ICP Materials

Progress of activities in 2023 and future work

Ninth Joint Session of the EMEP Steering Body
and the Working Group on Effects
11 – 15 September 2023

Contents

- Progress of current work plan items
- Trends in corrosion, soiling and pollution 1987–2021
- UNESCO Cultural Heritage Sites
- ICP Materials Meeting 2023
- Draft 2024-2025 Workplan
- Invitation to the next ICP Materials Meeting 2024

2022–2023 workplan for the implementation of the Convention

- 1.1.1.9 Impact of corrosion and soiling including trends
  - Report of corrosion and soiling data from the exposure for trend analysis 2017-2021 (2022) – Completed
  - Environmental data report October 2020 to December 2021 (2023) – Completed, short summary
  - Report of trends in corrosion, soiling and pollution 1987-2021 (2023) – On-going, status report
- 1.1.1.10 Policy-relevant user-friendly indicators (UNESCO sites)
  - Report on Call for Data – Part VI: Study on the relationship between the environmental and the artefact on selected UNESCO sites (2022) – Completed, short summary
  - Report on Call for Data – Part VII: Application of models with increased resolution on selected UNESCO sites (2023) - – Completed, short summary

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Environmental data report (2023)

October 2020 to December 2021

Table 4: No of 26 participating stations reporting environmental data parameters.

Year	2018-19 and 2019-20	2020-21
Parameter	No of stations	
T (°C)	24	26
RH (%)	24	24
Precipitation amount (mm)	23	24
SO_2 (µg/m^3)		24
NO_2 (µg/m^3)		25
O_3 (µg/m^3)		24
HNO_3 (µg/m^3)		23
H^+ in prec. (pH)		17
Cl^- in prec. (mgCl/l)		16
Passive particle deposition (µg cm^{-2} month^{-1})		22
PM_{10} (µg/m^3)		18

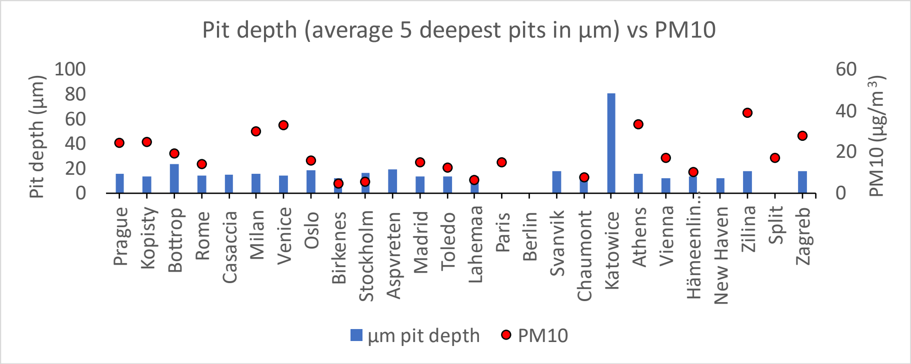
Conclusions

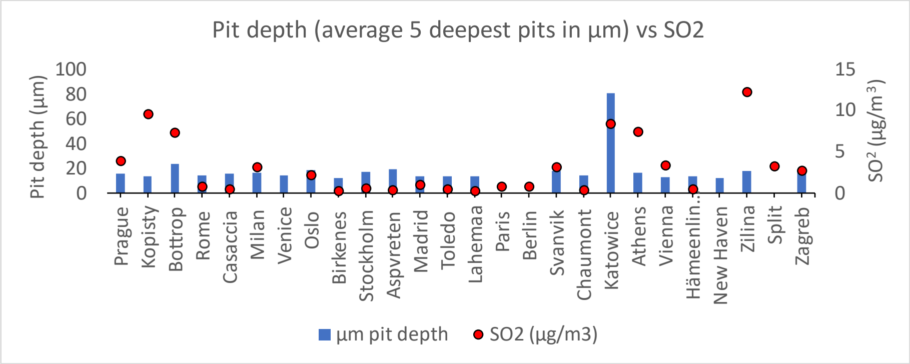
The database obtained during the trend exposure period 2020-2021 has a similar regularity and quality as the previous years of the ICP Materials programme. Sites belonging to the national surveillance programmes and EMEP, have the best regularity. Some of the urban sites have a lower regularity. Except the overall missing data from two station (nos. 41 and 58) and the missing data for the precipitation quality (pH and Cl^-) from several stations, the data coverage is good. The spread in the data for the different environmental parameters is sufficient for statistical dose response analyses.

