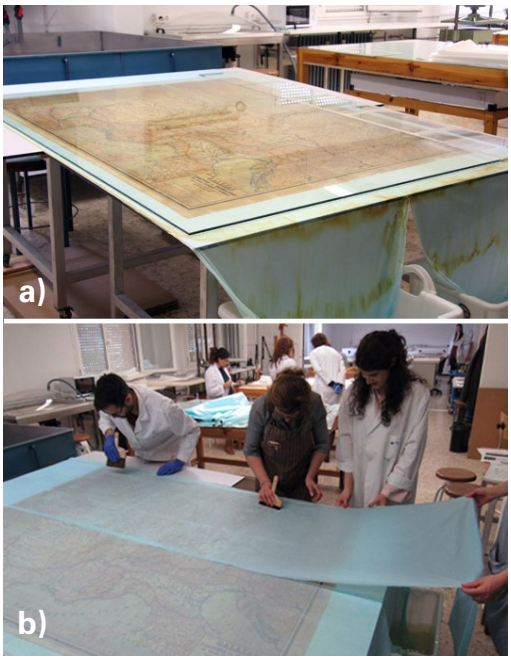

Figure 4. Map 00028, Henrico Kiepert (1894) *Galiae Cisalpinae e transalpinae*. Dimensions 1407 x 1780 mm. *a)* First phase: the conductive fabric is placed under the document. *b)* Second phase, the treatment is completed with the passage of water through a layer of fabric placed on the surface. *Image: ©Teresa Espejo.*

- The placement of auxiliary supports (Reemay®, Bondina®, Hollytex® or similar) between the document and the base, as well as between the base and the glass, prevents the materials from sticking together and reduces the risks that the manipulation of the document produces on the most fragile areas and loose or very weakened elements.
- The inclination of the plane is essential to speed up the process and reduce document humidification times. An inclination of approximately 4 % can be considered adequate to achieve optimum results.
- The capillary structure of the fabric is a determining factor in water conduction. A greater number of layers (two in our case) allows a greater passage of water, which speeds up the process and reduces the time required for treatment. After testing several fabrics, Sontara® was found to be the most suitable.
- In composite structures where it is necessary to intervene on the different supports at the same time, a sandwich-type system formed by a double conduction fabric –under and on the document– allows the solution of the degradation products and improves the results of the treatment (figure 4b). In this case, the upper fabric keeps the document in direct and homogeneous contact with the base, avoiding bulging without the need to incorporate additional weight. After the first cleaning phase, the water containers are removed. The drying process will function as a second cleaning phase, while the conductive fabric will gradually absorb the solubilized degradation products and retain them after complete drying.
- The result of cleaning the maps treated with this method was successful. The methodological improvements developed made it possible to treat the documents without the need to separate the secondary textile supports, thus avoiding the dissociation of the object. The combination of all these procedures means, in addition to the considerable reduction of risks for the document, the reduction of the conservator's participation time and makes the costs derived from the conservation action profitable.

Colección de dibujos de Martín Morales. Peña La Platería, Granada

Peña La Platería in Granada is the oldest flamenco association in the world, its funds include a collection of 22 drawings by the prestigious graphic artist Francisco Martín Morales (1946-2022). The drawings of 443 X 350 mm allegorically represent the different flamenco *Palos*. They are made with watercolor, Chinese ink, and gouache on bleached pulp industrial paper. Their condition was acceptable, although time and permanent exposure to light had caused the oxidation of the fibers of the support, which led to a decrease in pH and a general yellowing of the free surface of the mounting, more evident once the frames were removed.

