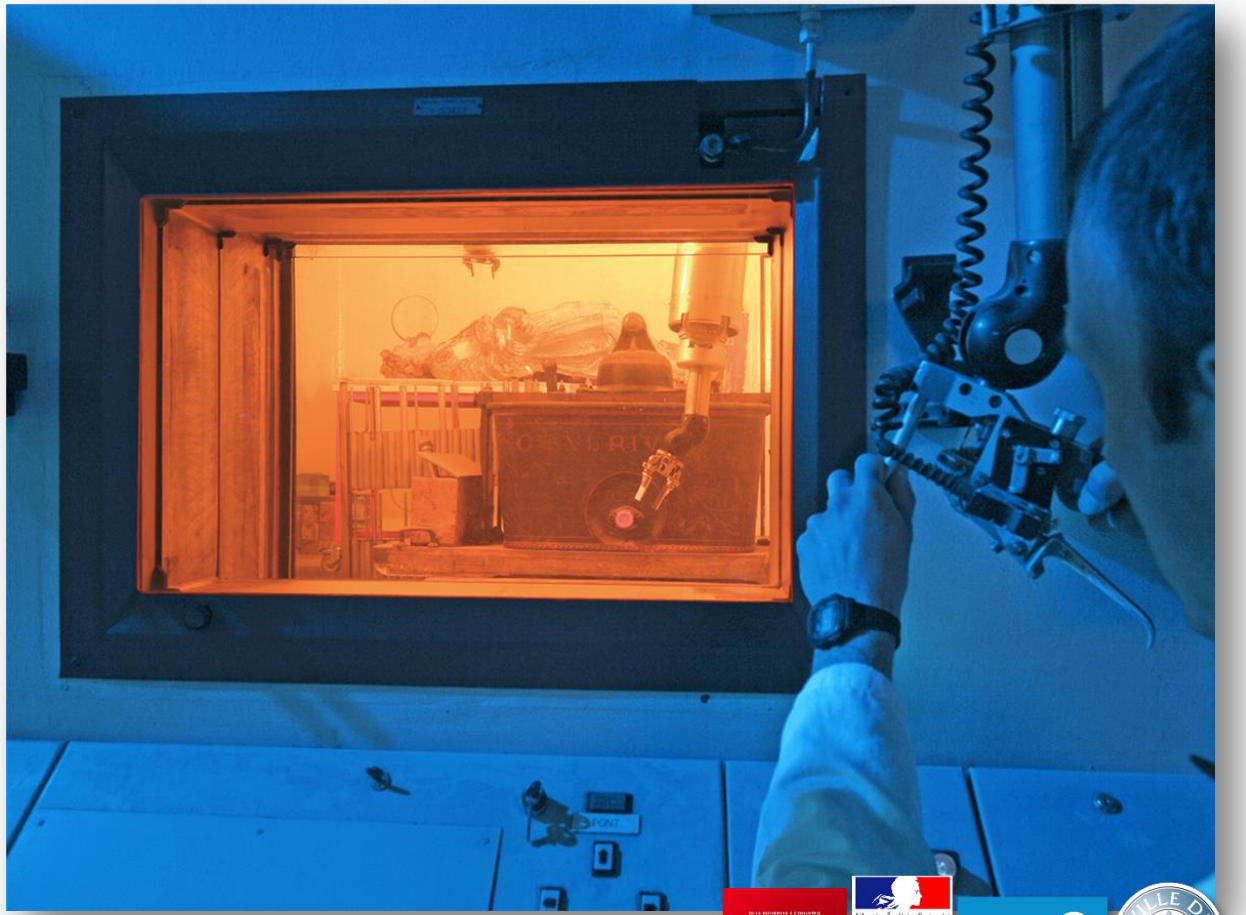
Uses and Prospects in Gamma Biocide Treatments for Cultural Heritage

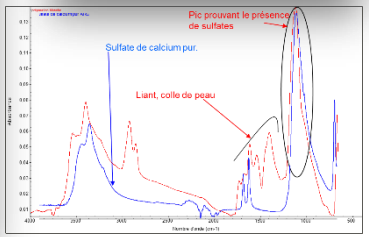


Laurent Cortella, Claudia Salvan, Christophe Albino, Quoc Khoi Tran

ARC-Nucléart, CEA Grenoble, France

ARC-Nucléart : An Unique Structure for Cultural Heritage Conservation

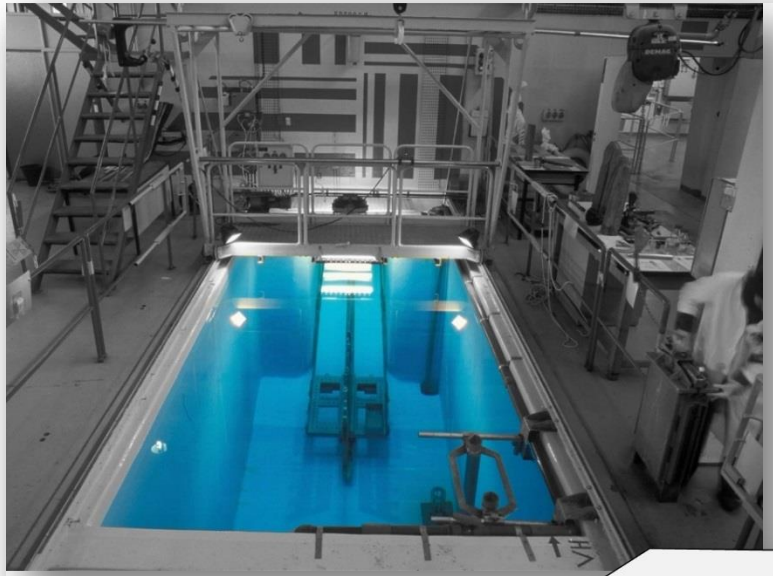
located in Grenoble / France, on the site of the CEA research center



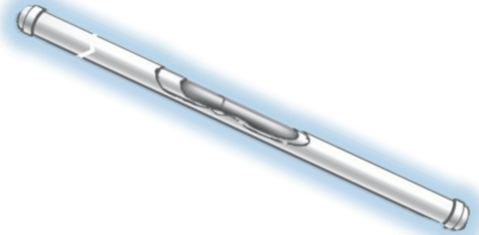
3000 m^2 facilities : irradiation facility, large scale freeze dryers, impregnation tanks (large scale, up to 14 meter long), restoration workshops, storage rooms, chemical and biological analysis laboratories