Report of trends in corrosion, soiling and pollution 1987-2021 (2023)

- Database of corrosion, soiling and environment compiled
  - Report of corrosion and soiling data from the exposure for trend analysis 2017-2021 (2022)
  - Environmental data report October 2020 to December 2021 (2023)
- Main results for Trends in corrosion, soiling and pollution 1987-2021

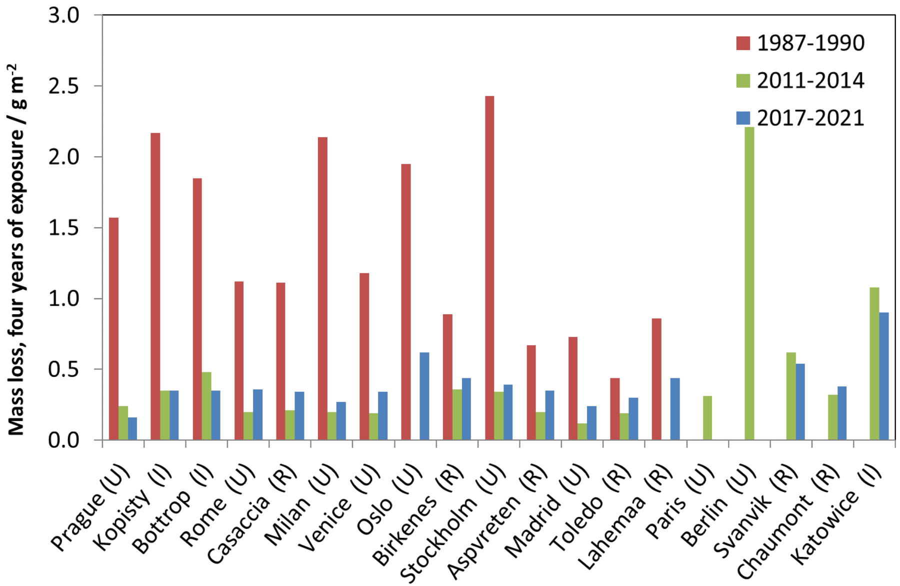
Aluminum exposure: 2017-2021





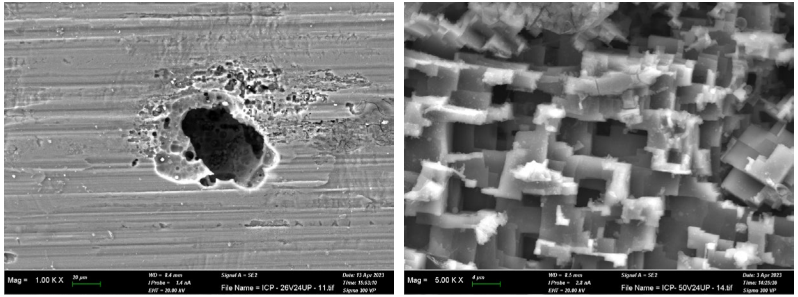
- Aluminum experiments corrosion in localized attacks. After pickling, the five deepest pits were measured from a 25x25 mm square.

Aluminum Trends: 1987-2021



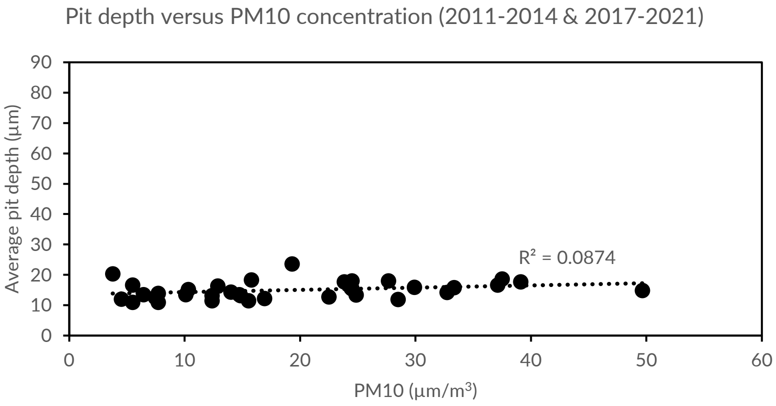
Mass loss four year exposure for 3 periods.

- Decreasing trend in yearly corrosion for all sites.
- Pit depth might be a more appropriate variable to describe local corrosion in aluminum.



Localized corrosion attack in aluminum samples

Aluminum Trends: 1987-2021

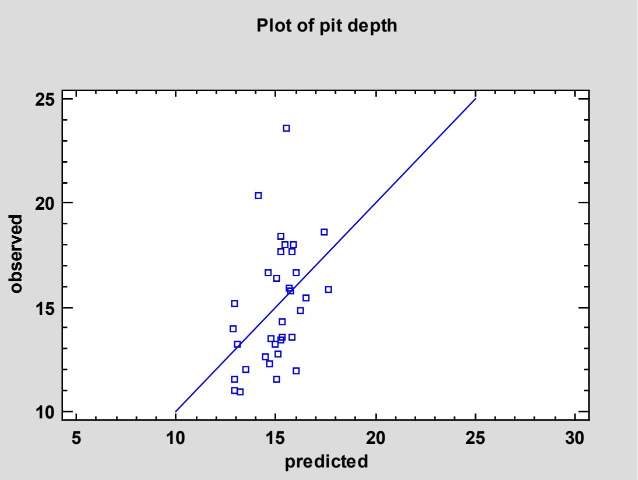


- Linear regression: No clear correlation between PM concentration and pit depth (average of five deepest pits).

