John Watt · Johan Tidblad ·
Vladimir Kucera · Ron Hamilton
Editors

The Effects of Air Pollution on Cultural Heritage

Springer

Editors

John Watt
Middlesex University
Hendon, UK
j.watt@mdx.ac.uk

Johan Tidblad
Swerea KIMAB AB, Stockholm
Sweden
johan.tidblad@swerea.se

Vladimir Kucera
Swerea KIMAB AB, Stockholm
Sweden
vladimir.kucera@swerea.se

Ron Hamilton
Middlesex University
Hendon, UK
r.hamilton@mdx.ac.uk

ISBN 978-0-387-84892-1 e-ISBN 978-0-387-84893-8
DOI 10.1007/978-0-387-84893-8

Library of Congress Control Number: 2008936210

Cover illustration: The cover image shows cherubs damaged by both soiling and corrosion. They are on the outside of St Mary Woolnoth, a fine Hawksmoor Church in the City of London. Our thanks to The Revd Andrew Walker for his permission.

Printed on acid-free paper

springer.com

Preface

Managing the risk to our heritage is, of course, an enormously diverse and complex task, reflecting as it does the tremendous variety of history, style, art and culture that is represented. We have many different types of monument, they are made of many different materials, they range in age over centuries and they are located in radically different environments. Air pollution is only one of the risks that threaten this heritage and may frequently not be the most pressing. In addition we have the added complication that weathering occurs naturally and indeed is often felt to contribute to a sense of age and serenity that is fundamental to the way that we value our ancient buildings.

The damage done by air pollution, however, is real, measurable and in many cases obvious. Our industrial development has left us with a legacy of faceless statues and blackened buildings that will take many years to repair and conserve, even when pollution levels are sufficiently reduced to make it sensible to do so. There are important questions to be asked. How much damage has been done and is being done? What is this costing us? How can we be practical in our conservation to prevent unnecessary loss while protecting context and artistic merit? How much value do people actually place on intangibles like the peace of a Gothic Cathedral and how can we account for these very real benefits and others like them (such as the desire to pass on our legacy to our children and grandchildren) in order to help us raise the money to carry out our repairs and maintenance?

The threat posed to cultural heritage, especially built heritage, by air pollution has been studied for many years and this book is designed to bring together a number of strands of that research to make it accessible to the people responsible for looking after our historic buildings, monuments and artefacts. It will help both these heritage managers to prioritise conservation action in response to this threat within the context of other risks and also environmental policy makers to evaluate the economic benefit of taking action to improve air quality.

We look at the way that buildings weather in the natural environment and then show how pollution adds an extra dimension of damage. We focus on two types of damage – corrosion and soiling – and also briefly review an emerging area of research, the role of air pollution in affecting bio-deterioration of

buildings. To develop this discussion we need to present the results of a number of scientific studies. First of all we look at current, past and projected levels of the pollutants that cause the damage. The picture has changed dramatically over the years. Before the policy actions to reduce coal burning, pioneered by the Clean Air Act in the UK but now reflected throughout the developed world, the major corrosion was caused by sulphur dioxide (later know as acid rain) and the buildings were darkened by black smoke. We will show how this scene has changed and examine the new, multi-pollutant, urban environment with its lower domestic and industrial emissions but greatly increased traffic. Second, we look at the way that pollution actually attacks buildings and review the findings of a long series of experiments where typical materials have been exposed to a range of different natural and pollution situations across the world. Assessment of the rate at which they are corroded and soiled has allowed scientists to develop equations that predict the amount of damage that will result from a given amount of pollutant. These are known as "dose-response functions" and can be very powerful when we try to assess the harm that might come to a given building in a given environment. Such studies take many years and are therefore very expensive. It is therefore no surprise that dose-response functions are only available for a limited number of materials. We discuss ways to make use of these insights to evaluate pollution impact in any situation. This leads us to the idea that certain materials can be used as indicators for a more general situation and simple test kits produced to utilise them.

This is not just a book about science, however, it is also about geography and economics. Modern map making tools such as geographic information systems are ideal for showing how the risk is distributed spatially. We show how the science discussed above can be mapped – pollution maps are developed into corrosion and soiling maps by application of the dose response functions. One of the themes of this book is scale and maps can provide information at many different scales. This is illustrated in Fig. 1. The risk maps are another way that building managers and owners can access the scientific data. If the risk categories can be made accessible and relevant, then it is relatively simple to locate the particular building or monument on the map and have an estimate of the likely impact.