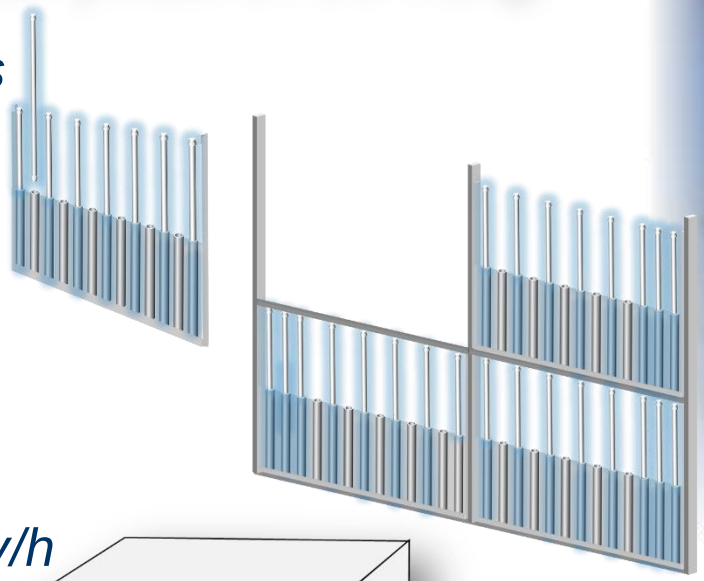
An Irradiator Dedicated to Cultural Heritage Conservation

A 2000 TBq ^{60}Co pool irradiator (max 3700 TBq)

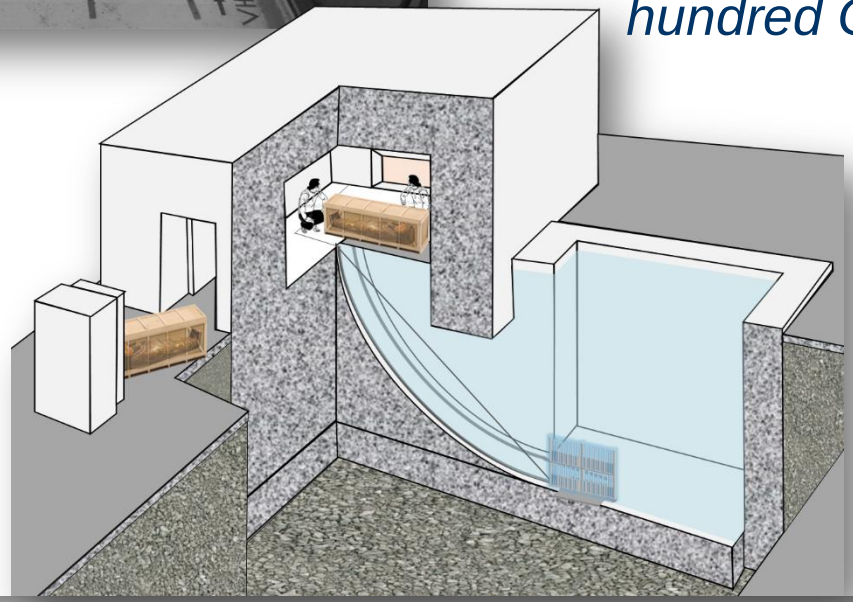


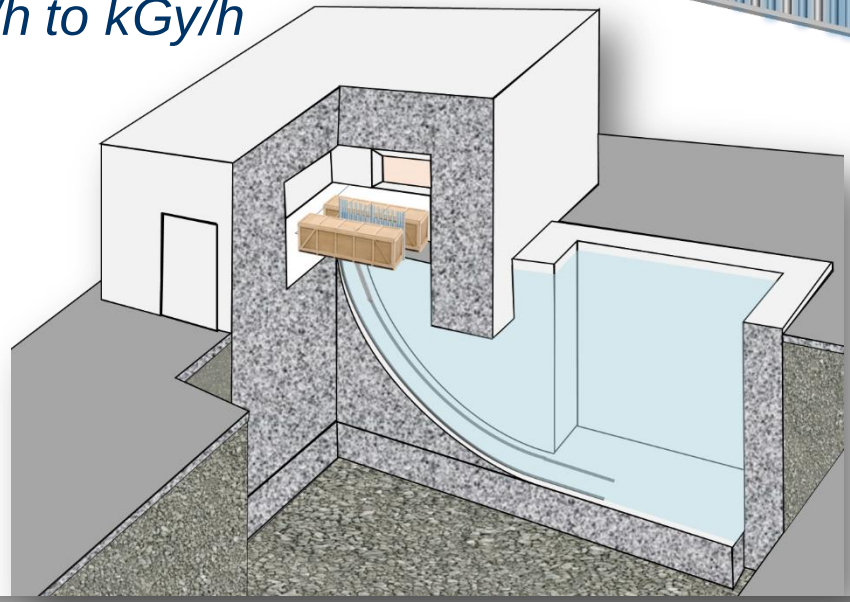
Industrial sealed sources





Dose rate from hundred Gy/h to kGy/h





Disinfestations Thanks to Biocide Power

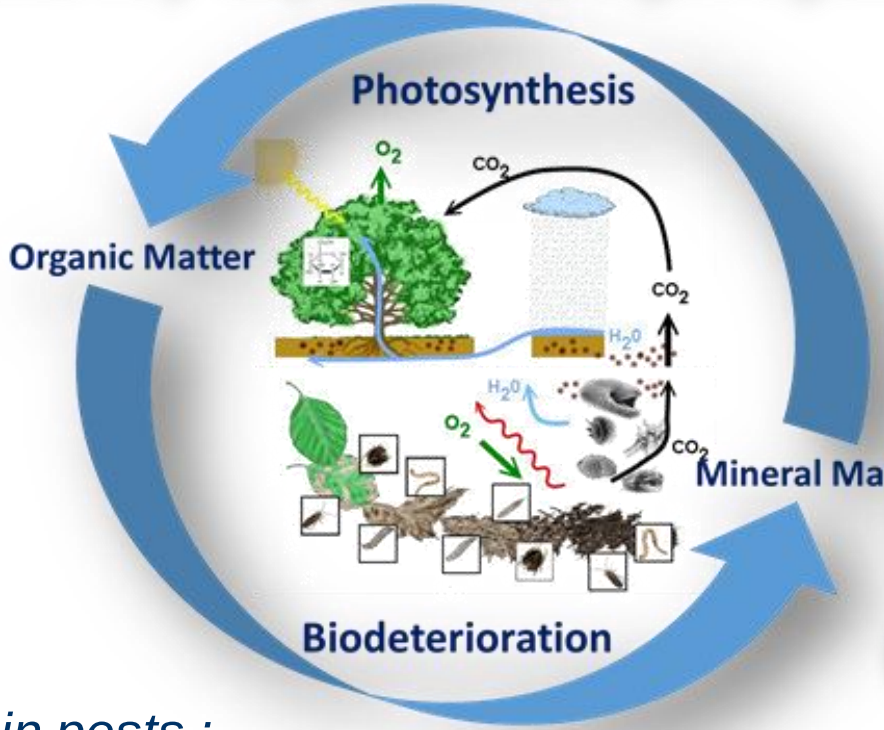
by simple gamma ray exposure to fight against biodeterioration