- Objective: develop models using other environmental variables.

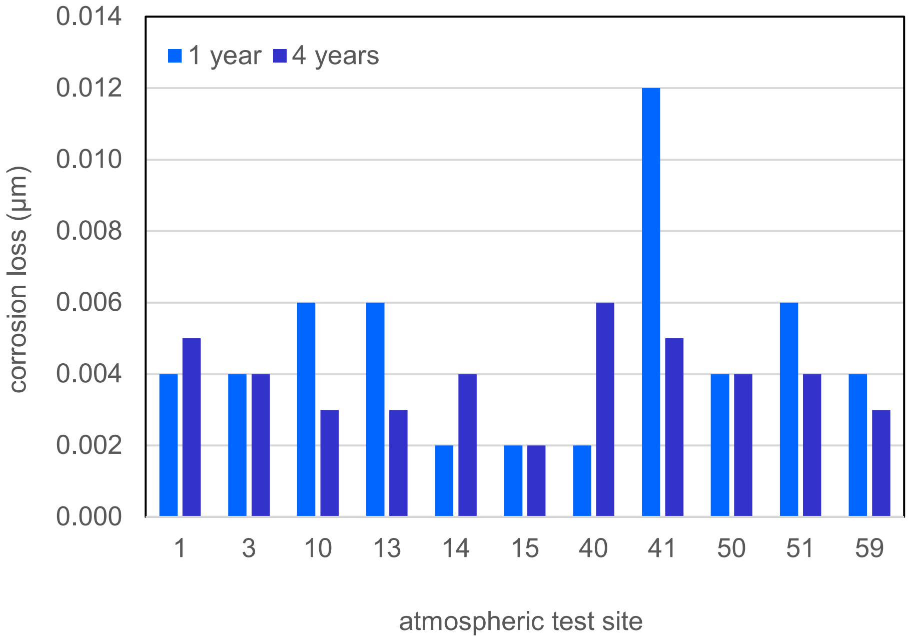
- Multilinear regression: Correlation of pit depth and environmental variables.

Predicted versus observed pit depth (data from two 4-year exposures).

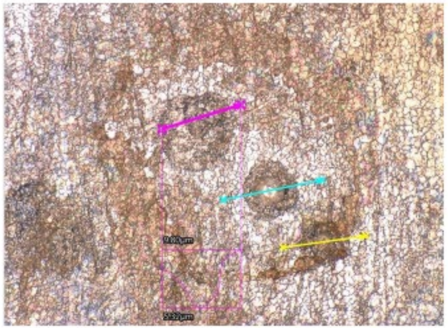


Variables: PM10, precipitation, NO2, O3
Equation of model:
pit depth = 17.2047 - 0.000675762*mm - 0.0465096*O3 + 0.0281917*NO2 + 0.00731376*PM10
<u>Low quality prediction</u> (R^2 ~18%). More data points are needed to improve prediction models.

