Assessment of Air Pollution Effects on Cultural Heritage – Management Strategies

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Background and aim

Damage caused to objects of cultural heritage belongs to the most serious among the detrimental effects of air pollutants as it endangers a vital part of the European identity. There is therefore an urgent need to include the impact of pollutants on cultural heritage alongside the human health and parts of the ecosystem that are already concerned in the EU Directives on urban air quality. This is especially relevant for the CAFE (Clean Air for Europe) program of the European Commission.

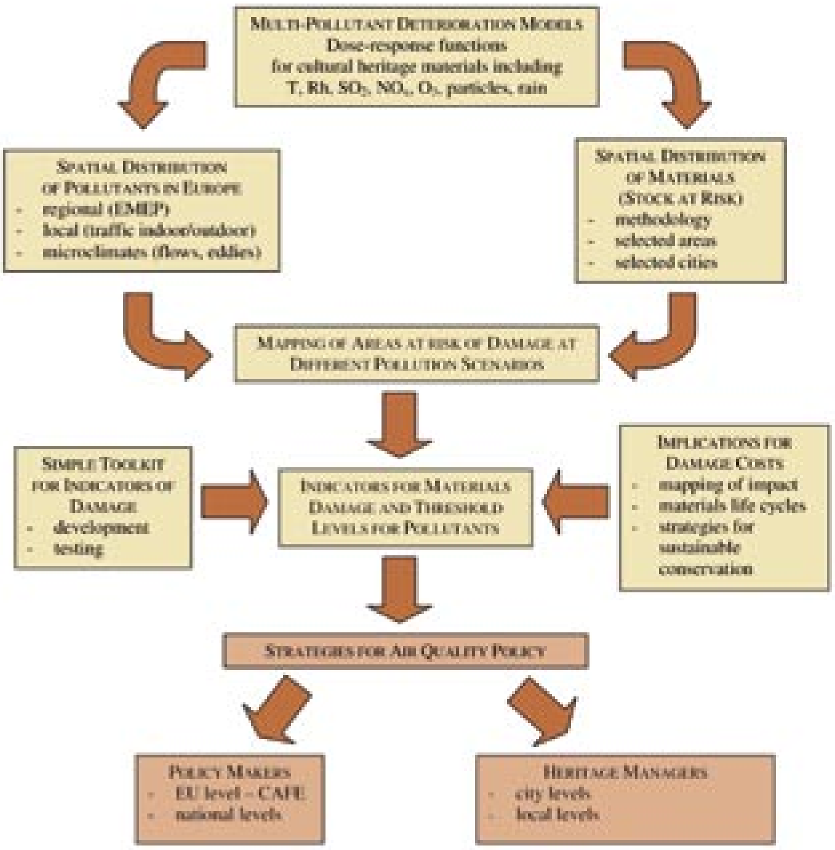
The overall aim of the project is to identify material indicators and threshold levels of pollutants to be used for development of strategies for sustainable maintenance and preventive conservation of European cultural heritage and air quality policy. The models used will permit ranking of the effects of pollutants in the multi-pollutant situation on corrosion and soiling of material. The stock of cultural heritage materials at risk in selected areas and the life cycles and costs for cultural heritage materials at different pollution scenarios will serve as economic components in the process of selection of indicators and threshold levels.

Main objectives and expected results

The major objectives of the project are:

- To provide a timely impact assessment on the effects of current and projected air pollution levels on corrosion and soiling of cultural heritage materials that can act as an input into existing more refined models on regional and city levels
- To collate information on the spatial distribution of pollution throughout Europe and demonstrate how this can be related to local flux.
- To develop a methodology for estimation and provide estimates of the stock at risk of sensitive materials in heritage objects in selected areas in Europe.
- To develop and utilize mapping procedures of the spatial distribution of damage throughout Europe for current pollution levels and the CAFE baseline scenarios for 2010 and 2020.
- To interpret the implications of the damage estimates and the mapped impact on the stock-at-risk in terms of material life cycles and strategies for sustainable conservation.
- To provide damage thresholds and indicators for heritage materials analogous to health and ecosystem indicators that relate the impact of the above effects on sensitive materials..
- To produce a reference volume collating all of the data and information available on the effects of air pollution on heritage materials in a form that is readily usable by policy makers and heritage owners and managers.

