IAEA-CN301-032

APPLICATION OF ELECTRON BEAM ACCELERATOR FOR PRESERVATION OF BIODETERIORATED CULTURAL HERITAGE PAPER-BASED OBJECTS: MULTIPARAMETRIC ANALYSIS

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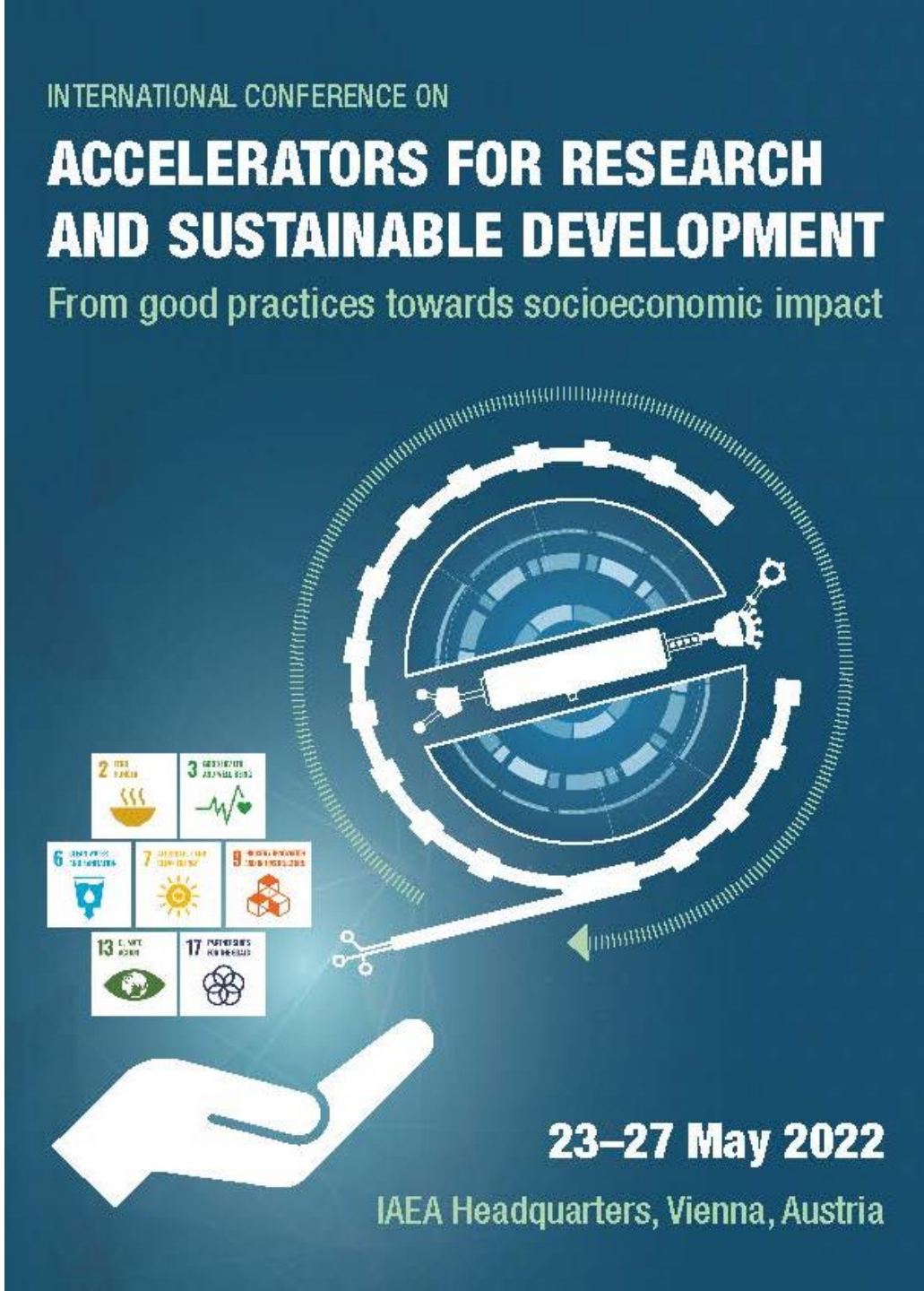


IAEA Collaborating Centre for Radiation Dosimetry and Industrial Radiation Processing

Biological factors in deterioration of paper

Bacteria

Material / Bacteria	Paper, cardboard	Leather	Parchment	Glue	Fabric	Photographs	Audiotapes
Cellvibrio	X						
Cellfacicula	X						
Serratia			X	X			
Bacillus subtilis		X	X		X		
Cytophaga	X						
Sporocytophaga	X						
Nocardia	X						
Streptomyces		X	X			X	X

Insects

Material / Insect	Paper, cardboard	Leather	Parchment	Glue	Fabric	Photographs	Wood
Blattodea	X		X	X			
Lepisma saccharine	X			X			
Liposcelis terricolis	X			X	X	X	
Stegobium paniceum, Anobium punctatum	X	X					
Anthrenus museorum, Dermestes lardarius	X	X	X	X			X

Fungi

Material / Fungi	Paper, cardboard	Leather	Parchment	Ink	Glue	Fabric	Photographs	Audiotapes
Rodotorula	X	X						
Mucor	X	X	X			X		
Rhizopus	X	X	X			X	X	
Chaetomium	X	X	X			X	X	X
Gymnoascus	X							
Aspergillus	X	X	X	X	X	X	X	X
Penicillium	X	X	X	X	X	X	X	X
Phoma	X					X		
Trichoderma	X	X	X			X	X	
Paecilomyces	X	X				X	X	
Trichotheclum	X				X			
Cephalosporium	X							
Scopulariopsis	X	X				X	X	
Monilia	X		X			X		
Verticillium	X					X		
Aureobasidium	X	X				X		
Hormiscium	X							
Helminthosporium	X				X			
Stachybotrys	X				X	X		
Cladosporium	X	X	X			X		
Altermaria	X	X	X		X	X		
Stemphylium	X	X			X	X		
Fusarium	X	X	X		X	X	X	
Doratomyces	X					X		

Fausta Gallo „Biological factors in deterioration of paper"
International Centre for the Study of the Preservation and Restoration of Cultural Property, ICCROM, Roma 1985

Methods

- **EtO** – the gas is also so called "S-9", a mixture of 9 % EtO and 91 % carbon dioxide.

! The pressure is lowered to 750-800 mbar, the temperature is elevated to 30-45 °C, RH 50%, gas concentration 100-250 g/m^3.

! Decontamination time 24-36 h, several hours of air washing in order to extract the leftover gas from the books. Quarantine: min. 5 days.

! To retain significant amounts of residual ethylene oxide subsequent to a fumigation treatment.

! Chronic exposure to ethylene oxide can increase the risk of leukemia, brain tumors and other cancers; it can cause chromosome damage and may also affect the reproductive system.