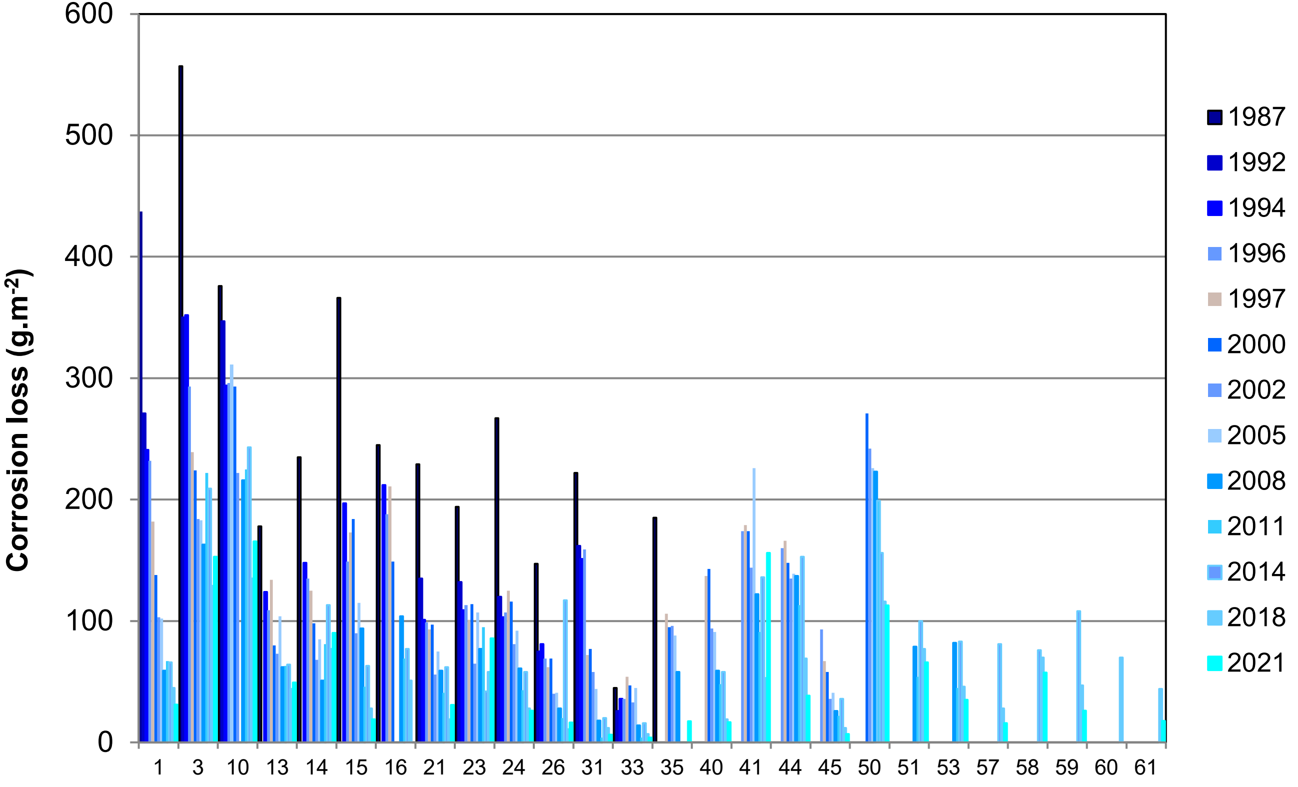
Stainless Steel: 1987-2021



Example of pitting corrosion after 4 years exposure at atmospheric test site 41 Berlin (effect of chloride deposition)



Carbon Steel Trends: 1987-2021



- Corrosion losses have decreased with the exception of site 26 (Aspvreten)
- The decreasing trend is less drastic for test sites 3 (Kopisty), 10 (Bottrop), 41 (Berlin) and 44 (Svanvik).

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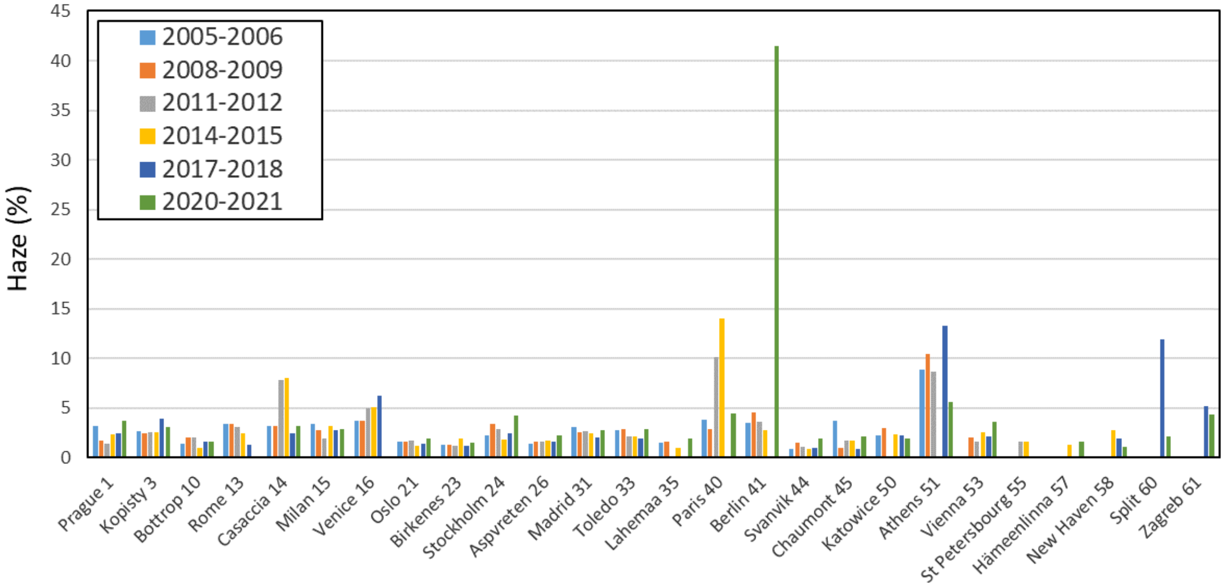
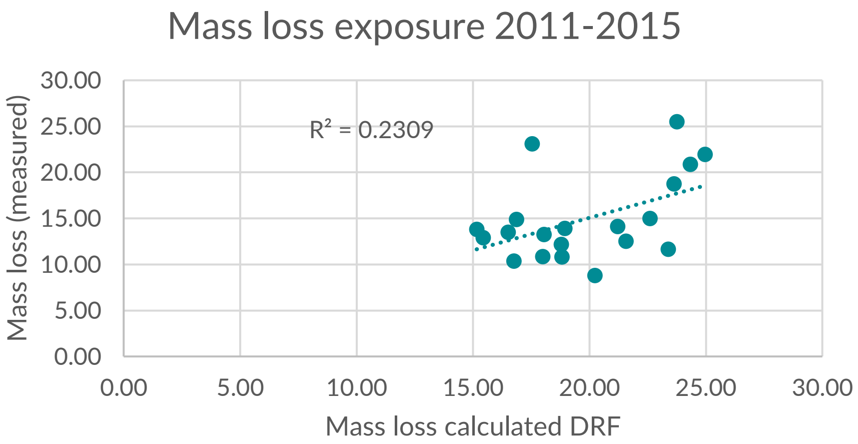
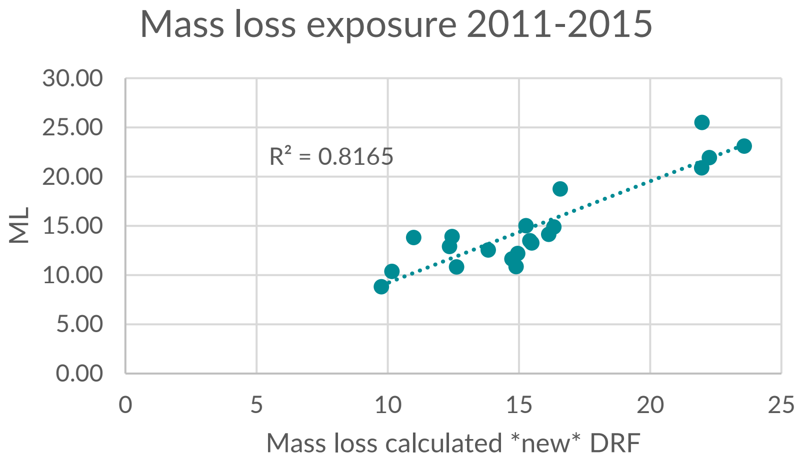
Modern Glass Trends 1987-2021