Organisation of the project



Dose-response functions and indicators for materials damage and threshold levels

Many parameters besides air pollution influence the damage to materials. Atmospheric corrosion involves chemical, physical and biological parameters. Materials behave differently and can be sensitive to pollution in general or sensitive to a particular pollutant or relatively insensitive to pollution. In the present multi-pollutant situation several different options, i.a. change of SO_2, HNO_3 and/or PM10, can be used in order to reach a situation that is acceptable and where the effects of corrosion attack can be managed. Dose-response functions exist both for the SO_2 dominating situation and for the multi-pollutant situation. Dose-response functions links the dose of pollution, measured in ambient concentration and/or deposition, to the rate of material corrosion. They are thus important tools in the assessment of the consequences of different pollutant strategy options to the deterioration of objects of cultural heritage.

The use of indicators is one way of summarising the complicated phenomenon of atmospheric corrosion into measurable and easily understandable quantities. An indicator is something that helps us understand where we are, which way we are going and how far we are from where we want to be. Material corrosion is affected both by the climatic situation as well as the pollution situation. Therefore the best indicator for corrosion damage is the corrosion attack on a few selected materials. These materials are called primary indicators. The primary indicators will be selected based on the following criteria:

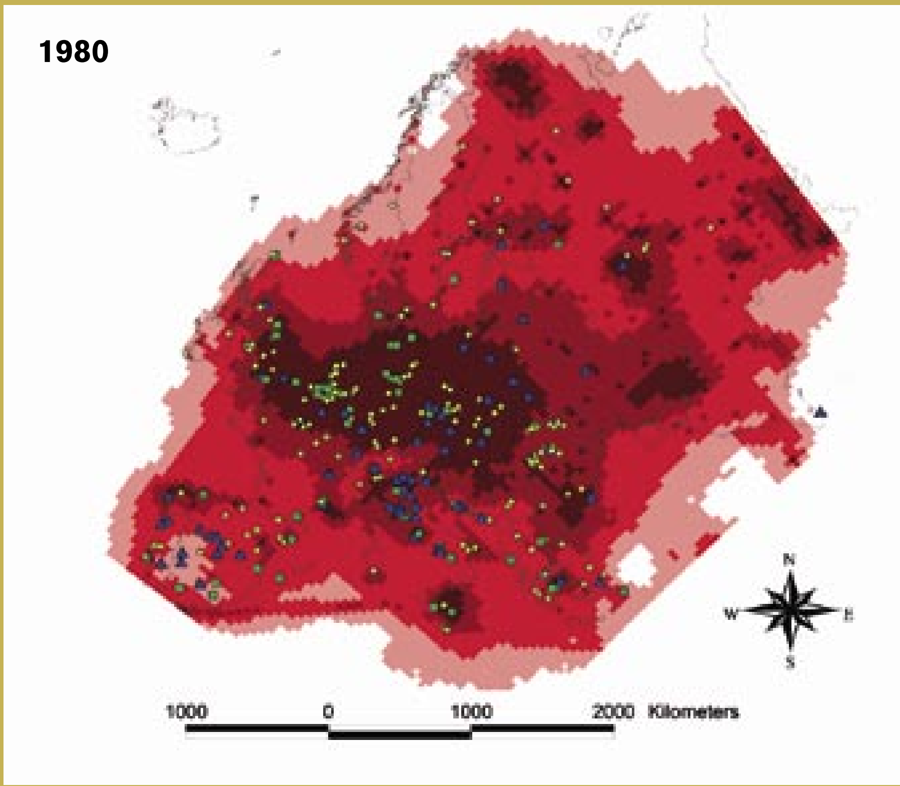
- availability of dose-response / damage functions
- frequency of use in European CH
- sensitivity to pollutants
- economic considerations
- possibility of reliable and rapid evaluation