The damage maps may be developed into cost maps, which illustrate some of the air quality policy implications, if there is good economic data on repair and maintenance costs and on the extent of the material potentially affected (the stock at risk). We discuss a number of studies that have examined these things. The cost estimates are relatively straightforward in area terms (e.g. per square metre of exposed limestone) but it is much more difficult to estimate how much heritage material is affected. We discuss pioneering estimates of what might be termed technical materials (i.e. materials used in houses, factories and infrastructure), which use generalisations about ratios of materials to develop "identikit" buildings whose numbers are then estimated from land use maps or population density. Unfortunately, while it is relatively safe to say that, within a

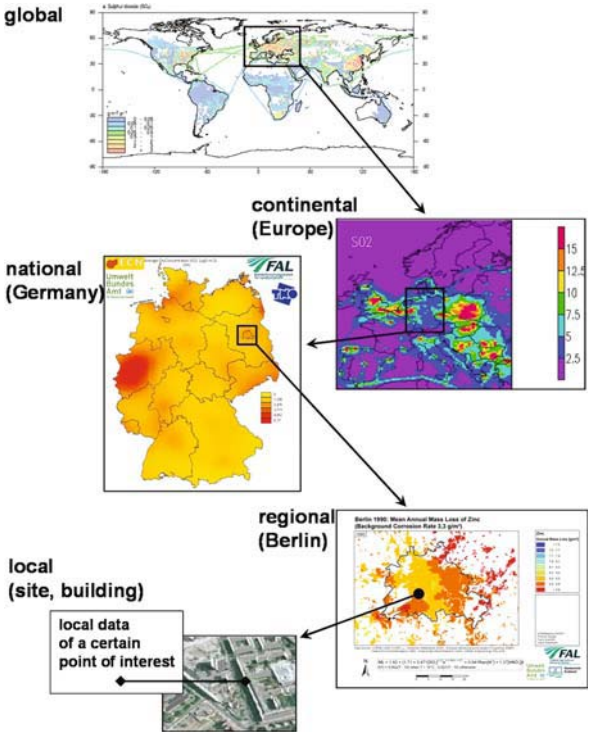

Fig. 1 Maps provide information at many different scales

limited area, most houses are of a certain type, it is certainly not possible to do this for heritage buildings. The latter are, by their nature, less frequent and may reflect a wholly different material makeup due to their importance at time of construction, and therefore use of special materials, or due to their having survived from an earlier period with different construction materials to those used later. We discuss newly emerging research that is starting to address stock at risk inventories for cultural heritage, sometimes including estimates of construction materials.

This is also a book about risk management and policy. We discuss ways that people's values may be brought into decision making. Risk management cannot rely solely on numbers, however much scientists and economists might like it to. Numbers come laden with value judgements anyway, of course, and we discuss the ways that both can inform each other. We show how conservation values such as "truth to original materials" or "reversibility of treatments" can be built into the costs calculations but, just as importantly, we show how it is possible to use peoples' willingness to pay to protect heritage and to develop more equitable business cases for fund raising. We discuss the way economic impact assessments are used in air quality policy making. The cost-benefit analysis in this field rely

today largely on human health impact but other costs should also be accounted for, especially impacts on crops, ecosystems and materials. Heritage materials are important here too and people have pointed out that materials may be more sensitive than plants and animals since they have no healing capacity. The final part of our discussion unites all of our threads into an evaluation of what heritage owners and managers can do.

The book has been developed to permit access to the material at a number of different levels. A short overview is presented at the beginning of each chapter to summarise the discussion and place it in the context of the narrative laid out in this preface. Each chapter is a review of the studies undertaken to date within the topic to present the aims and objectives of the research and the main features of the methods used. Results are discussed in terms of the current state of the art and any consensus view that may be articulated. Implications and likely future scenarios are evaluated. These discussions are written for a general reader without assuming prior specialist knowledge and, where technical results are presented, they are fully explained. More specialist readers will find expanded technical detail in the specially created "sources of additional material" sections that close each chapter.

Acknowledgements

A great deal of the research presented in this book was undertaken within a series of projects sponsored by the UNECE and the European Commission and others. The book is the final product of the CULT-STRAT project, also given below, and the European Commission is gratefully acknowledged for the financial support of manuscript preparation and publication costs. The main ones were:

"ICP Materials": The International Co-operative Programme (ICP) on effects on materials including historic and cultural monuments is one of several effect oriented ICPs within the United Nations Economic Commission for Europe (UNECE) and the Convention on Long-range Transboundary Air Pollution (CLRTAP).

"CULT-STRAT" Project: Assessment of Air Pollution Effects on Cultural Heritage – Management Strategies 2004–2007. Contract number: SSPI-CT-2004-501609.

"MULTI-ASSESS" Project: Model for Multi-pollutant Impact and Assessment of Threshold Levels for Cultural Heritage. Contract EVK4-CT-2001-00044 MULTI-ASSESS.

"REACH" Project: Rationalised Economic Appraisal of Cultural Heritage.

EU: Environment and Climate Programme under Topic 2.2.4. PROJECT No: ENV4-CT98-0708 (REACH).