- Haze is stable or varies without clear trends in most sites.
- Site 13 (Rome) and 58 (New Haven) show a decrease in haze.
- Site 16 (Venice) and 53 (Vienna) show a slight increase in haze.

Dose-response functions for trend materials: Zinc example





ML = 1.82 + t(1.71 + 0.471$[SO_2]$^0.22*e0.018Rh ef (T) + 0.041Rain[H+] + 1.37$[HNO_3]$)

R^2 = 0.23

New ML = 5.36 + t(0.23*SO2 + 0.0023*Rain + 0.04*Cl + 0.04*pH)

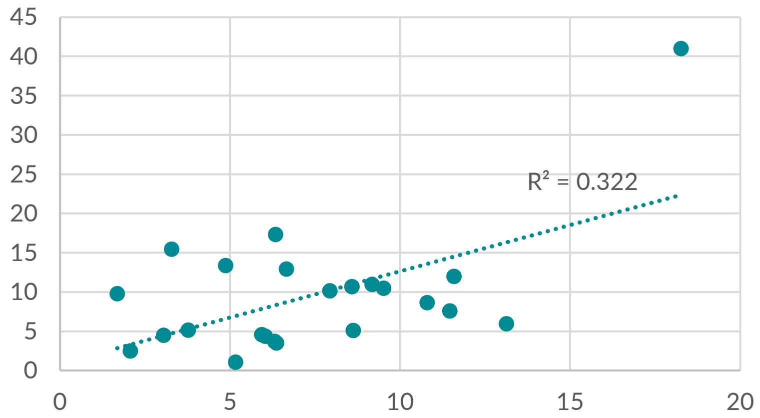
R^2=0.81

The influence of air pollutants (SO_2) have decreased so that natural factors like temperature, rel. humidity and rain become more important for the corrosion process.

