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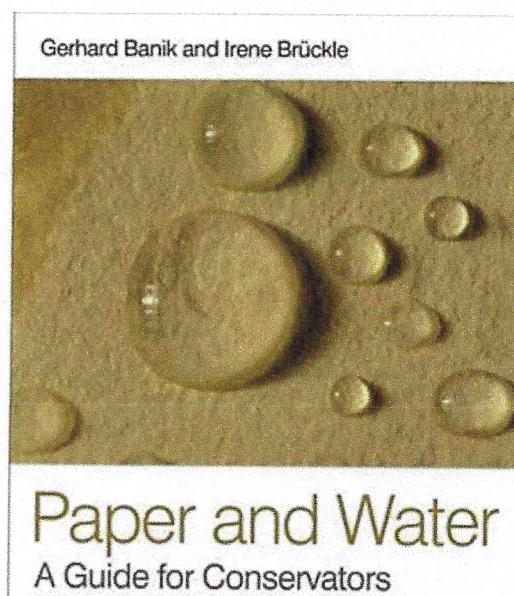
Paper and Water: A Guide for Conservation—A Review

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Paper and Water: A Guide for Conservation, Gerhard Banik and Irene Brückle, Second revised and enlarged edition, Siegl (Munchen), 2018. 634 pp. ISBN: 978-3-935643-91-7

Water is a substance that interacts with cellulose from the beginning when paper is formed and throughout its life via the aging process.

Professor Gerhard Banik and Professor Irene Brückle, the authors of *Paper and Water* have experience in paper conservation science, conservation practice and teaching. Through *Paper and Water* Banik and Brückle intend to fill the gap between conservation scientist and practitioner. In addition, several other authors well known within their specialised fields contributed, including Dr Vincent Daniels, Dr Ute Henniges, Stefan Fischer, Associate Professor D Steven Keller, Joanna Kosek, Reinhar Lacher, Associate Prof. Antje Potthast, Dr Anthony W Smith, Prof. Alfred Vendl, the late Gunther Wegele and Professor Paul Whitmore.

The first edition of *Paper and Water* was supported by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), the Institute of Conservation (ICON) and the Leonardo da Vinci Programme, and was published in 2011 by Elsevier-Butterworth-Heinemann. The second edition is published by Siegl (Munchen) in 2018.

The book starts with a revised and expanded preface to the first edition, forewords from the perspectives of conservator and conservation scientist, an introduction and guide to the book structure with an explanation of the creative visual models and their colour code, treatment simulation, a list of abbreviations and three pages of acknowledgements. What follows is 15

reference-rich chapters, a glossary of terms and definitions, and 10 useful appendices. The final pages provide a brief about each author and a DVD is provided where animated graphics and video clips can be found.

Paper and Water aims to help paper conservators make the right decisions, and answer questions such as: How does cellulose interact with water in the process of papermaking? Why can wood and vegetable fibres when dispersed in water and scooped up in a screen and dried form a strong sheet whereas animal hair or chemical and artificial fibres break up into pieces? How does water influence the ageing process? What are the characteristics of paper and how does it become acidic? What is the effect of sizing on paper? What is the aging process of cellulose fibres? How does bleaching affect paper fibre composition? How does drying affect the mechanical characteristics of paper? And many other questions that relate to aqueous treatments, deacidification, and drying strategies.

To answer these, it is necessary to understand the properties of cellulose and its interaction with water molecules, something discussed at length in the first four chapters of the book, explaining terms such as 'self-adhesion', 'hydrophilicness' and 'hydrogenic cohesion'.

The first chapter is fundamental. Banik explains the relevant chemistry, chemical bonding and the molecular forces at play in the interaction of water and cellulose. Ionic and covalent bonds as well as physical interaction forces between molecules such as hydrogen bonding and Van der Waals forces are explained nicely in table 1.2. The concept of energy in relation to chemical and physical bonding is described in simple detail, using examples such as cellulose synthesis in plants from carbon dioxide and water using the energy of sunlight. Electronegativity and the special ability of carbon to form polar and non-polar structures is also discussed.

Chapter two is devoted to the properties of water as the basis for papermaking and many conservation interventions. The molecular structure of water in three aggregation states: gas, liquid and solid is thoroughly discussed. The way water molecules are absorbed by cellulose surfaces is elegantly shown in Fig 2.8 as well as surface tension and its role in absorption and cohesion to cellulose. The concepts of hydrophilia and hydrophobia are explained in pp. 27–30; water is able to penetrate porous polar substances very easily but is repelled by those that are largely non-polar or hydrophobic, e.g. sized paper. The parameters that conservators make use of working with water in conservation—i.e. viscosity, volatility as well as cohesive forces—are explained.

In chapter three, the principles of acid-base chemistry are introduced by Banik, which is important with respect to the preservation of paper objects. Acidic compounds are capable of accelerating the hydrolytic depolymerisation of cellulose, affecting the stability of paper. Aqueous and non-aqueous deacidification methods, dissociation, acids and bases, hydronium ion, the pH concept and buffer solutions are described in this chapter.

In chapter four, Bruckle explains how the presence of water changes the structure and key properties of dry and wet paper. As these changes originate at the molecular level, special attention is given to cellulose structure at the beginning of the book in chapters one to three.