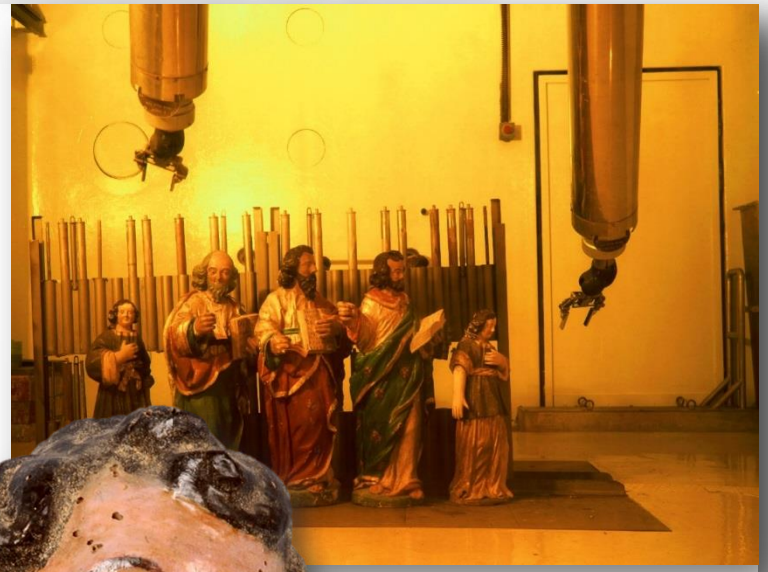
COMPTES RENDUS
DES SÉANCES
DE L'ACADÉMIE DES SCIENCES.

1929 198, 102

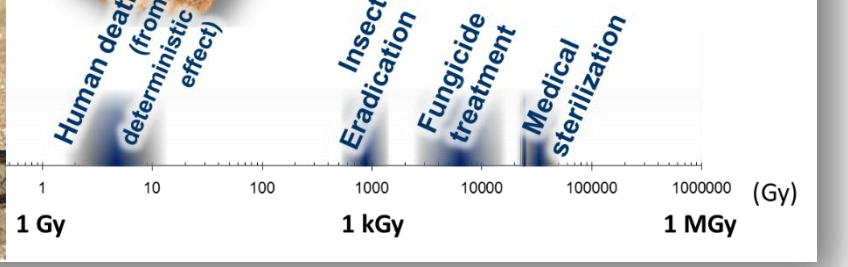
SUR L'ÉTUDE DES COURBES DE PROBABILITÉ RELATIVES À L'ACTION DES RAYONS X SUR LES BACILLES

On a représenté dans la figure les courbes P = F(v) pour quelques valeurs de s, inscrites à côté des courbes, et la courbe φ(p). On a utilisé pour les abscisses p la même échelle que pour les abscisses v.





Main pests :
Fungi (mold, rot) and insects



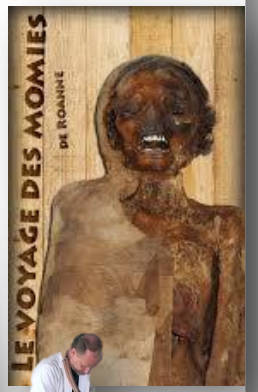
The most popular application of gamma radiation in the field of cultural heritage conservation

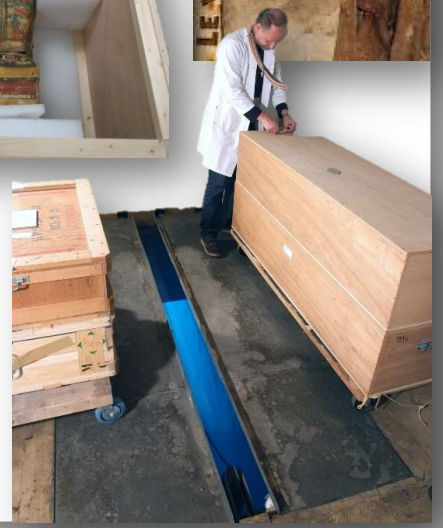
Several thousand cubic meter since the 70's in ARC-Nucléart:

- *Furniture*
- *Wooden Sculptures*
- *Ethnological Objects*
- *Musical Instruments*
- *Taxidermy*
- *...*
- *Modern Art*

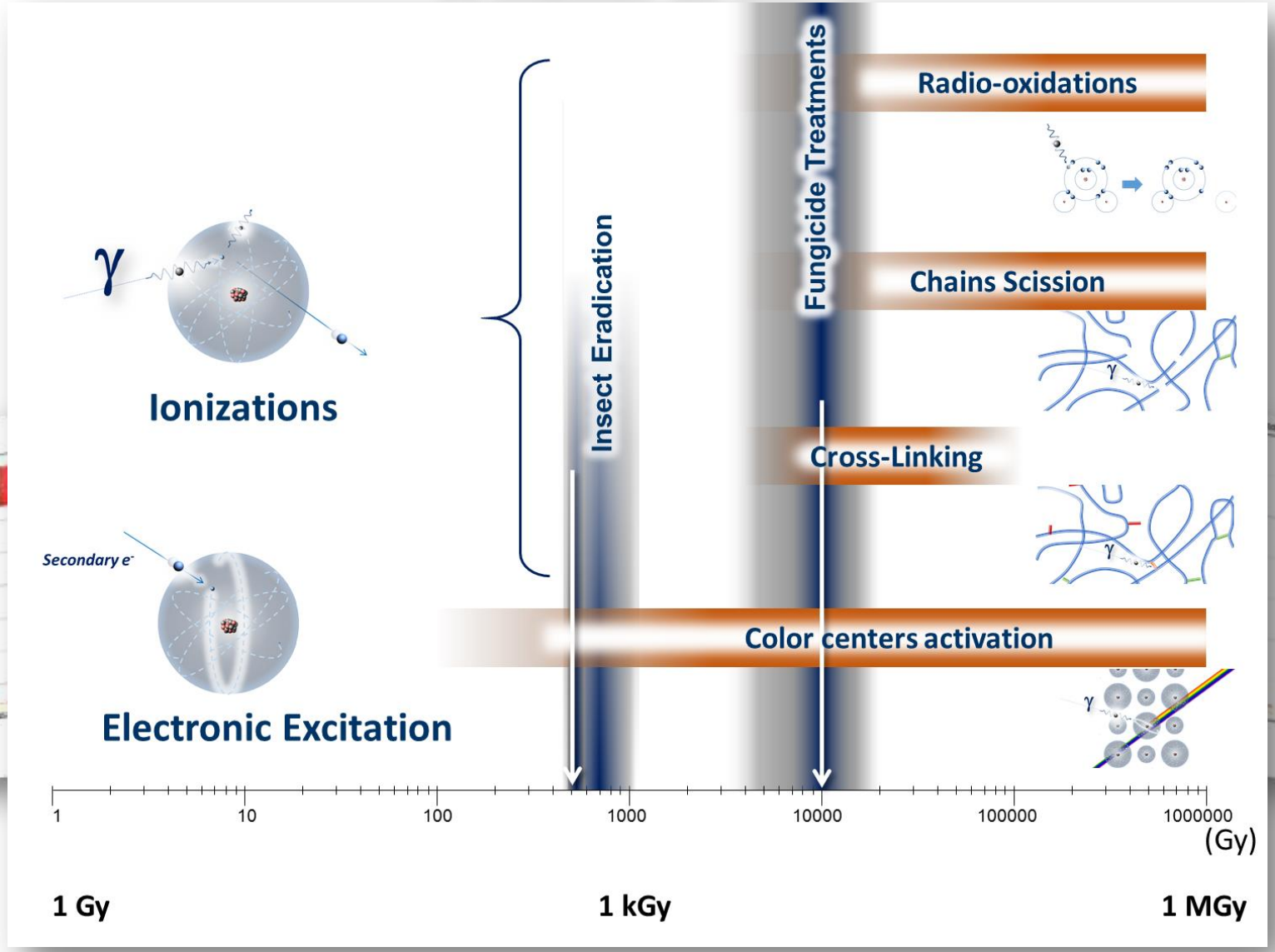
Some "exotic" clients

(frozen baby mammoth and mummies)