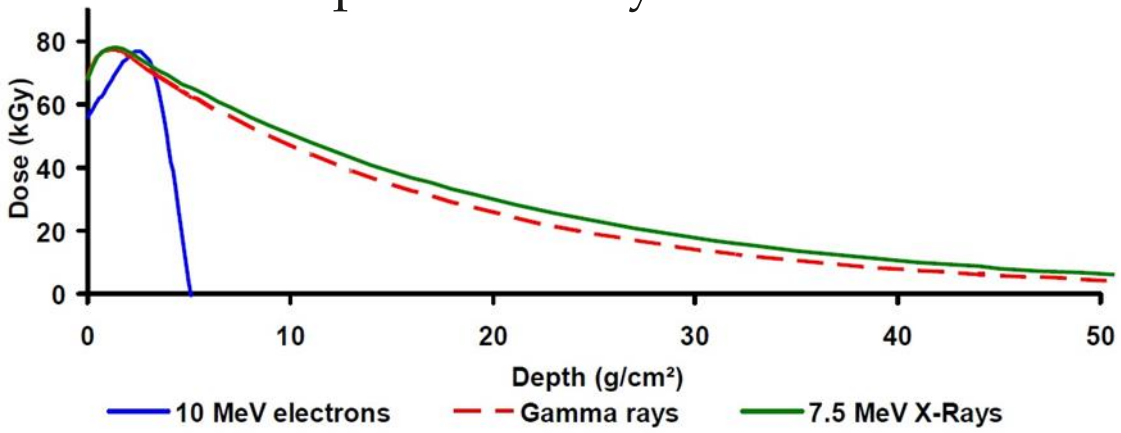
- **Ionizing radiation** - electron beam, gamma rays.

! Exposition time: seconds vs. hours/days

! Neutral conditions

! Penetration: limited for EB

! Any harmful residues



EB, Gamma Ray and X-ray Penetration

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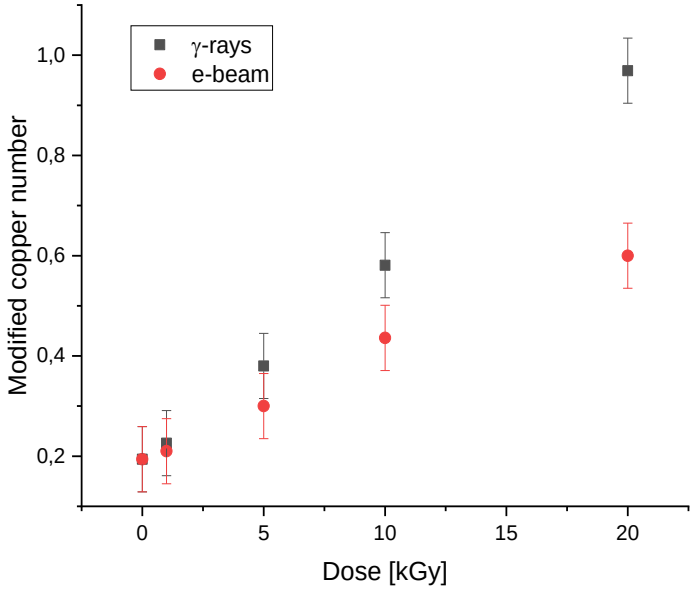
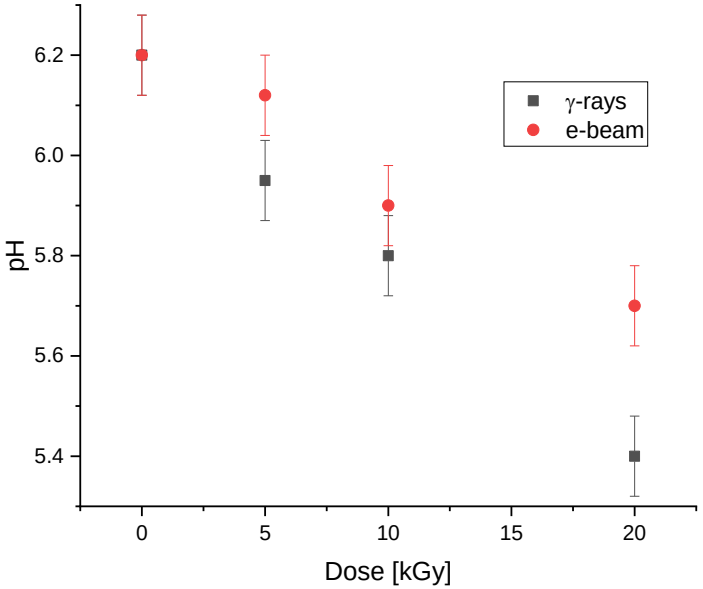
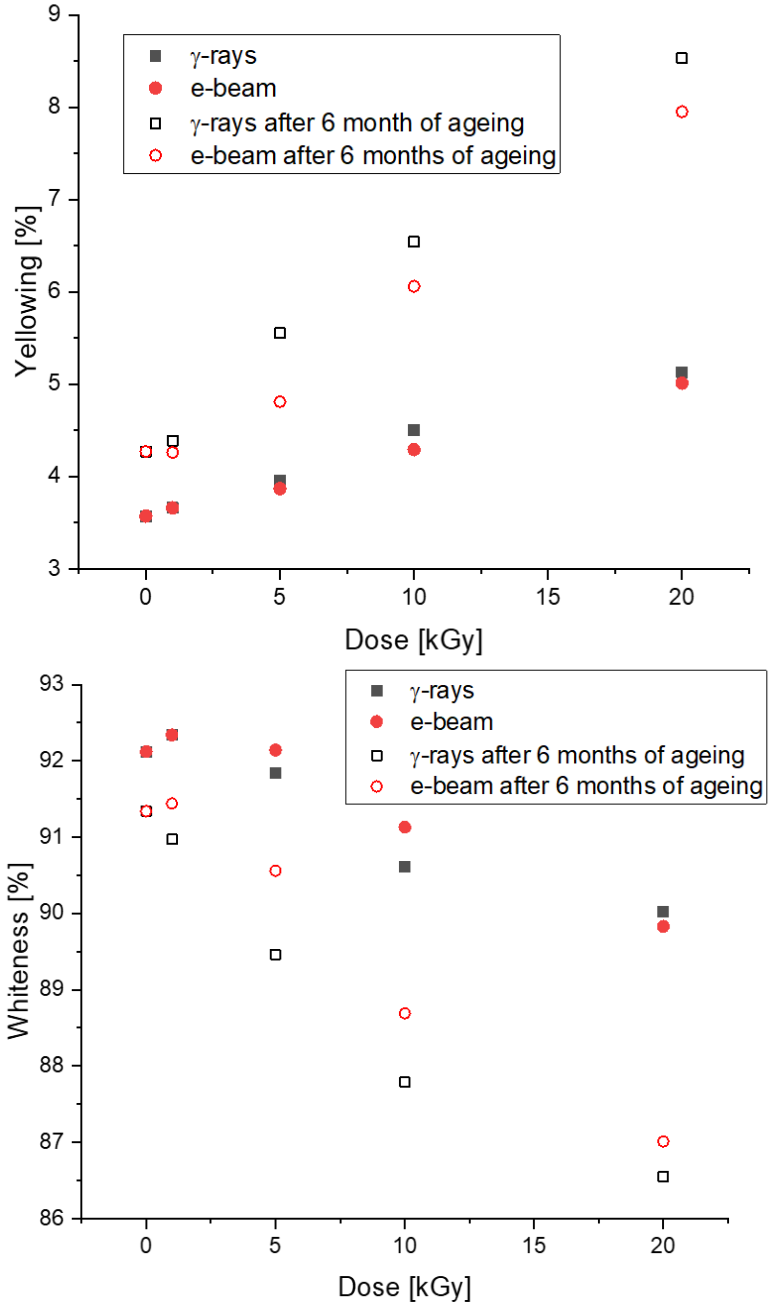
IRRADIATION
γ-rays vs. electron beam