Chapter five focuses on how processing paper pulp affects the interactions between paper and water. By comparing the art of paper making to modern cooking, Bruckle describes how cellulose, hemicellulose and lignin need to be processed both chemically (pulping and bleaching) and physically (beating and refining) in order for the paper to have the appropriate strength, flexibility and durability.

Chapter six is dedicated to sizing, a process affecting the penetration of water and other liquids by adding agents such as starch, gelatin and alum rosin through surface application or during the paper-making process. The effects of the latter and additional factors such as pH conditions are all explored. Special attention is given to gelatin and rosin sizing, the sizing methods practised in western papermaking. In Figures 6.4 and 6.23 the interaction of aqueous ink with the gelatin-sized and rosin-sized paper surface is clearly shown. The use of starch in Arab paper making is discussed briefly in this chapter. Starch is introduced as a surface-strengthening agent rather than a sizing material because starch 'is removable by cold water', p.149. This chapter would have benefited from further research into areas of paper making from a non-European point of view such as different sizing materials (like plant mucilages).

One of the most important steps in paper making is the process of drying freshly produced papers. Chapter seven gives a comprehensive overview of the effects of the loss of water on the chemical, structural and dimensional properties of paper as well as how the dried paper reacts once water is reintroduced. This chapter provides a comprehensive summary of technical information about machine versus handmade papers.

The focus of chapter eight is the ageing process and its relationship with water. While older papers made with pure cellulose are extremely stable, papers made with wood pulp produced from the 19th century onwards are not. The common effects seen during ageing are a loss of strength and flexibility, acidification leading to degradation, discolouration and, finally, change in moisture content and crystallinity within paper, which reduces flexibility. Through hydrolysis, oxidation, alkaline and mechanical degradation, the cellulose chains start to break down resulting in yellowing, loss of flexibility and stability, and eventually degradation.

In chapter nine, Ute Henniges and Antje Potthast present analytical methods for characterising paper. This chapter was not in the first edition. The analytical approaches range from simple methods such as testing tensile strength, tear strength and folding endurance to increasingly sophisticated methods: i.e. microscopy, pH measurement, colour measurement, molar mass

distribution and chemical kinetics, to name but a few. Understanding the characteristics of different papers can inform different handling techniques, preservation and conservation treatments.

Chapter ten explores different ways water is introduced to the paper and its effects, complementing chapters four and eight. Water is transported through the paper fibres by gas and surface diffusion, capillary transport and bulk solid transport. This chapter also explores how water is used in the treatment of paper-based objects using DVD animations to supplement the discussions.

In chapter eleven, removal of discolouration through washing is explored. Different compounds contribute to paper discolouration such as degraded carbohydrates, lignin derivatives, resins and proteins. Some discolouration compounds are insoluble in water but water-soluble ones can be removed by washing. By diffusion, these products can be removed from the fibres; however, factors such as the thickness of the paper and presence of sizing and its application method affect the rate in which water can penetrate the paper.

In chapter twelve, different washing techniques are explored: immersion, float washing, blotter washing (open and sandwiching) and washing through a suction table. Appropriate washing and drying methodology should result in reduction or removal of discolouration, reduction in acidity (increase in pH), increase in mechanical properties (flexibility and strength) and minimal distortions while preventing changes in media and colourants.

Paper can become acidic due to factors such as oxidation of cellulose, hemicellulose and lignin, the acidic pulping process, accumulation of acidic degradants, presence of alum during the sizing process, absorption of pollutants (sulphur dioxide, nitrogen oxides) and application of acidic media. In order to neutralise the acidity, deacidification processes are introduced, the focus of chapter thirteen. While there are non-aqueous deacidification methods, the aqueous ones can also remove soluble acidic products from the paper fibres. Alkaline solutions (calcium hydroxide, calcium hydrogen carbonate, magnesium hydrogen carbonate and aqueous ammonia) introduced to paper neutralise acids and can provide an alkaline reserve. It is, however, mentioned on p.430 that papers that are dyed, dense, calendared, have short fibres or contain certain media may be sensitive when in contact with alkaline solutions. Hence, the composition of the object treated, and concentration of the solution must be carefully considered. This chapter would have benefited from research into the effect of alkalis on paper dyes used extensively in Middle Eastern manuscripts.

Drying of paper based on good conservation practice is explored in chapter fourteen. Factors considered are the dampness of the object, how it is stacked, air exchange, the amount of pressure and lateral restraints. Freeze drying of water-damaged paper is also explored. During drying, excess liquid is removed first through interfibre pores and then through intrafibre pores. The lateral part happens over a much longer period and it's at this stage that surface structure and dimensions are affected. Air drying limits control over such changes, which is why application of pressure, friction and lateral tension is required.

The final chapter explores the decision-making process. The risk vs benefits of aqueous treatments. How long the effects will last, the visual difference after treatment, the presence of water-soluble or sensitive media and whether aqueous treatment would increase the stability of the paper are factors that need to be considered. Moreover, with every aqueous treatment, the structure and dimensions of the paper are altered. The risks need to be minimal and benefits maximised in order to retain the object's integrity.

Paper and Water is the only comprehensive work of its kind designed for professionals in the field of cultural heritage, specifically those involved in the conservation and preservation of paper documents and works of art. However, the reader should bear in mind that the book should not be treated as a manual or step-by-step guide for paper conservation treatment but rather a great source of information to inform the decision-making process. This book is complemented by hundreds of attractive coloured illustrations, as well as a DVD with animations to demonstrate clearly the concepts and techniques described—a great visual aid for teaching.


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