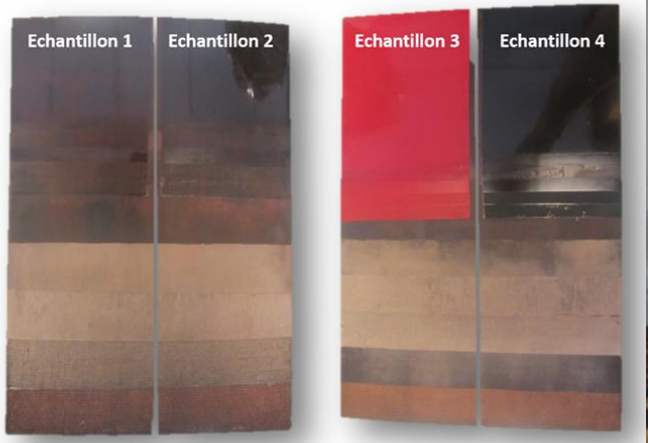


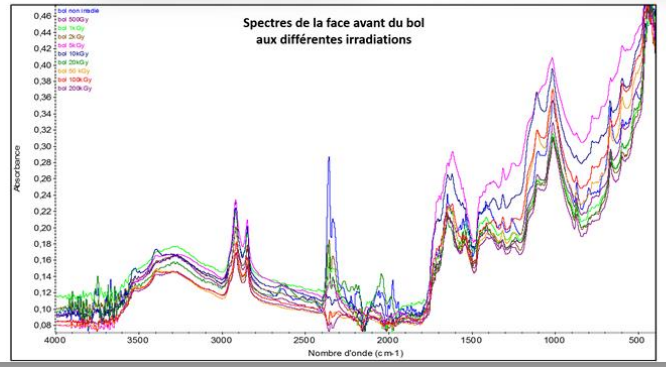
A matter of dose

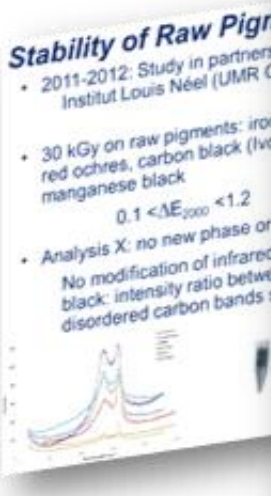


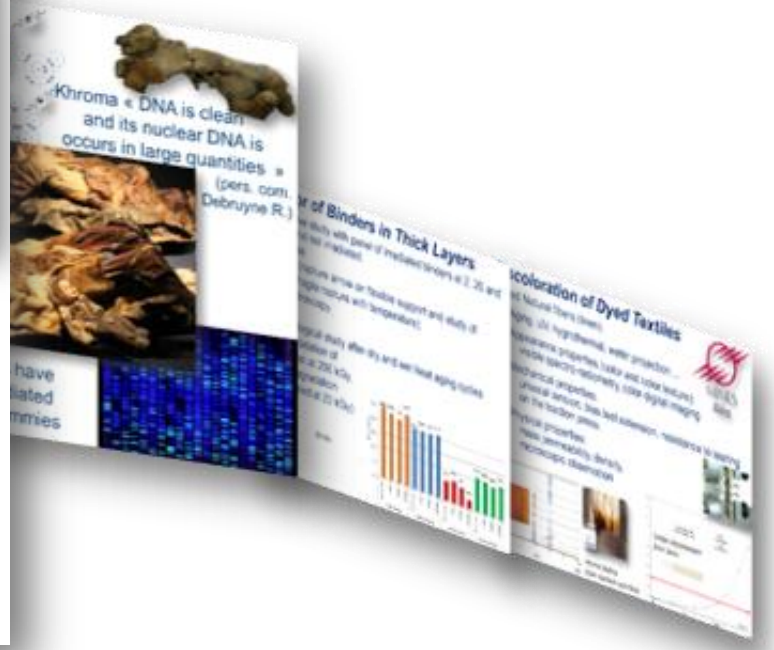
Behavior of Oriental Lacquer

- No direct macroscopic alteration up to 200 kGy
- Begining of oxidation (Increase of groupings C = O revealed by FTIR analysis) at 200 kGy
- After dry and wet heat cycles, fragile areas of samples previously irradiated to 200 kGy separate more perceptively from the wood







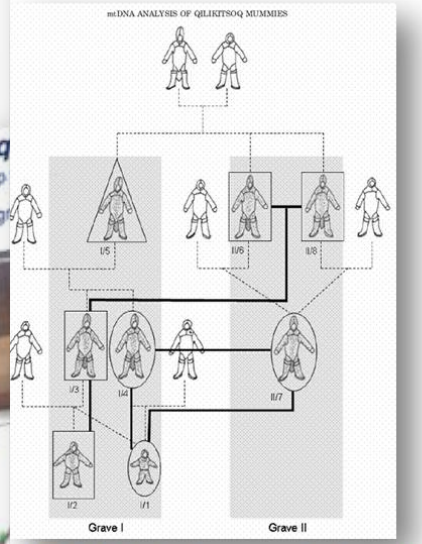


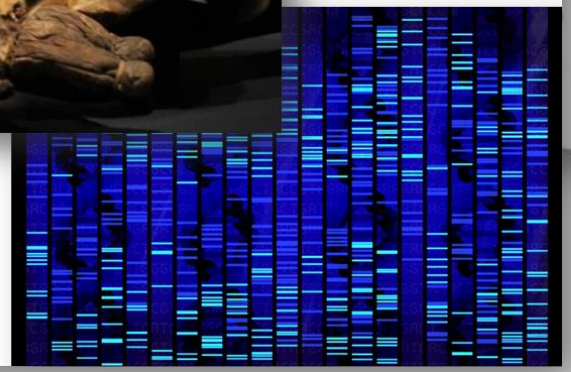
Theoretical analysis based on literature survey

DNA Analysis

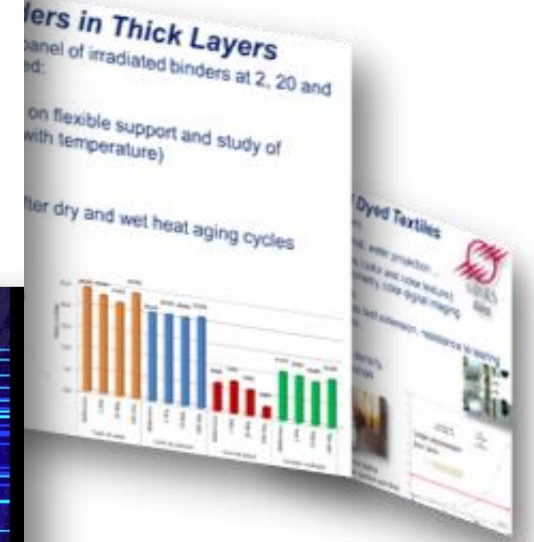
0.25 lesions per Gy for one million base pairs
⇨ about a lesion for 400 base pairs at 10 kGy

Khroma « DNA is clean and its nuclear DNA occurs in large quantities » (pers. com. Debruyne R.)