According to PN-84/P-50109 (ISO 6588) standard

According to PN-76/P-50169 standard



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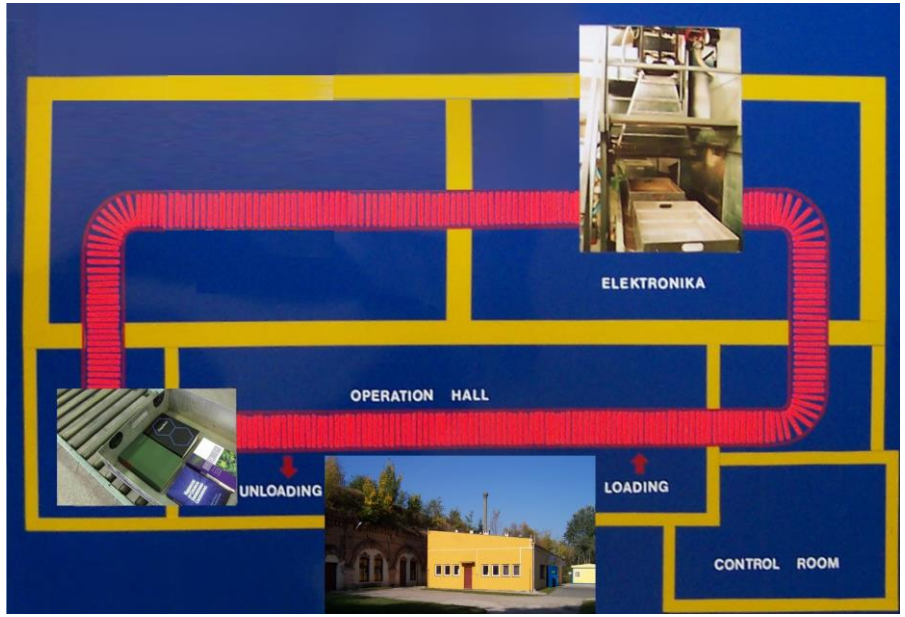
Electron beam irradiation



Accelerator Elektronika 10/10

Accelerator	Manufacturer	Power	Energy	Mode	Scanning length
Elektronika 10/10	NPO Torij, RU	10 kW	10 MeV	linear, pulsed 400Hz, RF 1886 MHz	65cm

Doses: 0.4-25 kGy

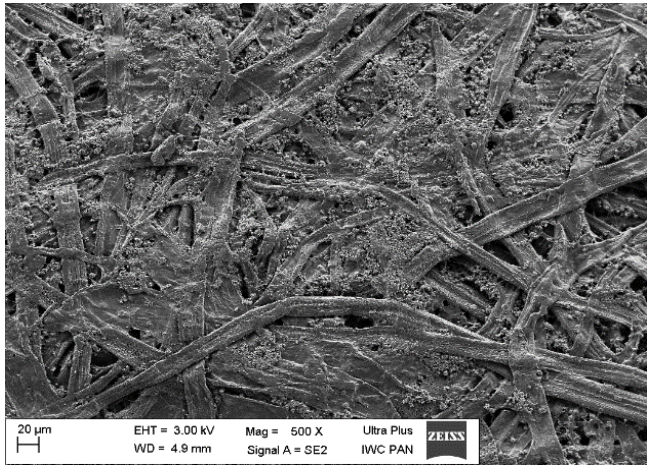
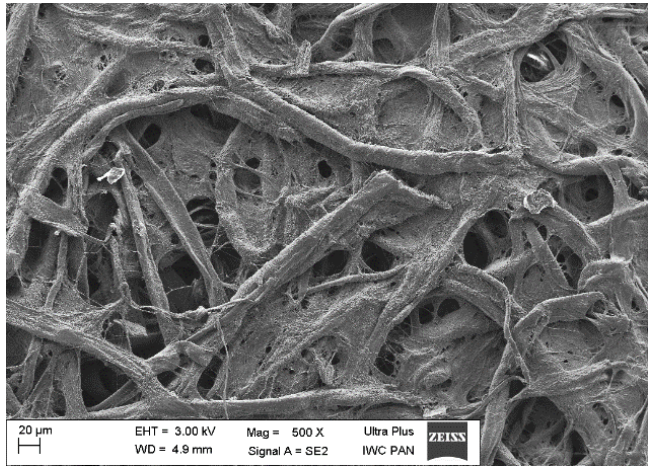
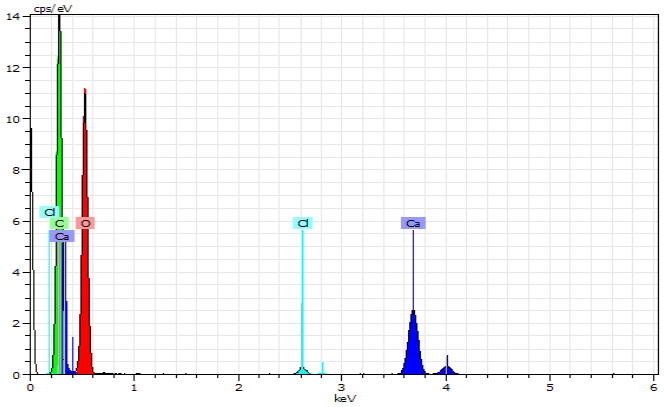
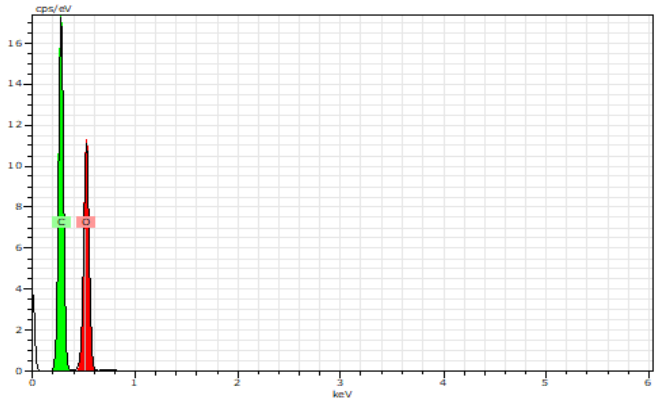
Dosimetry

- Graphite calorimetries (5-25 kGy)
- Alanine dosimeters (lower doses)
- PVC Foli dosimeters (dose distribution)

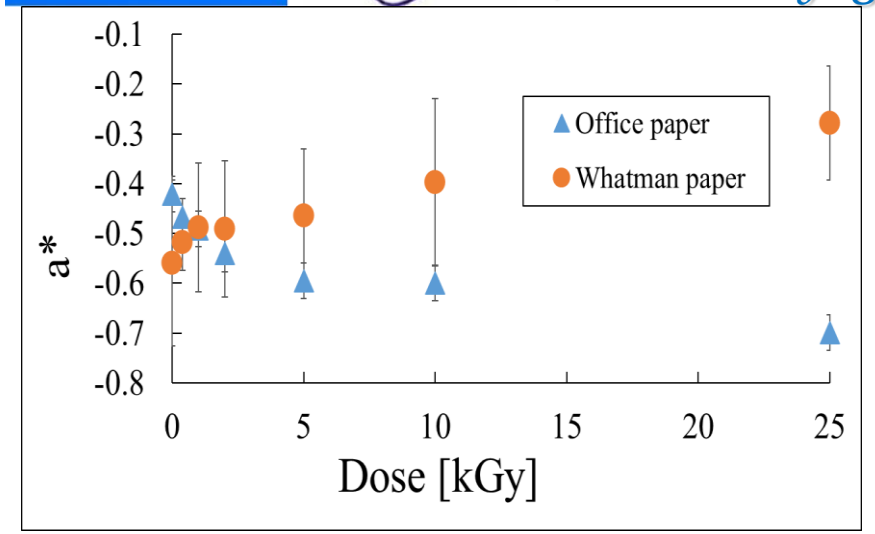
Measurement of electron energy is made according to ISO 51649

(Practice for dosimetry in an electron beam facility for radiation processing at energies between 300 keV and 25 MeV).

