Concerns over Radiation-Induced Side Effects in Cultural Heritage:
A Common Issue for Scientific Communities Using Radiation for Characterization or Preservation of Cultural Heritage

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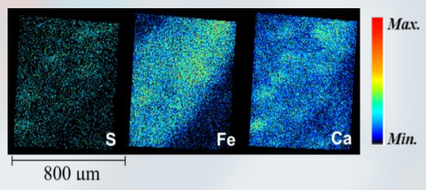
Analyses – Imaging – Characterization

"Nuclear" methods for research

- Radiography, gammagraphy, neutrography, electron microscopy
- Elemental analyses (XRF, PIXE, XANES, NAA, etc.)
- Crystallography (XRD, neutron diffraction)
- …

External ion beam set-up at C2TN. 2 MeV proton beam is used to measure iron gall ink in an ancient manuscript.

The beam can raster the surface and 2D elemental maps from PIXE spectra can be obtained.



Electrons, X-rays, synchrotron radiation, neutrons, ions, etc. are used to provide information about materials in archaeological, paleontological, historic or artistic objects...

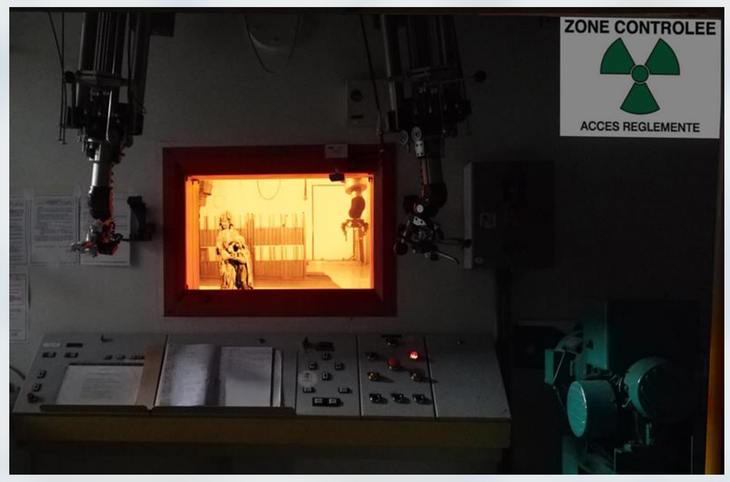
Level of exposure from mGy to MGy *according to the techniques*

(For nuclear analyses techniques that exploit natural radioactivity data, e.g. dating, there are not concerns about radiation induced side effects)

Remedial conservation treatment

Radiation processing for protection, preservation and conservation

- Insect eradication (500 Gy minimum)
- Fungicidal treatment (typically 5 to 10 kGy)
- Consolidation with radio-curable resin (30 kGy or more)



"Gamma" insect eradication by a 500 Gy minimum irradiation dose of a polychrome wooden sculpture in ARC-Nucléart

Gamma and electron radiation are used for biocidal treatments of artefacts in historical, archaeological, ethnographic, natural history, modern art collections… Consolidation of structurally weakened objects with radio-curable resins is less common.

Level of exposure from kGy to ten of kGy

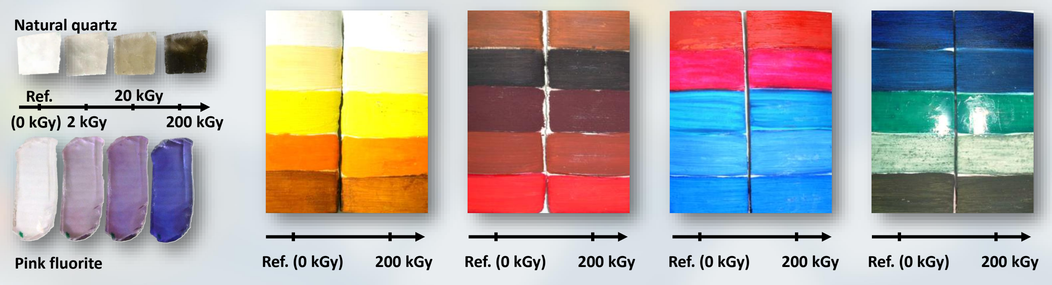
Radiation-based techniques offer unique opportunities for Cultural Heritage.

World-wide, they are used more and more.

Side effects

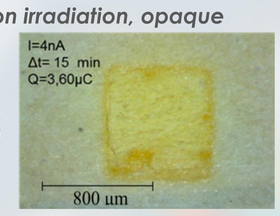
General understanding from targeted studies or other fields of knowledge

- Trapping of electron leading to coloring of transparent material, even at doses in kGy range
- Modification of mechanical strength due to broken bonds and cross-linking, as result of exposure in the range of ten kGy and beyond
- Chemical change triggered by radiation-induced radicals (oxidation, surface erosion, long-term autocatalytic degradation), from range of ten of kGy or hundred of kGy
- Temperature-induced effects (at least hundred of kGy)
- Knocked out of atom with heavy or very energetic particles, giving rise to vacancies and molecular defects



While transparent materials like gemstone tint easily under photon or electron irradiation, opaque materials, such as polychrome layers (here different classic pigments in poppy seed oil on gesso coated wooden samples), do not.

In PIXE analyses, high intensity proton beam can cause irreversible damage on a white paper sample (degradation of cellulose chains and oxidation processes) ; in extreme cases the paper will collapse structurally.



The diversity of materials encountered in cultural heritage is vast and objects are often made of heterogeneous composition on several scales, always requiring more applied and fundamental research.

Knowledge of side effects on cultural heritage materials and objects is the key for a safe application of "nuclear" techniques.

Risk analyses

Expected benefits of exposure must be weighed against possible drawbacks

- In terms of information about the cultural object. Take into account that there is also a risk that exposure distorts immediate or future analyses,
- In terms of behaviour of the heritage object. For instance, fungicidal treatments up to 10 kGy can generate minimal effects on paper but are often the best option for conservation.

The question "is the radiation treatment better or worse than alternatives, including doing nothing?" must be asked.

Mitigation

To avoid over-exposure

- Optimization: ALARA approach (As Low As Reasonably Achievable)
- Mastering of dosimetry parameters
- Control of environmental parameters
  - Humidity can cause secondary reactions linked to water radiolysis.
  - Inert gas, vacuum, low temperature, can mitigate some adverse side effects like oxidation.

Experimentalists training and increasing awareness is of paramount importance and has been supported by IAEA.

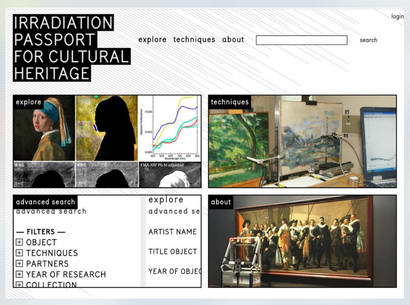
Documentation

A crucial pillar of cultural heritage field

It must include:

- Dosimetry data
- Detected change

A digital exposure passport reporting the main radiation parameters experienced by an object is currently under development.



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