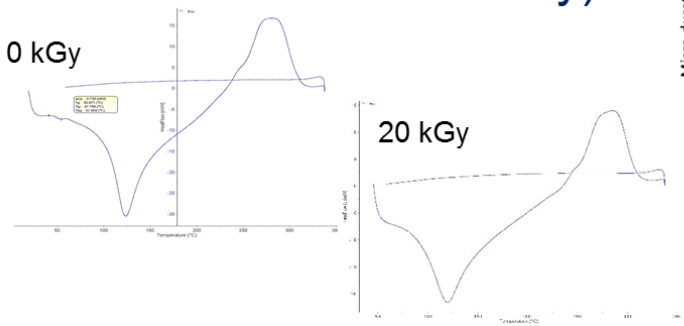
DNA interrelatedness analysis (family relationship) have been made on 20-25 kGy irradiated Qilakitsoq inuit mummies (15th century)

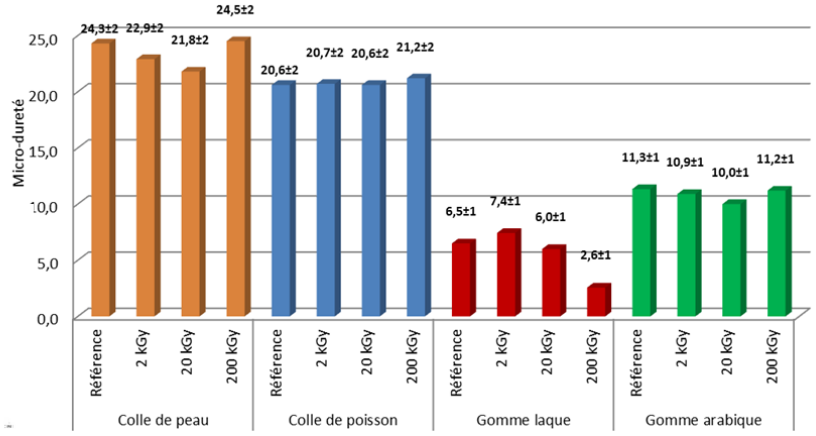


Behavior of Binders in Thick Layers

Comparative study with panel of irradiated binders at 2, 20 and 200 kGy and not irradiated:

- Hardness
- Flexion (rupture arrow on flexible support and study of ductile-fragile rupture with temperature)
- IR spectroscopy
- DSC
- Morphological study after dry and wet heat aging cycles
  (Degradation of Shellac at 200 kGy, No degradation revealed at 20 kGy)





Fungicide Treatment of 11 linear kilometer of National Archive

A large-scale disaster

- Discovery on the fifth basement floor: 5 cm of water covering 8 000 m² (July 2015, after the storage building closed for more than one year due to structural weaknesses)

ARCHIVES NATIONALES

- 56 000 standard folders boxes
- 1 482 rolls of planes, packaged or not
- 443 portfolios of planes …

55% of packaging contaminated with mold

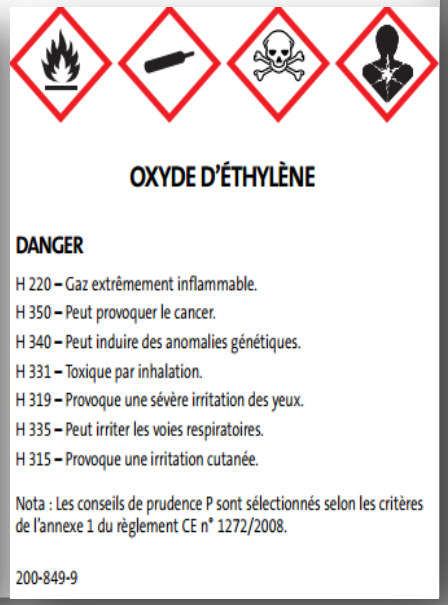
Fungicide Treatment of 11 linear kilometer of National Archive

Choice of the fungicide treatment

A conventional solution:

Fumigation with ethylene oxide

- A mastered technique approved by the French competent cultural authorities
- No facilities in capacity of processing such a volume of archives in less than six years
- Drastic regulatory rules



OXYDE D'ÉTHYLÈNE

DANGER

H 220 – Gaz extrêmement inflammable.
H 350 – Peut provoquer le cancer.
H 340 – Peut induire des anomalies génétiques.
H 331 – Toxique par inhalation.
H 319 – Provoque une sévère irritation des yeux.
H 335 – Peut irriter les voies respiratoires.
H 315 – Provoque une irritation cutanée.

Nota : Les conseils de prudence P sont sélectionnés selon les critères de l'annexe 1 du règlement CE n° 1272/2008.

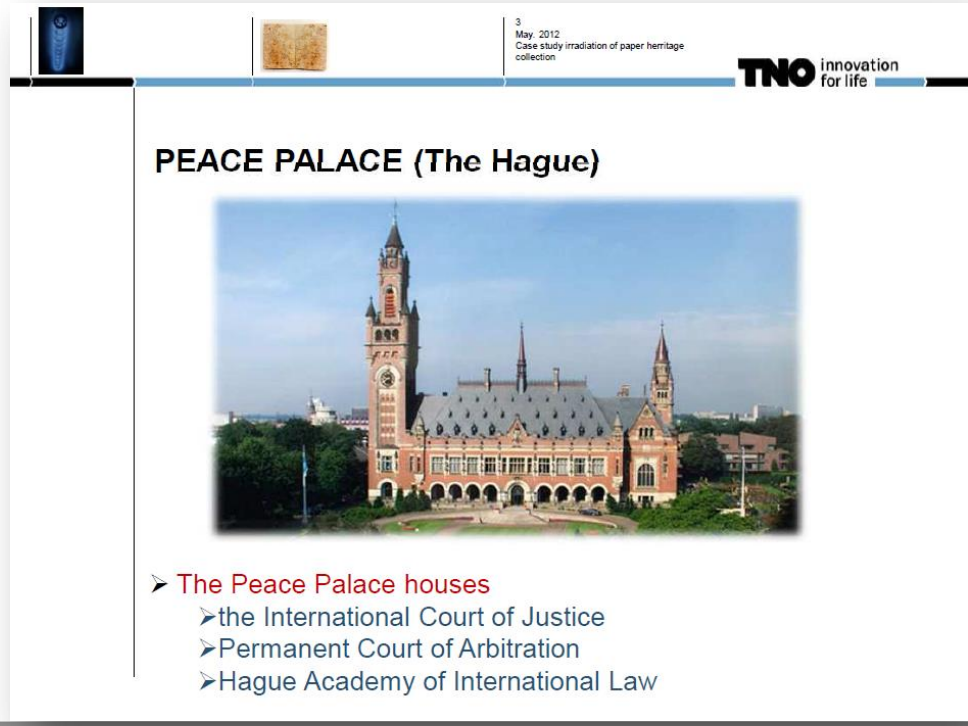
200-849-9

An alternative solution:

Gamma Irradiation

- Known to induce cellulose depolymerization
- Widely used in the world

(The Netherlands, Brazil, Romania, Germany,…)



Fungicide Treatment of 11 linear kilometer of National Archive

Definition of dosimetry constraints of the treatment

Biological efficiency:

- 2 main genus of molds: *Aspergillus* (2 species) and *Penicillium* (2 species). Other genus: *Botrytis*, *Trichoderma…*
- Inoculated cellulose disks placed on a culture medium before to be irradiated with 0, 2, 3, 4, 5, 6 and 8 kGy,
- 3 kGy lead to 100 % inhibition rate on three species and to 97% inhibition rate on *Penicillium sp.* (green with yellow exudates)

LRMH

Laboratoire de Recherche des Monuments Historiques

minimum dose = 3 kGy

Preservation of archive material:

- Abundant literature on effect of gamma irradiation on classical archive material

maximum dose = 10 kGy

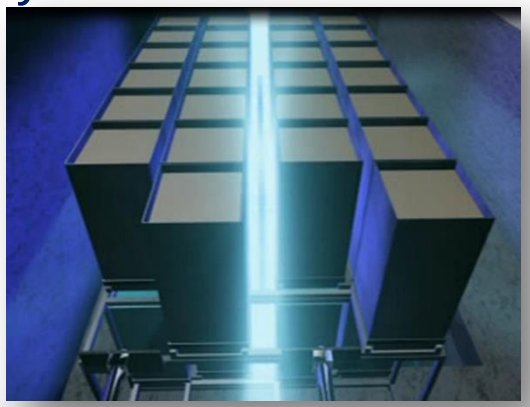
”Paper deterioration by mold is more severe than by gamma irradiation” - John Havermanns

Fungicide Treatment of 11 linear kilometer of National Archive

Breakdown of tasks

Standard folders boxes: Industrial facilities

- Better capacity (50 to 100 pallets per week)
- Good mastery of overdose coefficient even on large pallets



STERIS
Applied Sterilization Technologies

1170 pallets

Non standard format or material at ARC-Nucléart irradiator:

- Complementary studies
- Non automated procedure

ARC-nucleART
Atelier Régional de Conservation

54 “processing units”

Fungicide Treatment of 11 linear kilometer of National Archive

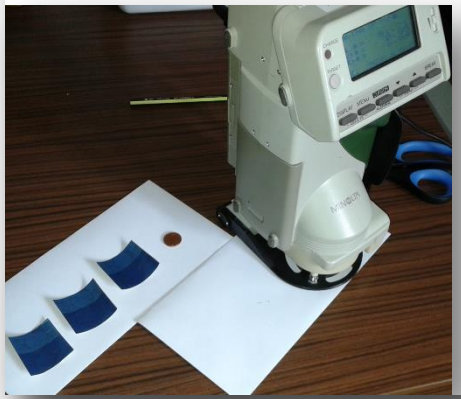
Non-standard archival support materials

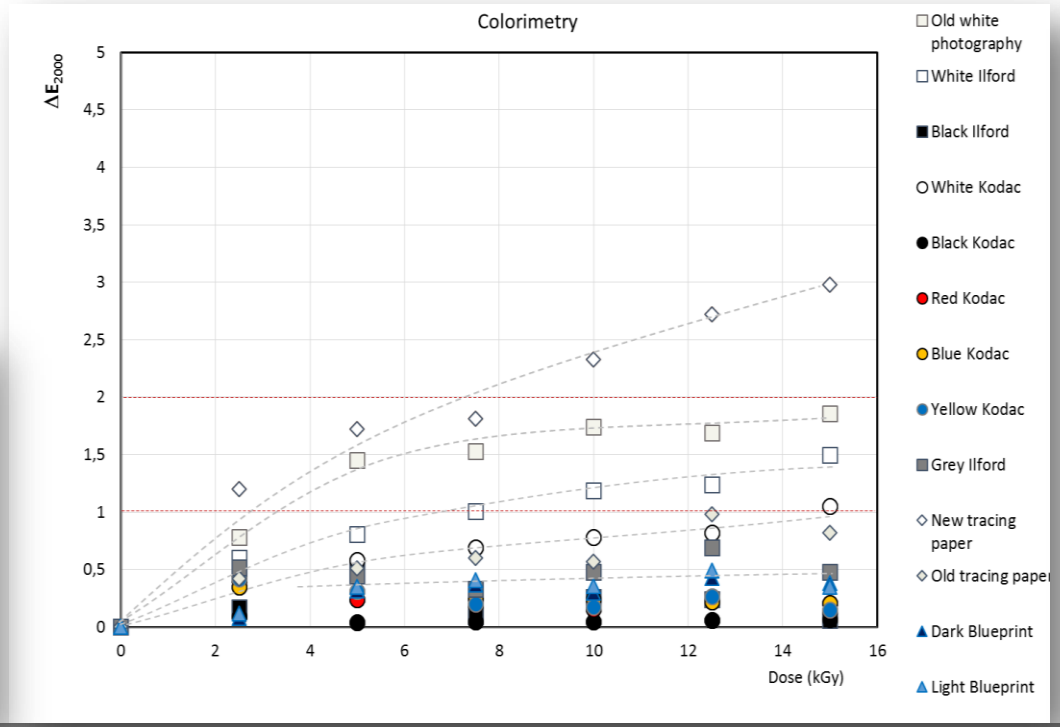
Materials:

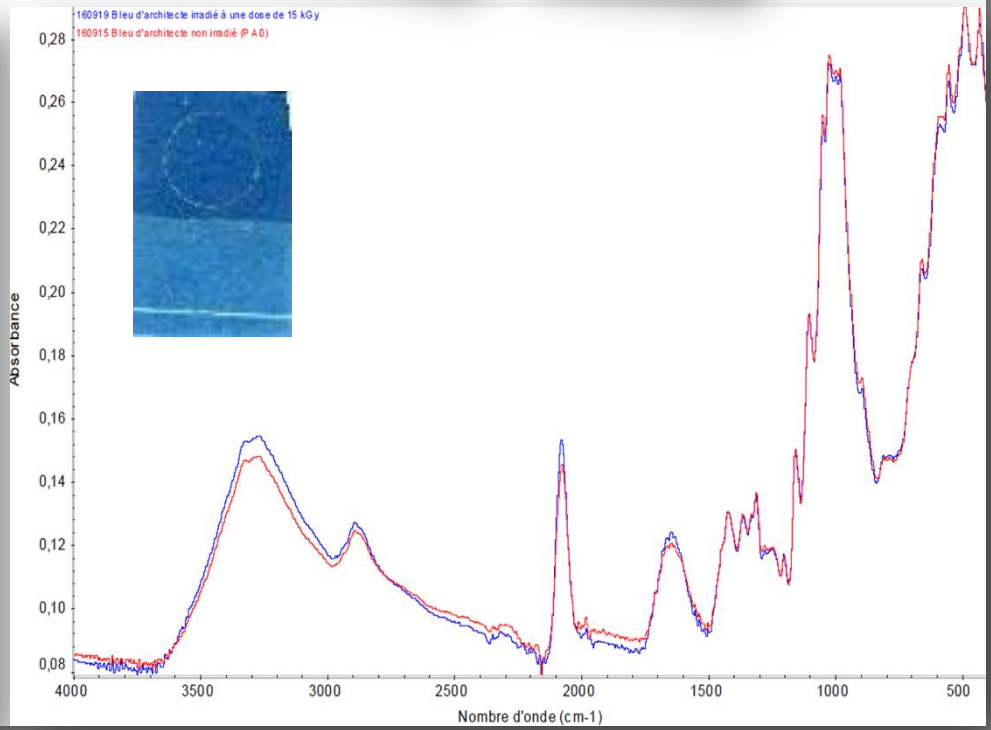
- Tracing paper (rolls, portfolios and long archival storage box),
- Argentic photography (portfolios and long archival storage box)
- Architect blueprint (portfolios)

Measurements:

- FTIR
- Colorimetry







Fungicide Treatment of 11 linear kilometer of National Archive

Setting of treatment

Packaging:

- Roll Cage Trolley (plane rolls)

- Long archival storage box (various)

- Portfolios (various)

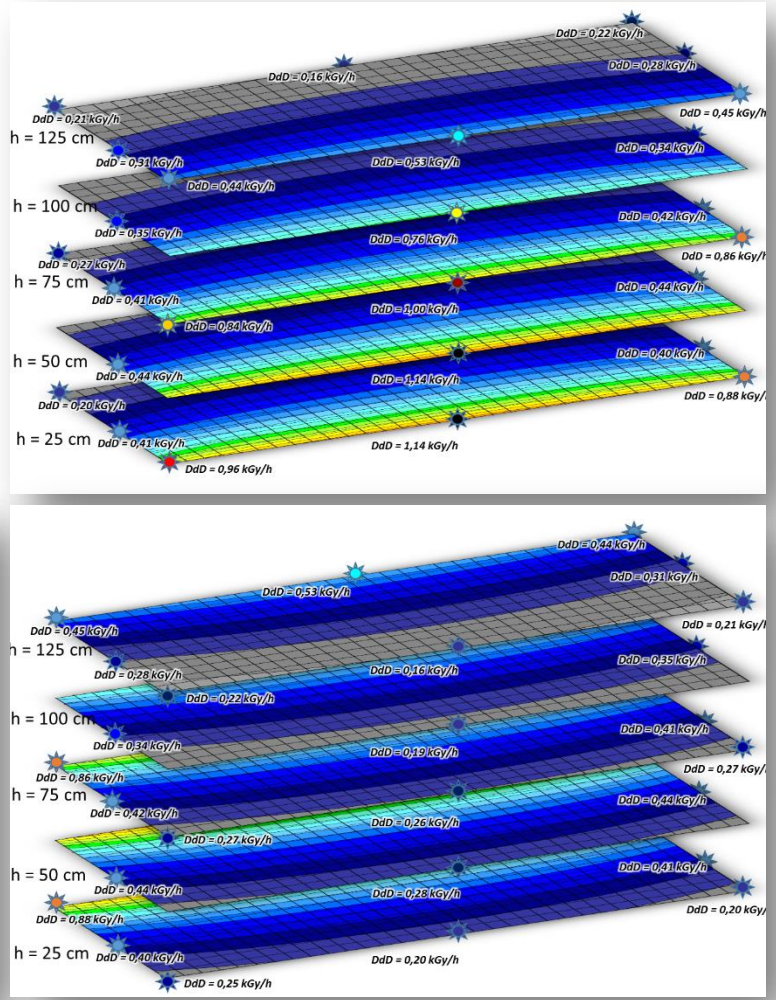
Fungicide Treatment of 11 linear kilometer of National Archive

Setting of the treatment parameters

- *Simulation and Preliminary Dosimetry Measurement*

Dose rate

50 cm
from the
source rack

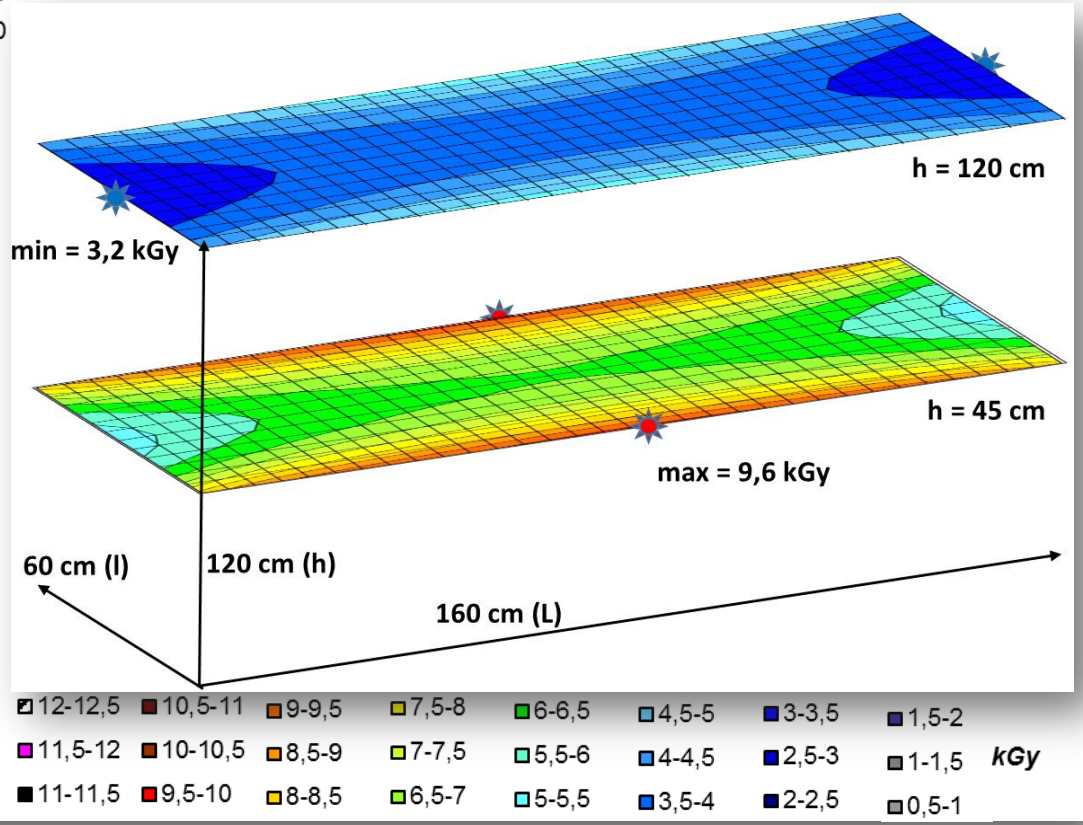


Double Cage Trolley

Cumulative dose

(simulation of 9 hours on each side)