"PPASDC" Project: Particulate Pollution And Stone Damage Contract. EU Contract: EV5V CT94 0519 1/07/94 to 31/10/96.

"EAPMBSP" Project: Effects of Airborne Particulate Matter on Building Surfaces Project. CE Contract STEP-CT90-0097.

We are indebted to our colleagues on all of these projects for their friendship, inspiration and support and to the UNECE including organisations from signatory countries to the Convention on Long-range Transboundary Air Pollution and the European Commission for their financial support. Many of the original contributions to this volume have been made by these colleagues. We are especially grateful to Chrissie Watt for her invaluable assistance in compiling the final manuscript.

We are also grateful to many organisations for their permission to use information which they have made available in the public domain, including: United States Government/USEPA, UK Government/Office of Public Sector Information/DEFRA and the European Environment Agency.

Contents

Contributors

Helen Crabbe Centre for Decision Analysis and Risk Management, School of Health and Social Sciences, Middlesex University, The Burroughs, London NW4 4BT, United Kingdom, helencrabbe@yahoo.co.uk

Daniel de la Fuente Materials Engineering, Degradation and Durability National Centre for Metallurgical Research (CENIM/CSIC), Avda. Gregorio del Amo 8, 28040 Madrid, Spain, delafuente@cenim.csic.es

Stefan Doytchinov ENEA – Environmental Department, 301 S.P. Anguillarese, Santa Maria di Galeria, I-00100 Rome, CR Casaccia, Italy, doytchinov@casaccia.enea.it

Miloš Drdácký Institute of Theoretical and Applied Mechanics (ITAM), Prosecká 76, 190 00 Prague, Czech Republic, drdacky@itam.cas.cz

Stephan Fitz Umweltbundesamt, Wörlitzer 1, 06844 Dessau, Germany, stephan.fitz@chello.at

Anna Gorbushina University of Oldenburg, Ammerländer Heerstraße 114-118, D-26129 Oldenburg, Germany, a.gorbushina@uni-oldenburg.de

Terje Grøntoft NILU – Norwegian Institute for Air Research, Urban Environment and Industry, Instituttveien 18, N-2007 Kjeller, Norway, teg@nilu.no

Ron Hamilton Centre for Decision Analysis and Risk Management, School of Health and Social Sciences, Middlesex University, The Burroughs, London NW4 4BT, United Kingdom, r.hamilton@mdx.ac.uk

Anda Ionescu CERTES, University of Paris 12, 61 Avenue du Général de Gaulle, 94010, F-94010 Créteil Cedex, France, ionescu@univ-paris12.fr

James Irwin University of the West of England, Coldharbour Lane, Bristol, BS16 1QY, United Kingdom, jimiirwin@aol.com

Kateřina Kreislová SVUOM, U Mestanskeho pivovaru 934/4, 170 00 Praha 7, Czech Republic, kreislova@svuom.cz

Wolfgang Krumbein University of Oldenburg, Ammerländer Heerstraße 114-118, D-26129 Oldenburg, Germany, wek@uni-oldenburg.de

Vladimir Kucera Swerea KIMAB AB, Box 55970, SE-10216 Stockholm, Sweden, vladimir.kucera@swerea.se

Ståle Navrud Department of Economics and Resource Management, Norwegian University of Life Sciences, 1432 Ås, Norway, stale.navrud@umb.no

Roger-Alexandre Lefèvre Laboratoire Interuniversitaire des Systèmes Atmosphériques, University of Paris 12, 61 Avenue du Général de Gaulle, 94010, F-94010 Créteil Cedex, France, lefevre@lisa.univ-paris12.fr

Stanislav Pospíšil Institute of Theoretical and Applied Mechanics (ITAM), Prosecká 76, 190 00 Prague 9, Czech Republic, pospisil@itam.cas.cz

Augusto Screpanti ENEA–Environmental Department, 301 S.P. Anguillarese, Santa Maria di Galeria, I-00100 Rome, CR Casaccia, Italy

Susan Sherwood Center for Technology and Innovation, P.O. Box 314, Endicott, NY, United States, sisherwood@eartlink.net

Zuzana Slížková Institute of Theoretical and Applied Mechanics (ITAM), Prosecká 76, 190 00 Prague 9, Czech Republic, slizkova@itam.cas.cz

Johan Tidblad Swerea KIMAB AB, Box 55970, SE-10216 Stockholm, Sweden, johan.tidblad@swerea.se

John Watt Centre for Decision Analysis and Risk Management, School of Health and Social Sciences, Middlesex University, The Burroughs, London NW4 4BT, United Kingdom, j.watt@mdx.ac.uk

Tim Yates BRE-Building Research Establishment, Ltd., Garston, Watford WD25 9XX, United Kingdom, Yatest@bre.co.uk