For the intervention, the scientific method has been followed through a detailed study to identify the materials of each work, the technique of creation, and alterations that were being triggered. The special problem of the artistic techniques used –particularly sensitive to humidity– led to the execution of an experimental process before the intervention in two phases: the recognition of the effects of the use of systems based on the principle of communicating vessels on soluble inks, and the determination of their suitability as an application system to deacidification treatments.[2]

The first phase began with the preparation of samples on high-quality, unaged cotton pulp paper, on which watercolor, Chinese ink, and gouache were applied due to their special sensitivity to the aqueous medium, with a selection of the most common dyes and pigments (figure 5). In the second phase, the samples used were from material printed on naturally aged wood pulp paper. The optimized parameters assessment in both cases were: document humidification, unit cover material, humidity supply to the system, cleaning solution, system support material, pressure to be applied, and reaction time. The protocol for assessing the results was carried out by comparison of patterns after examination under direct vision, amplified observation with a magnifying glass and optical microscope, and colorimetric study with which detailed information was obtained on color variations according to the CIELAB color-difference formula ($\Delta E^*_{ab,10}$, ΔL^*_{10}, $\Delta C^*_{ab,10}$, $\Delta H^*_{ab,10}$). The analysis of the support was completed by visualization under raking light and determination of pH variations.

Regarding the effects of the system on wet techniques, the studies carried out have helped us to determine the suitability of the method for application in documents in which the fibers are soaked in the colored solution. However, we observed that thick, poorly solubilized layers or very long exposure times can lead to bleeding or solubilization. Only the black Chinese ink is the most sensitive to the passage of water (Figure 5a). The main results were as follows:

- 100 % concentration: bleeding after 2 hours.
- 50 % solution: bleeding after 9 hours.
- Solutions higher than 50 %: there is no modification.

The results obtained concerning the support indicate that:

- The grammage of the paper determines the presence of physical alterations. Higher grammage papers are stable to the effects of humidity, while lower grammages may suffer bending and deformation during treatment and after drying. This effect can be eliminated by using a soft and homogeneous weight during the process or by drying under light weight or edge tension (figure 6).

[2] On the subject, the texts Esteban *et al.*, 2014 and 2019 can be consulted.

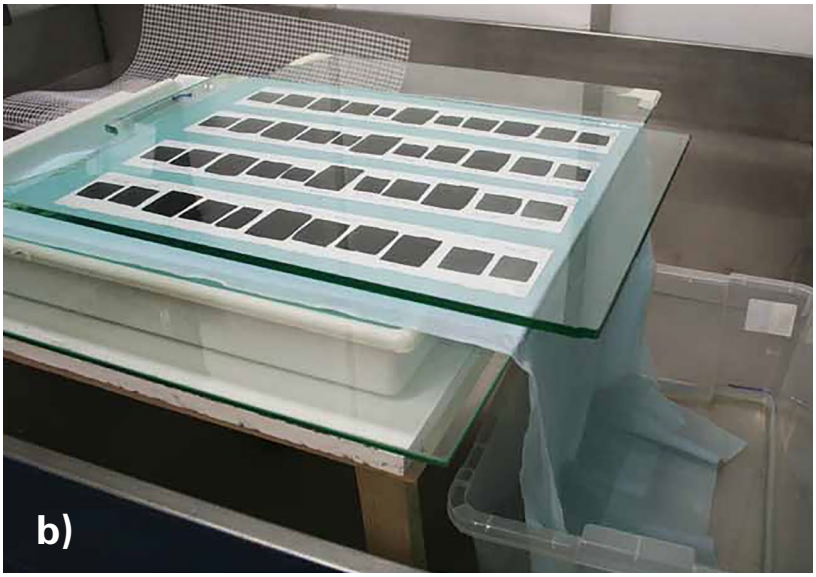

Figure 5. *a)* Study of the effects of the system on a selection of the most common dyes and pigments used in watercolor, Chinese ink, and gouache. *b)* The sensitivity shown by black, in this case, led us to replicate the study on black Chinese ink applied at different concentrations. *Image: ©Elena Esteban.*