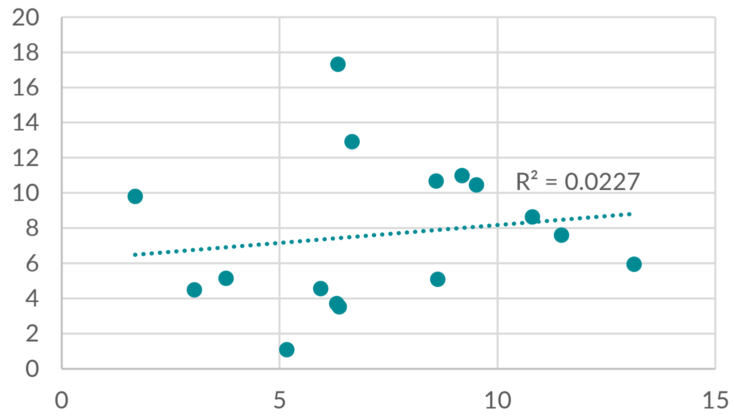
<u>A revision of the DRFs for trend materials is needed. Efforts will be made to develop functions without pH since this data is difficult to obtain.</u>

Coil-coated materials: dose-response

White with all PM10 measurements



White with PM10 only from test sites



- Loss of reflectance for white painted steel (WPS) related to PM10 concentration and time (Mapping Manual $\Delta R = R0[1 - e^{-3.96 \cdot 10^{-6}[PM10]t}]$)
- Calculation does not correlate with measured values in coil coated samples.
- More reliable PM measurements are needed (probably closer to the rack).

2024-2025 Workplan

Impact of corrosion and soiling including trends

1.1.1.9	Monitor and assess impact on environment of corrosion and soiling effects on materials and their trends	Report on dose-response functions for trend materials (2024) Technical manual for 2024–2025 exposure for trend analysis (2025)	ICP Materials	Recommended contributions

39th meeting
May 3-5, 2023

Bochum and the German mining Museum! Finally!

There were total of 25 participants from 13 countries, including the chair of the working group on effects

ICP Materials Meeting 2024

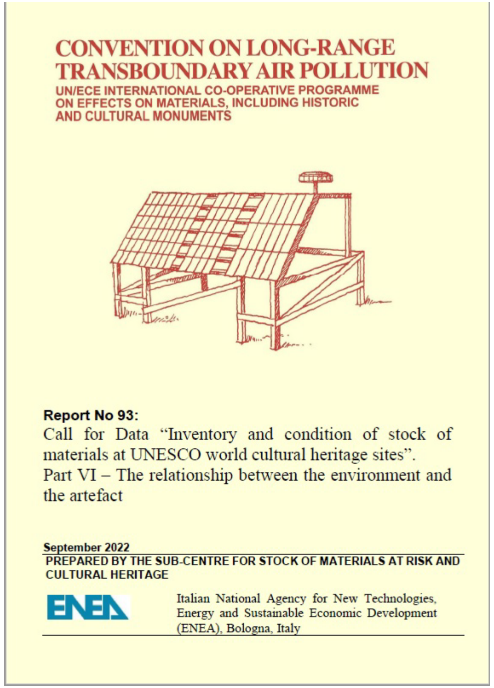
Welcome to CENIM (Centro Nacional de Investigaciones Metalúrgicas)

6th-8th May 2024

Madrid, Spain

UNESCO CASE STUDIES
ICP Materials Report 93 (2022) - summary

Call for data “Inventory and condition of materials at UNESCO world heritage sites”. Part VI. Study on the relationship between the environment and the artefact on selected UNESCO sites.



CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION
UN/ECE INTERNATIONAL CO-OPERATIVE PROGRAMME ON EFFECTS ON MATERIALS, INCLUDING HISTORIC AND CULTURAL MONUMENTS

Report No 93:
Call for Data “Inventory and condition of stock of materials at UNESCO world cultural heritage sites”.
Part VI – The relationship between the environment and the artefact

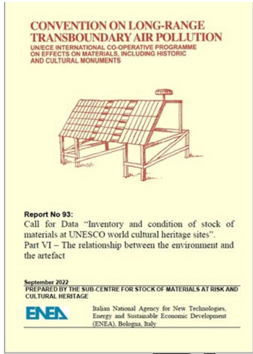
September 2022
PREPARED BY THE SUB-CENTRE FOR STOCK OF MATERIALS AT RISK AND CULTURAL HERITAGE

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Bologna, Italy

Report on Call for Data
Part VI: Study on the relationship between the environmental and the artefact on selected UNESCO sites (2022)

The relationship between the environmental context surrounding some selected UNESCO sites and the air pollution responsible for the corrosion and soiling effects of the material is investigated. Three different sites were chosen on the basis of their different estimated cost due to air pollution for the materials of the monuments

	Limestone (corrosion)	Limestone (soiling)
St. Domnius Cathedral	Low	Medium
Würzburg Residence	Medium	Medium
Royal Palace of Caserta	Very High	High/Very High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Range time investigated: years 2015-2019

To assess the damage due to attack of atmospheric pollutants at the selected UNESCO world cultural heritage sites, the methodology based on the use of dose-response function was used to estimate limestone surface recession and soiling.