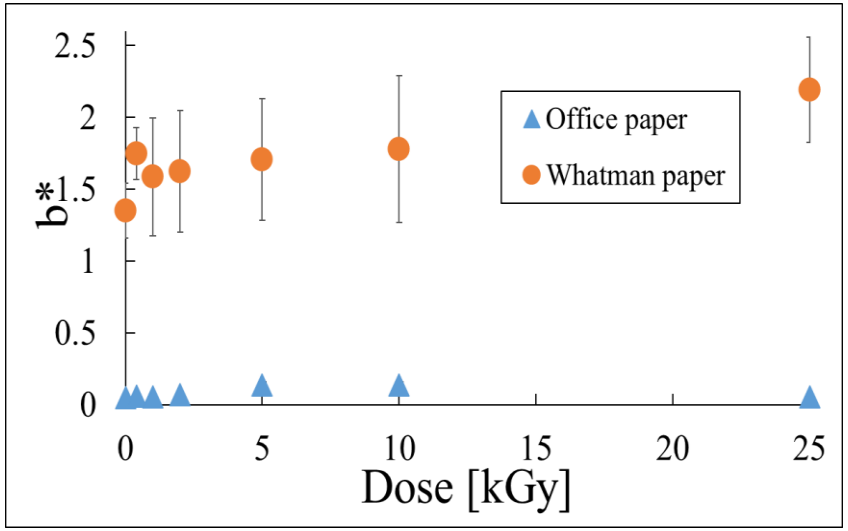
Samples

	Office paper	Whatman CHR1
Surface morphology:		
Composition:		
Grammage [g/m^2] :	80	88
Thickness [mm]:	106	180

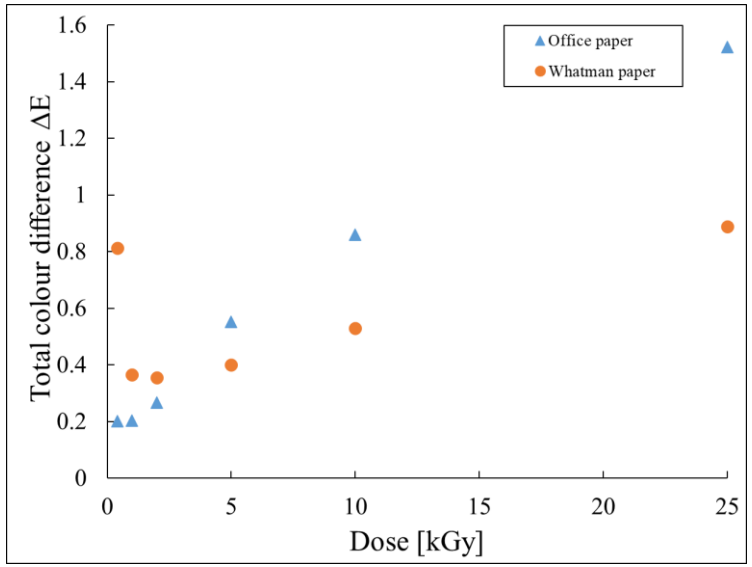
Colour parameters
ISO 11475:2004 Paper and board -- Determination of CIE whiteness, D65/10 degrees (outdoor daylight)