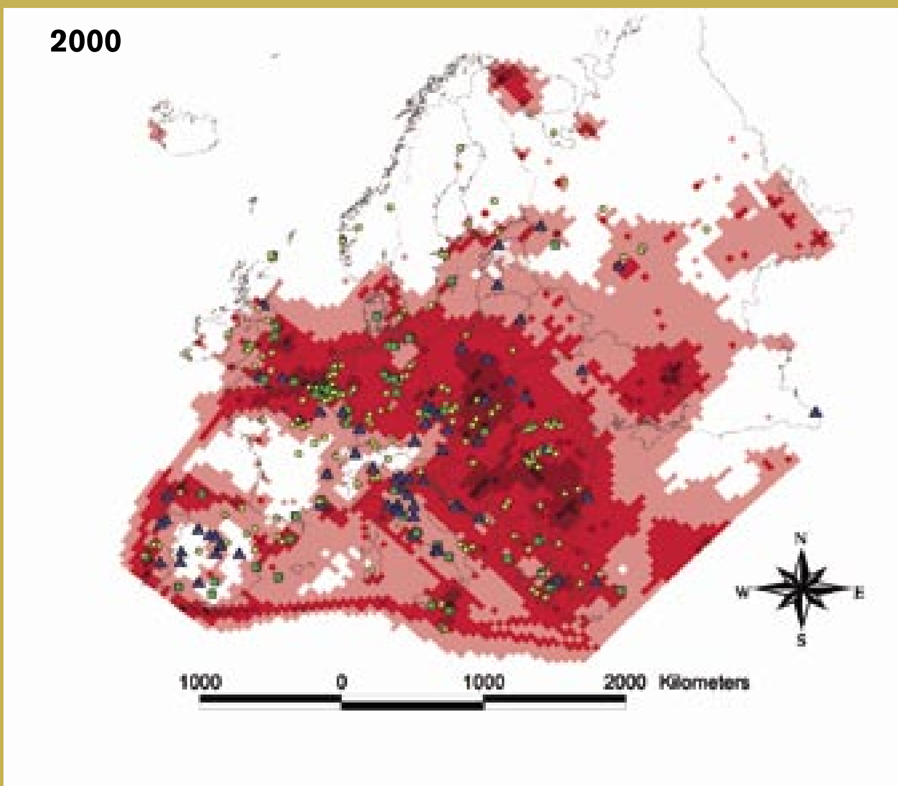
A drawback with the primary indicators is that an exposure time of at least one year is required in order to obtain a reliable indicator value. Therefore, it is practical also to allow for the use of secondary indicators. These should be environmental parameters with documented and quantifiable impact on corrosion damage.

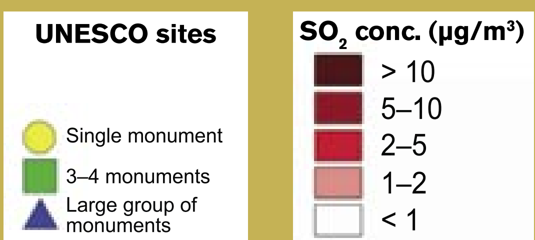
Material	SO_2	NO_2	O_3	Rain[H^+]
Weathering steel	x			
Zinc	x			x
Aluminium	x			
Copper	x		x	x
Cast bronze	x			x
Paint/galvanised	x			
Paint/steel	x			
Sandstone	x			x
Limestone	x			x
Nickel	x			
Tin			x	
Glass	x	x		x

Materials and environmental parameters included in dose-response functions for the SO_2 dominating situation.

UNESCO World heritage sites in Europe – Location and comparison of SO_2 levels in 1980 and 2000







Mapping spatial distribution of pollutants and materials in Europe

Maps are powerful tools for communicating results of corrosion attack. They can be used for identifying areas with elevated risk of corrosion and for selecting materials to be used in a particular area. A methodology for mapping of materials damage in general is described in the UN/ECE LRTAP document "Manual on methodologies and criteria for mapping critical levels/loads and geographical areas where they are exceeded". This mapping manual list the dose-response functions to be used and gives general recommendations on how to obtain the necessary environmental data. The resolution of the maps depends on the availability of data for all parameters included in the D/R-functions within the defined region. As this is limited until now, the project will concentrate on exemplary solutions: maps will be produced for the area of Europe, of whole countries, regions, and some bigger cities. The objects included in the UNESCO world heritage list in Europe can serve as an example showing the location of monuments in areas with increased risk of corrosion due to SO_2 pollution.