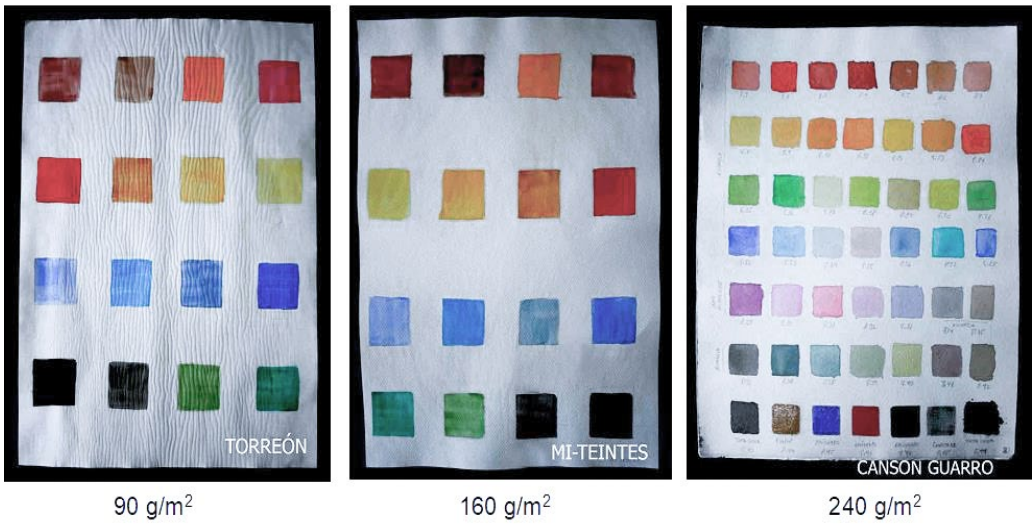

Figure 6. Effects of humidity on papers of different grammage. *Image: ©Elena Esteban.*

The colorimetric data reveal that the treatment produces an increase in the clarity of the support, more evident in the yellowish areas of the paper, with a small and generalized decrease in the chroma, while the tone does not undergo appreciable variations (figure 7).

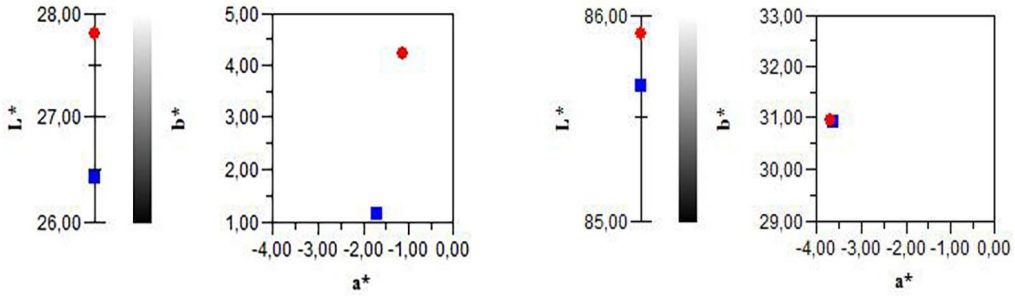

Figure 7. Sample A-5 (ink). Maximum (left chart) and minimum values (right chart). Red dot: prewash. Blue square: post-wash. *Image: ©Francisco J. Collado.*

The deacidification studies were carried out on acidified papers with pH values in the range of 4 to 4.5. They showed considerable differences concerning the solution used after treatment, the solutions were: *a)* tap water from Granada with a pH of 7.4 and containing 180-250 mg/l of calcium carbonate ($CaCO_3$) *b)* calcium bicarbonate ($Ca(CO_3H)_2$, and *c)* sodium borohydride ($NaBH_4$) (figure 8).

In all cases, it was found that the movement of water through the capillary structure of the fabric is not linear, but has a curvature directly related to the pressure on the concave side of the water surface at its encounter with atmospheric pressure, which is greater than the pressure exerted on the convex side. The liquid must rise until the same pressure is exerted on both sides. This movement is also conditioned by the presence of other elements that the liquid may contain in solution or dispersion, thus:

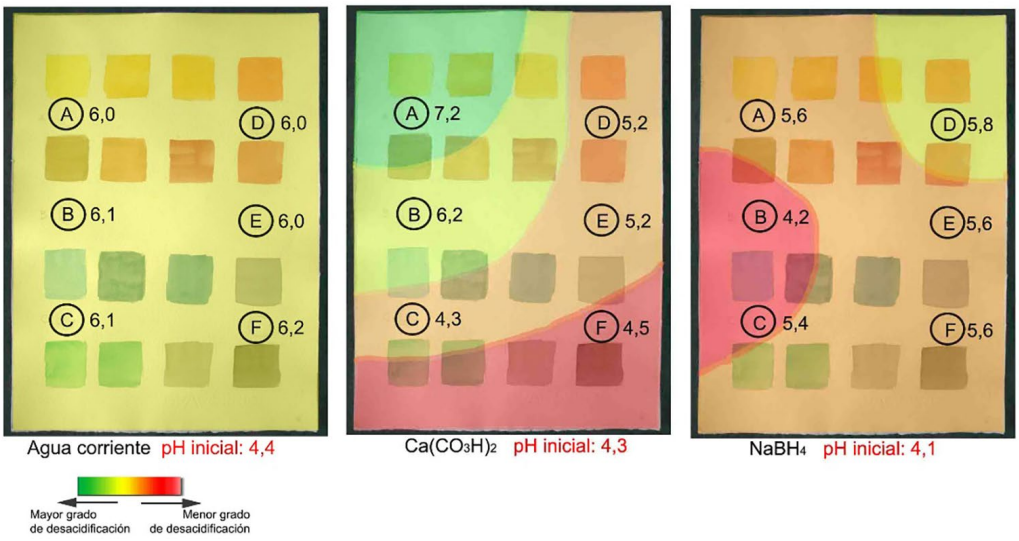

Figure 8. Diagram elaborated from the pH values obtained at points A, B, C, D, E, and F of the artificially aged and deacidified samples in prototype 3 of the capillary cleaning unit. *Image: ©Elena Esteban.*

- Tap water allows homogeneous deacidification of the entire document and raised its pH value to 6 in all cases.

- The distribution of calcium bicarbonate ($Ca(CO_3H)_2$) on the paper is variable. It reaches neutral values in the zones closest to the deposition of the solution, which decrease as the solution circulates through the document. The hypothesis is that the calcium bicarbonate ($Ca(CO_3H)_2$) deposited in the first vessel of the system begins to rapidly transform into calcium carbonate ($CaCO_3$), releasing carbon dioxide CO_2 into the environment, thus decreasing the amount of reagent that acts on the system. Therefore, carbonate (CO_3^{-2}) initially increases the pH but loses effectiveness.

- In the case of sodium borohydride ($NaBH_4$), deacidification occurs more homogeneously than in the previous case. This solution increases the pH of the paper, but not equally in all areas.

The results represent the first phase of research that leaves open new lines of research related to the study of the movement of water through the system –studied by dyeing the paper as a control solution and the distribution of the solutions on the surface of the papers and their application on different treatments– and with the variability of the treatment times depending on the inclination of the support, the nature and density of the conductive fabric and the heights of the water deposits.

Conclusions

The application of capillary systems to the conservation of documentary heritage offers numerous advantages for the works: reduces the physical and chemical risks caused by other conventional treatments, such as washing, allows the control of the treatment at all times, and requires a simple, inexpensive and accessible infrastructure.

About the support, the capillary structure of the paper directly influences the passage of water, determining the effectiveness of the treatments and reducing negative side effects. It is essential to consider the composition of the paper (fibers, glues, and fillers), the dimensions, thickness, and other physical-chemical characteristics, as well as the condition of the work.

Furthermore, the graphic technique is an appropriate treatment depending on the nature of the inks and the technique. The control of the dissociation degree of the ink, the absorption capacity of the paper, and the treatment time are essential to minimize the risk of bleeding or ink dissolution.

These studies have provided variations in the system that enhance the success of the treatment. Thus, the inclination of the plane and the use of several layers of Sontara® (two in this case) reduces treatment times without creating an excessively cushioned bed. The homogeneous weight allows full contact between the paper and the base material, and the use of tap water with a high carbonate content, as in the case of Granada, helps in deacidification and always leaves a small alkaline load on the document.

Therefore, it is a system that can be adapted according to the characteristics of the document and the treatment to be applied since it offers great advantages while reducing the stress caused by other cleaning systems, allows acting on document structures made up of several supports, combining several treatments in the same procedure. Moreover, allows continuous control of the process and reduces the amount of water required for the treatment.

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