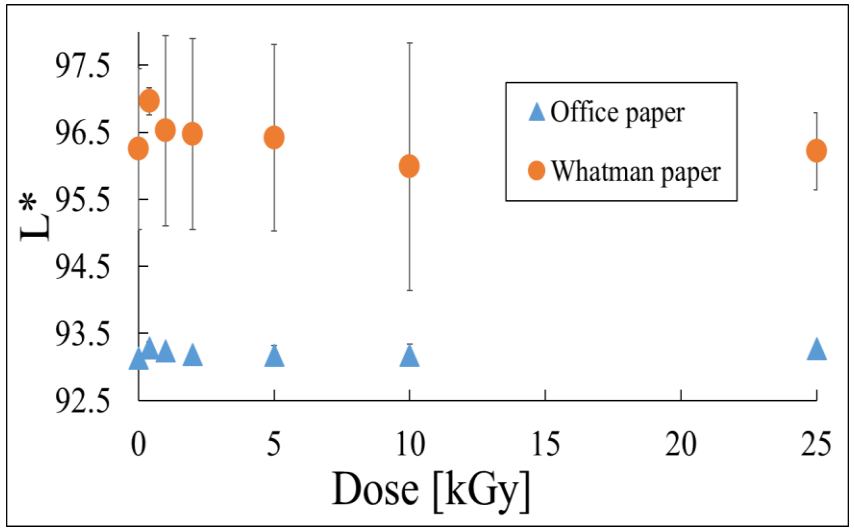
*Colour coordination a**



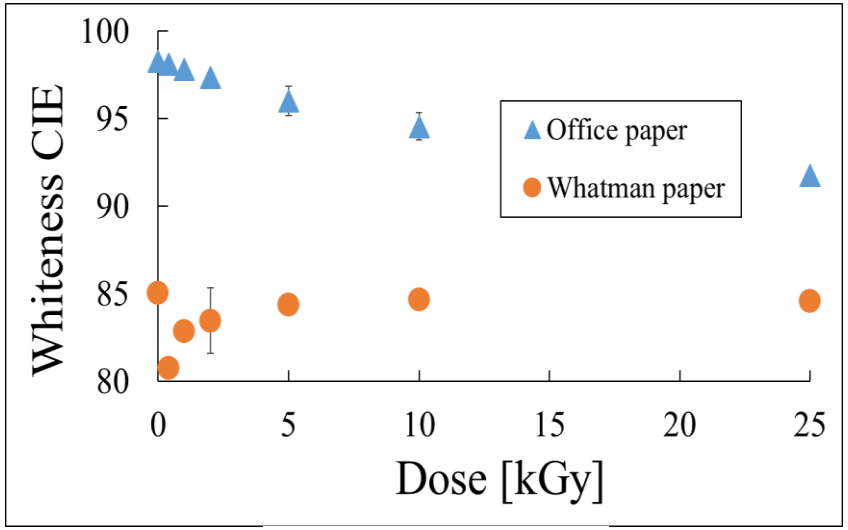
*Colour coordination b**



Total colour difference ΔE



*Colour coordination L**



Whiteness

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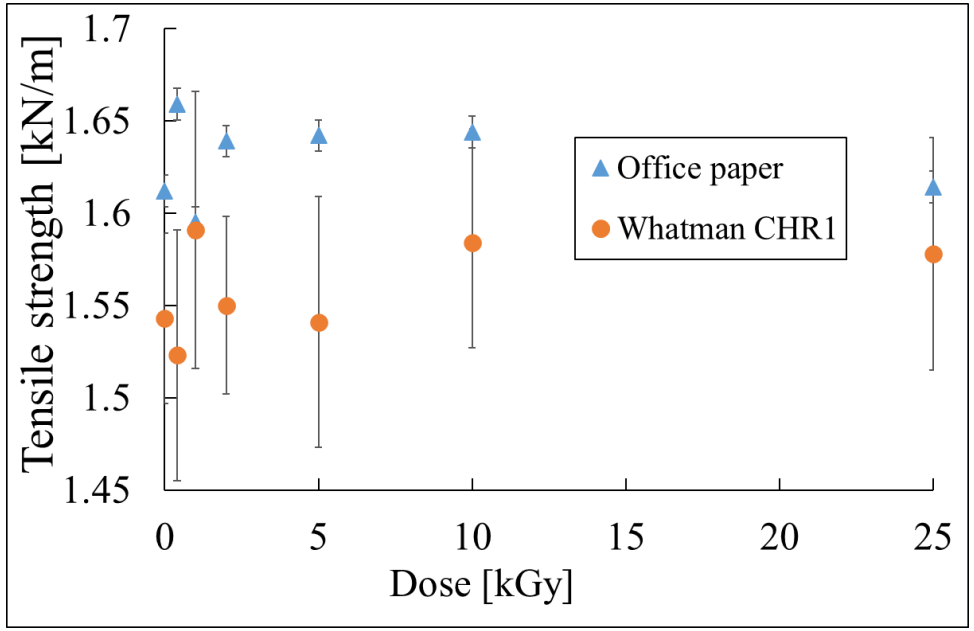
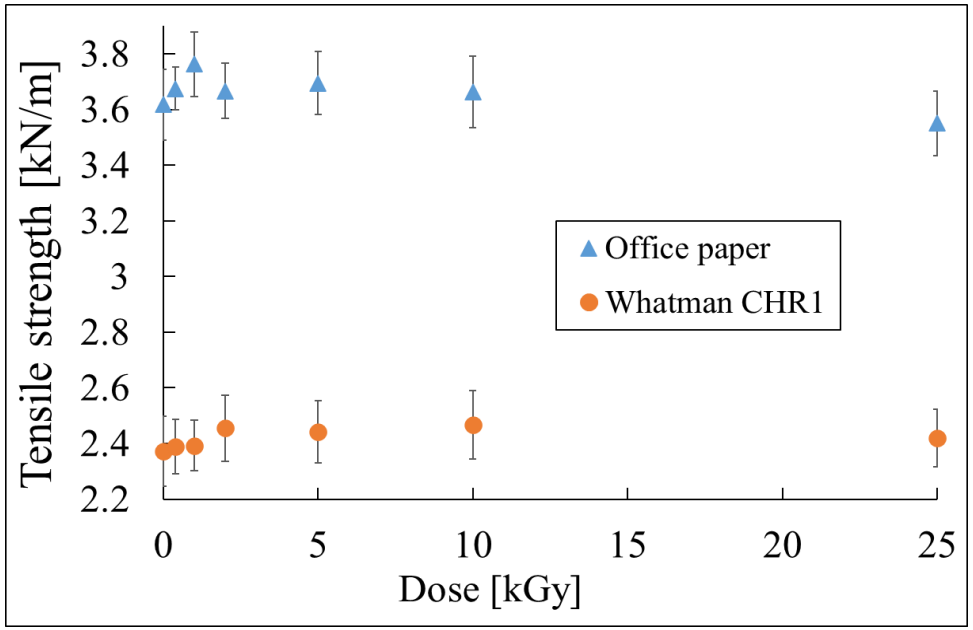
Mechanical parameters