Analysis of life cycles and costs

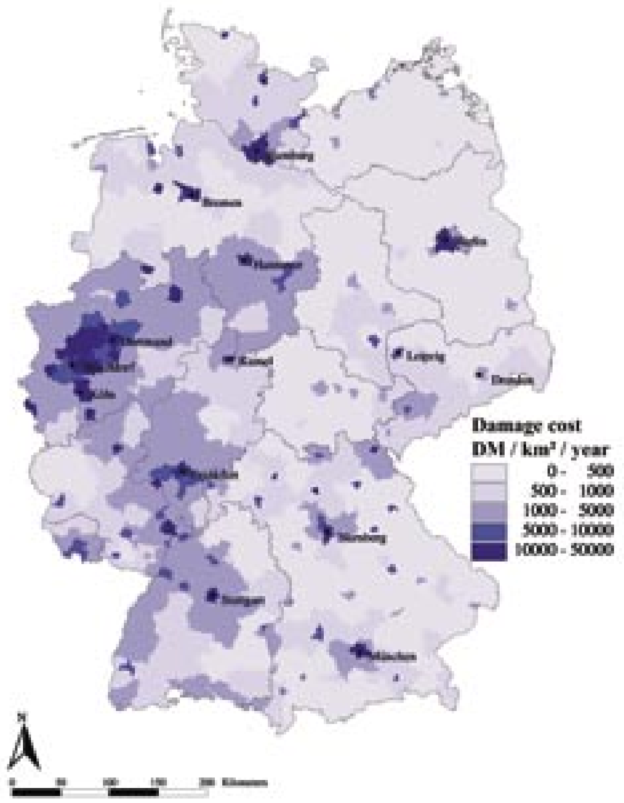
The enhanced knowledge of performance of historic buildings will enable to assess decisive deterioration effects substantially influencing life cycles. Here will be taken into account a complex long term impact on materials of cultural heritage objects from coupled action of differential agents and actions, as e.g. pollution, salts, humidity, temperature changes etc. The consequences of new multi-pollutant situation and new mechanisms of deterioration of materials of cultural heritage will be evaluated. In multi-material systems composed from elements, the weakest link with shortest lifetime will be identified. Lifetime estimation for materials, protective measures and elements represents an indispensable step for cost assessment and analyses. A workshop on economic impact of air pollution on cultural heritage will be organized and will serve as a background for the analysis.

The estimated economic damage (direct cost) can be calculated according to the equation

$$K_a = K \cdot S \cdot (L_p^{-1} - L_c^{-1}) = K \cdot S \cdot f$$

where Ka is the additional cost for maintenance/replacement, K is the cost per surface area of material, S is the surface area of material, Lp is the maintenance interval (life time) in polluted areas and Lc is the maintenance interval in clean areas. Both Lp and Lc may be assessed by the use of dose-response functions. The maintenance frequency, f, is the fraction of material that is subject to actions each year as a result of increased pollution. The equation has to be applied for each material individually. For objects of cultural heritage also the indirect costs has to be taken into account. Even of the geographical distribution of cost in Europe and in different regions is of interest and may be illustrated using mapping procedures.

Cost of corrosion damage on zinc surfaces in Germany (mid 1990's)



Strategies for air quality policy

There are two main ways in which it is possible to take action to protect heritage. Firstly by reduction of ambient levels of air pollution and secondly by instigating local management strategies that either reduces the impact of pollution or repairs the damage. These two types of strategies can be portrayed as follows:

Local management strategies based on:

- Damage inspection
- Conservation practice including preventative maintenance
- Local perspectives

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National and international strategies based on:

- Policy (informed by scientific evidence and values such as sustainability of heritage resources)
- Analysis of strategic data including air pollution, environmental status and stock at risk
- Estimates of damage impacts on life cycles of materials and benefits arising from pollution reduction

The outcome will be a volume collating data and information on the effects of air pollution on materials in a form which is readily usable both to policy makers on international and national levels and to heritage owners and managers.

Participants

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Norwegian Institute for Air Research (NILU)	CR	Kjeller / Norway
Italian National Agency for New Technologies, Energy and the Environment (ENEA)	CR	Rome / Italy
Middlesex University (MU)	CR	London / United Kingdom
Umweltbundesamt (UBA)	CR	Berlin / Germany
Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)	CR	Paris / France
Institute of Theoretical and Applied Mechanics (ITAM)	CR	Prague / Czech Republic
Building Research Establishment Ltd. (BRE)	CR	Watford / United Kingdom
Centro Nacional de Investigaciones Metalúrgicas (CSIC)	CR	Madrid / Spain
European Association of Historic Towns and Regions (EAHTR)	SC	Norwich / United Kingdom
Thomann-Hanry Company	SC	Paris / France
Instituto Centrale per il Restauro (ICR)	SC	Rome / Italy
Swiss Federal Labs. For Materials Testing and Research (EMPA)	SC	Dübendorf / Switzerland

CO=co-ordinator; CR=principal contractor; SC=sub-contractor

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