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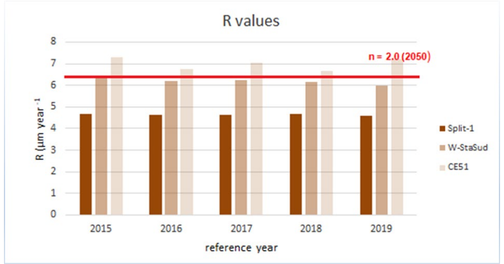
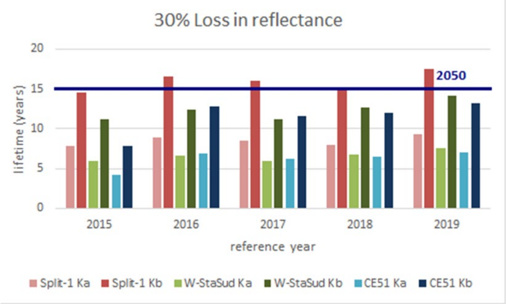


$R = 4.0 + 0.0059[SO_2]Rh60 + 0.054Rain[H+] + 0.078[HNO_3]Rh60 + 0.0258PM_{10}$



$\Delta R/Ro = 1 - \exp(-PM_{10} \times t \times K)$

$Ka = 6.5 \times 10^{-6}$ (not official)

$Kb = 3.47 \times 10^{-6}$ (Polycarbonate Membrane Material)

- ✓ **Total emissions: decreasing**
- ✓ **NO_2 and PM_{10} concentrations: light decreasing.**

- ➢ **Not observed a real trend for R and ΔR/Ro (more or less same values in 2015-2019)**
- ➢ **R values below 2050 target (6.4 µm $year^{-1}$) except for Caserta**
- ➢ **Years number to reach 30% loss of reflectance increasing but far from 2050 target (15 years) except for Split considering the lower value for soiling K**

- ❖ **Despite the decrease in emissions in recent years and the slight decrease in the concentrations of atmospheric pollutants, the materials of the cultural objects studied are still partly at risk**

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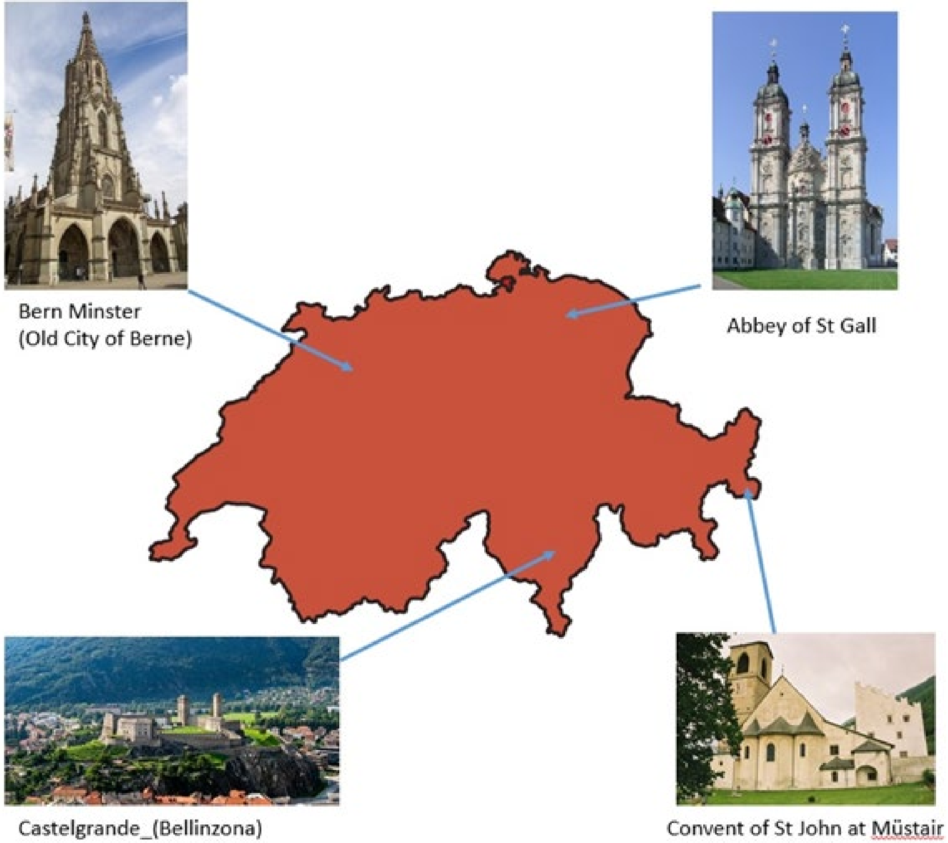
Part VII (2023): Application of models with increased resolution in the study of damage at selected UNESCO sites - Switzerland [work in progress]



Application of air quality models with increased resolution at selected UNESCO sites in Switzerland to assess the damage on materials due to air pollution

EMEP01 with resolution 01°x 01°long-lat (9x11 km at 40°N)
Swiss national models with higher resolutions 100x100m ÷ 1000x1000m

Old City of Berne, Abbey of St Gall, Benedictine Convent of St John at Müstair and Three Castles, Defensive Wall and Ramparts of the Market-Town of Bellinzona.