ISO 1924-2:2008 Paper and board -- Determination of tensile properties -- Part 2: Constant rate of elongation method (20 mm/min)



Cross machine direction (CD)



Machine direction (MD)

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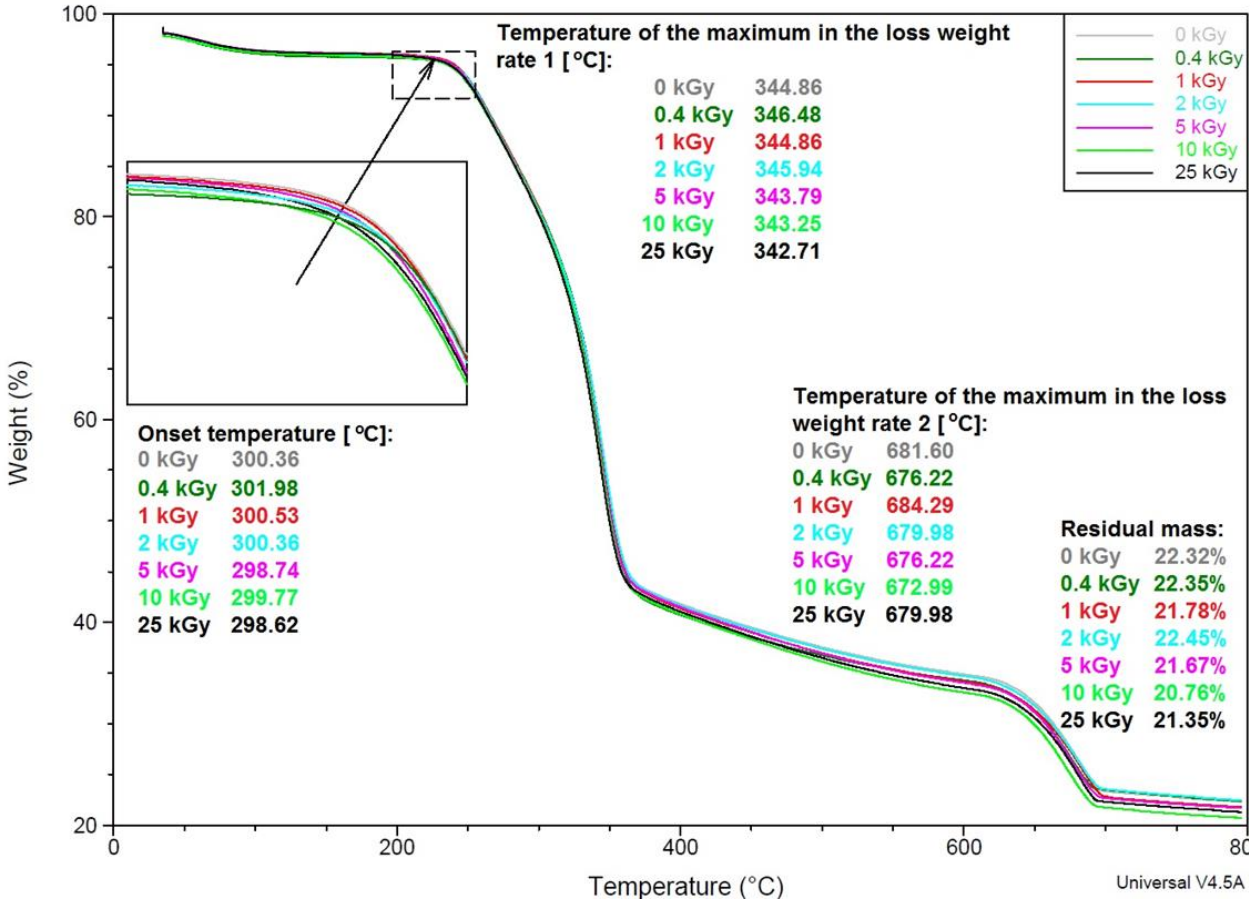
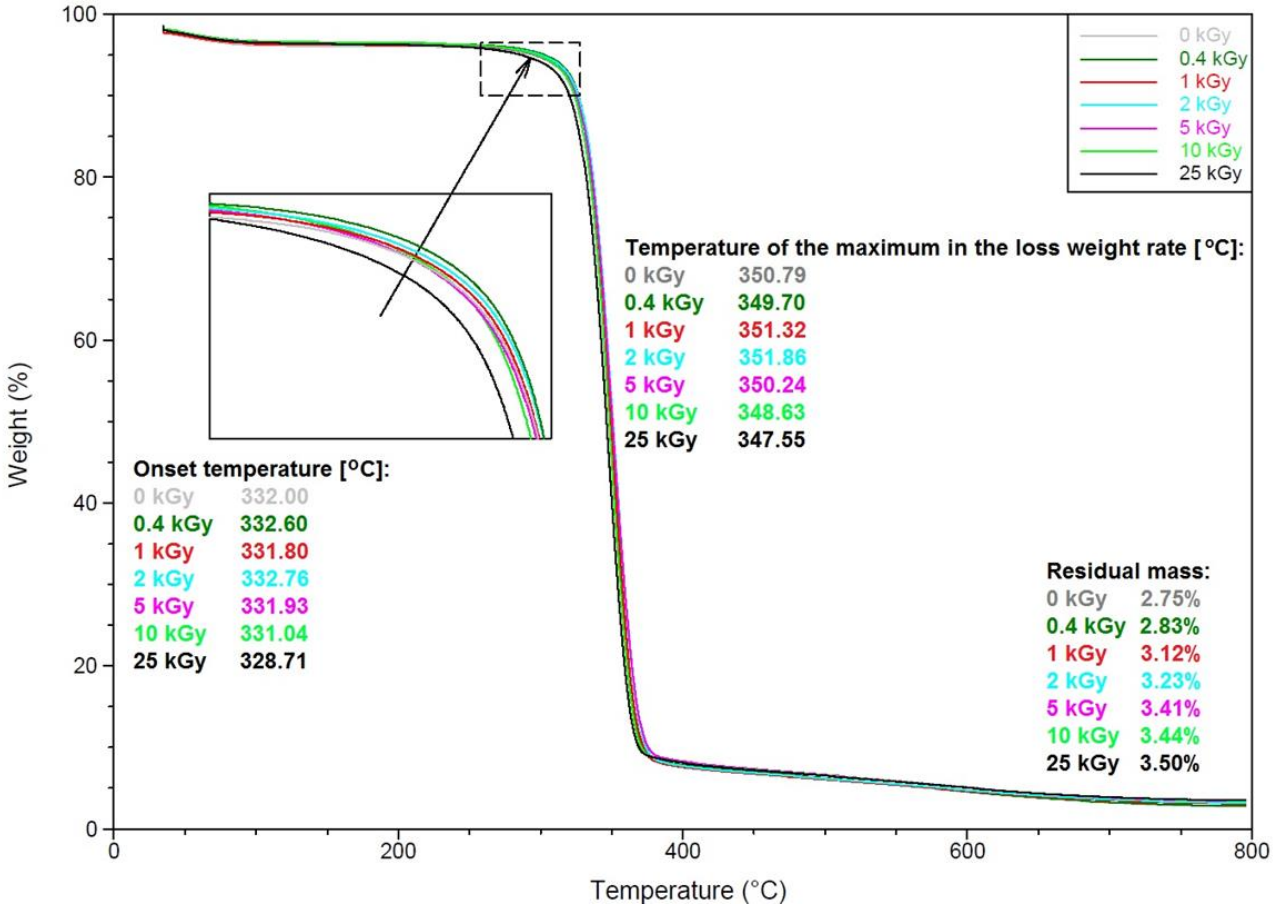
Thermal properties