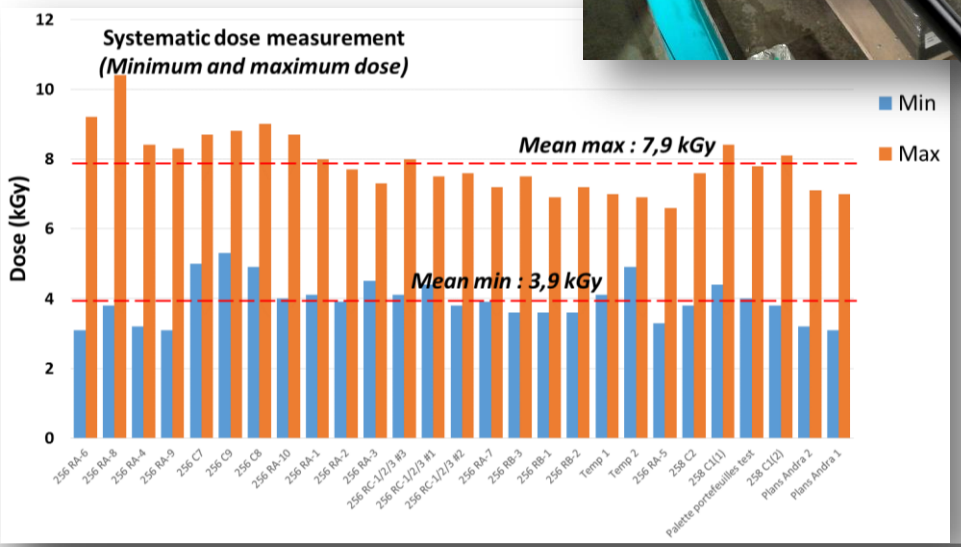
Archives nationales, ANF77, Lot 2 : calques en rouleau
Double Roll (60 cm x 160 cm, 1,2 m high, 180 kg)
20 sources, 1767 TBq at 22/08/2016



Fungicide Treatment of 11 linear kilometer of National Archive

Control

Systematic Routine Dose Control



Statistical Biological Control

ATP Test (growing activity)

L R M H
Laboratoire de Recherche des Monuments Historiques

Classical culture on medium
(before dust removal)

Laure Méric **for** A2C SERVICES

Thank you for your attention

Thanks to:

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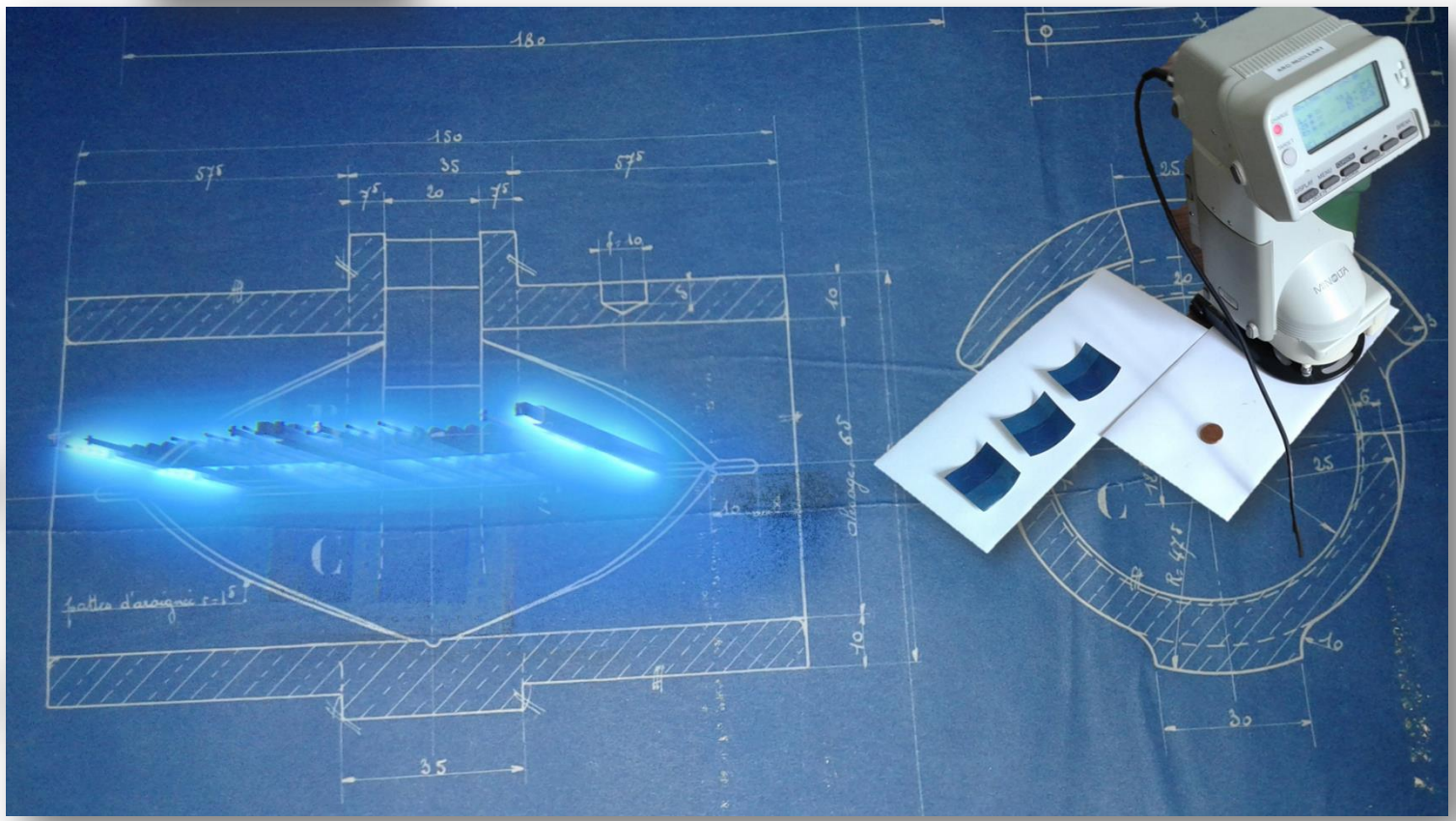
Daniel Negut
Ioana Stanculescu

IPIN HH



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Sergey Gorbunov Petr Lazarev

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Archives de France

Marie Courselaud
Michel Thibault
Michel Mastrolillo

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Gilbert Leguen
Yvan Pion-Goureau

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STERIS
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Camille Perez

AGGLO ROANNE
MUSÉE DES BEAUX-ARTS ET D'ARCHÉOLOGIE JOSEPH DÉCHELETTE

Wojciech Głuszewski

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