Limestone_Recession rate, µm

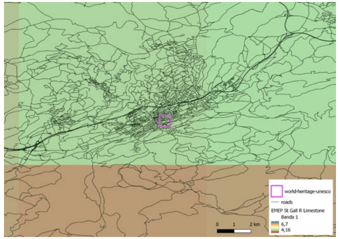
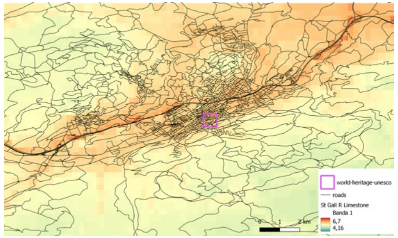
range for R: (4.16÷6.7) µm

UNESCO SITE	Coordinates	Recession Rate (µm)	
		EMEP01	Swiss model
Abbey of St Gall	47.4233; 9.3778	4.8	5.8
Old City of Berne	46.9481; 7.4503	4.9	5.7
St John at Müstair	46.6294; 10.4476	4.2	4.8
Castel Grande Bellinzona	46.1931; 9.0224	4.7	5.8
Montebello Bellinzona	46.1912; 9.02636	4.7	6.0
Sasso Corbaro Bellinzona	46.1881; 9.03012	4.7	5.7

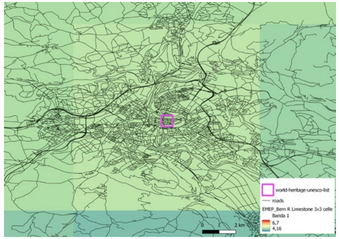
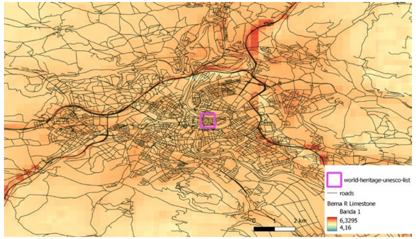
The recession rates modelled with national input maps are higher than those based on EMEP01 maps (around 20%).

EMEP 01° x 01°

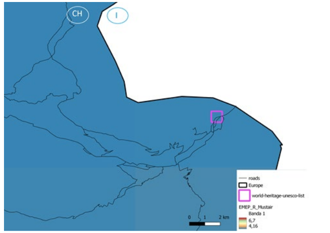
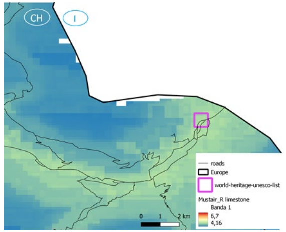
SWISS 100m x 100m (aligned)

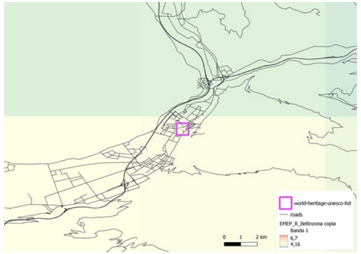
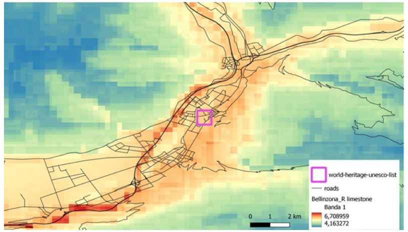
St Gall
(47.4233; 9.3778

Bern
46.9481; 7.4503

Müstair
46.6294;
10.4476

Bellinzona
46.1931; 9.0224

Air pollutant concentrations are not elevated for the selected Swiss UNESCO sites investigated:

- the recession values are below 2050 target (6.4 µm year-1)
- number of years to reach 30% loss of reflectance is above or very close to 2050 target of 15 years before action.

Looking at all the maps:

- the colour red/orange highlights the places with high buildings density and with traffic roads

The concentration of a pollutant calculated in a cell of a grid represents the mean value of the concentration of that pollutant in the whole area of that cell.
The reducing of the area of the cell improves the estimation of the concentration value of a pollutant in the zone of interest.

The major evidence of this study is that using a model with a resolution at urban scale it can have more realistic estimation of the effect of air pollutants on cultural object.

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2024-2025 Workplan

Policy-relevant user-friendly indicators (UNESCO sites)

1.1.1.10	Gather information on policy-relevant user-friendly indicators to evaluate air pollution effects on materials by conducting case studies on UNESCO cultural heritage sites	Risk assessment for selected monuments based on retrospective trends in 2000, 2010 and 2020 and EMEP 01° x 01° data (2024) Cost assessment for selected monuments based on retrospective trends in 2000, 2010 and 2020 and EMEP 01° x 01° data (2025)	ICP Materials	Recommended contributions