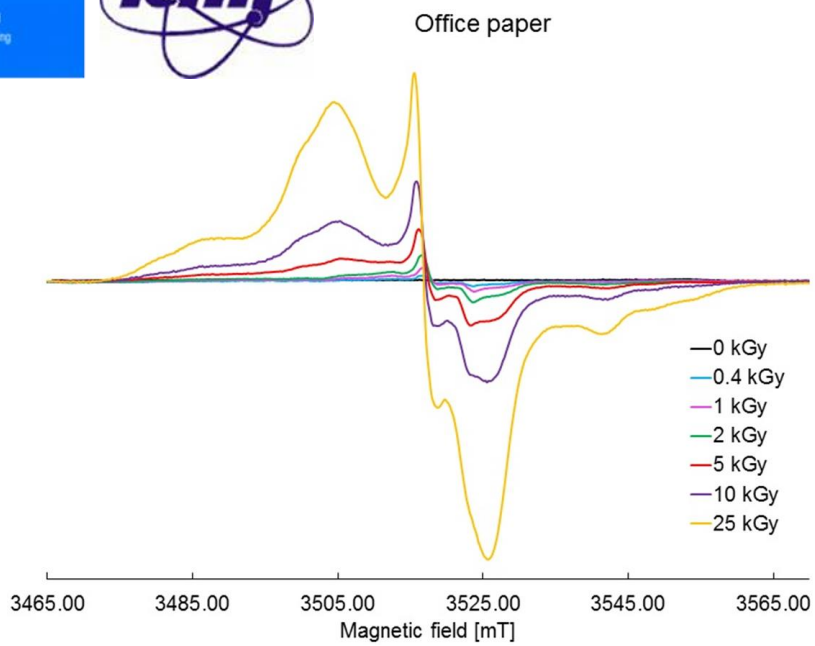


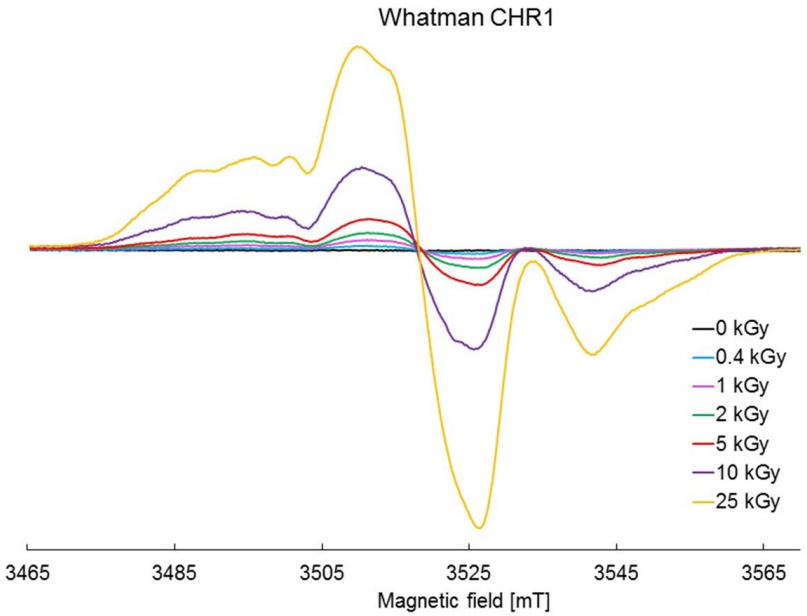
Office paper

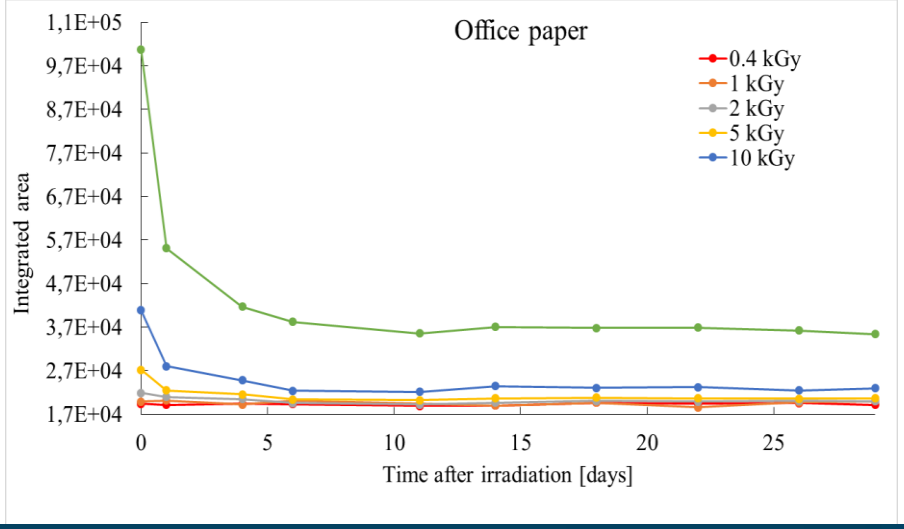


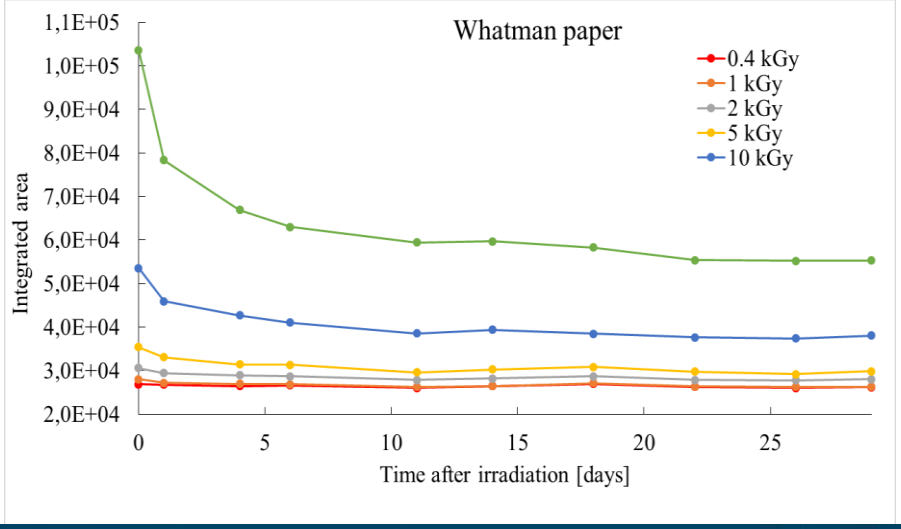
Whatman CHR1

Radicals









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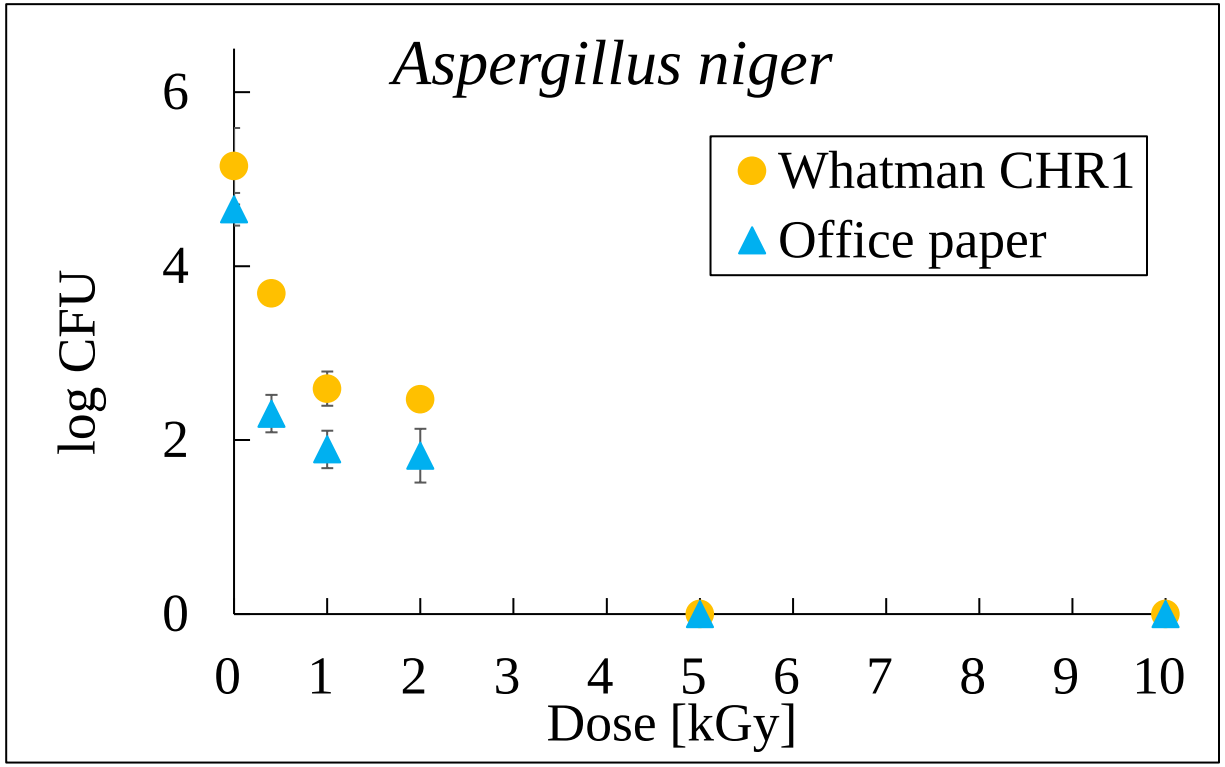
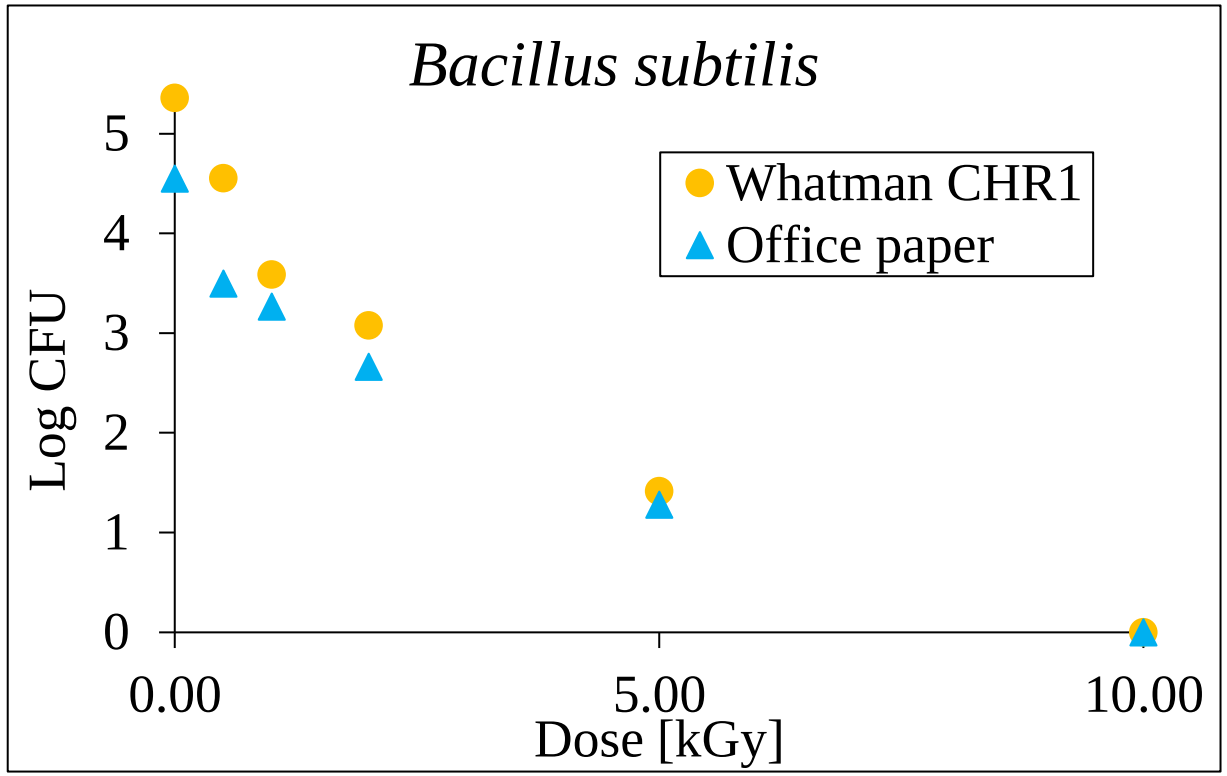
Elimination of microorganisms





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Chemical parameters – natural aging

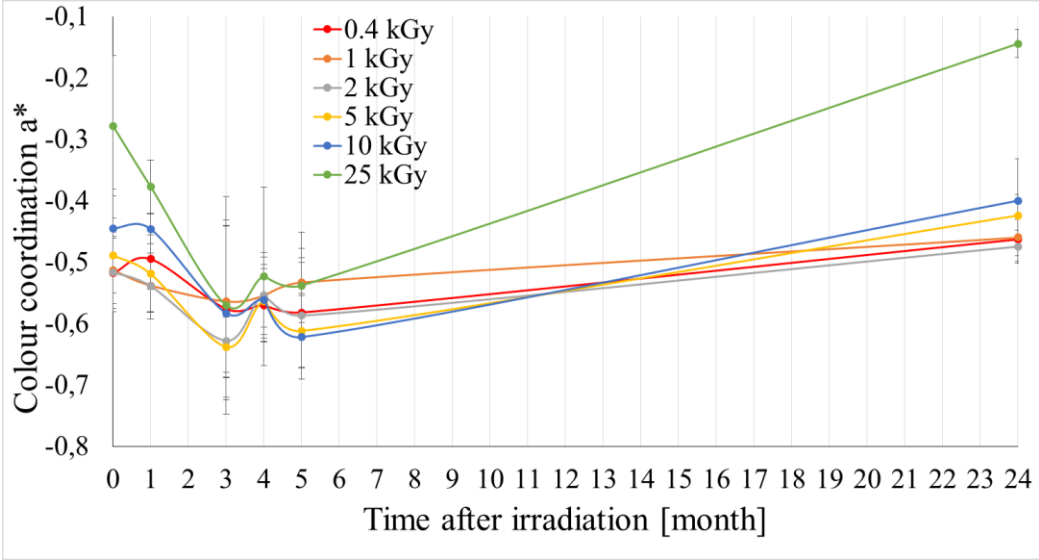
TAPPI T 529 - Surface pH measurement of paper

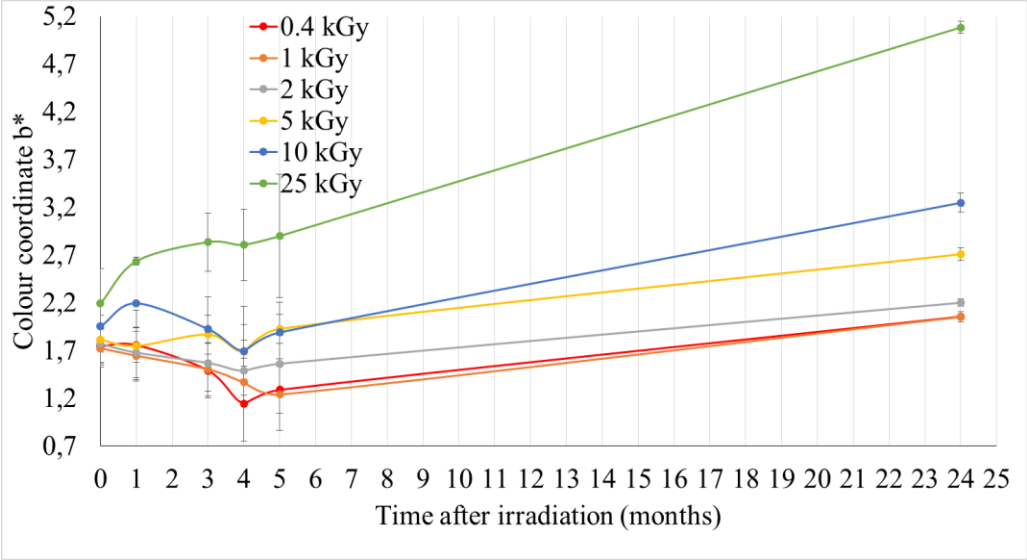
Time [months]	Office paper		Whatman	
	0	3	0	3
Dose [kGy]				
0	7.48	7.45	6.55	7.13
0.4	7.38	7.51	5.67	6.66
1	7.40	7.53	6.01	6.86
2	7.40	7.43	6.28	6.56
5	7.48	7.56	6.38	7.14
10	7.40	7.51	6.87	7.15
25	7.35	7.44	6.46	6.82

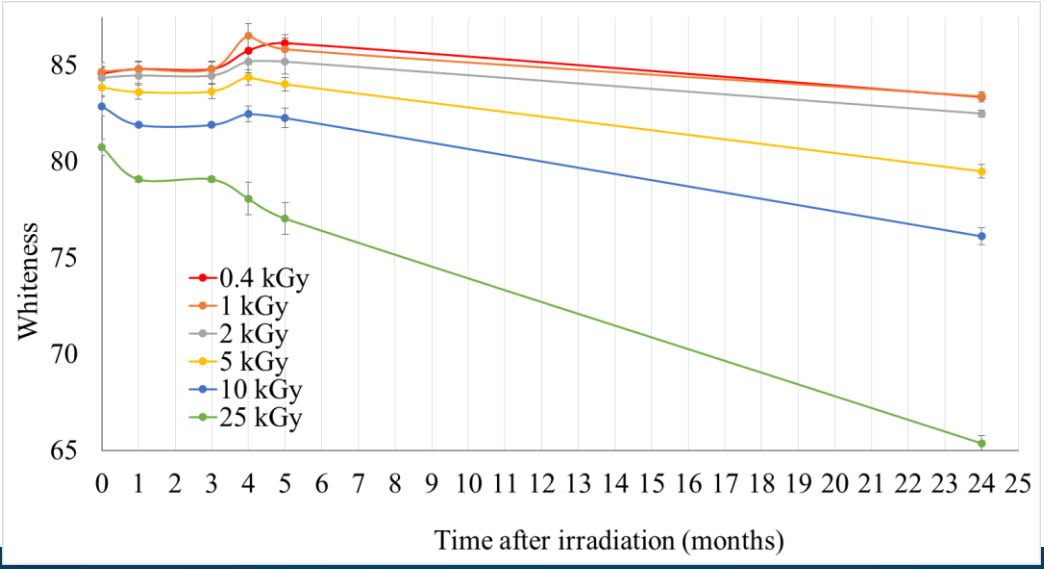
TAPPI T 509 Hydrogen ion concentration (pH) of paper extracts (cold extraction method)

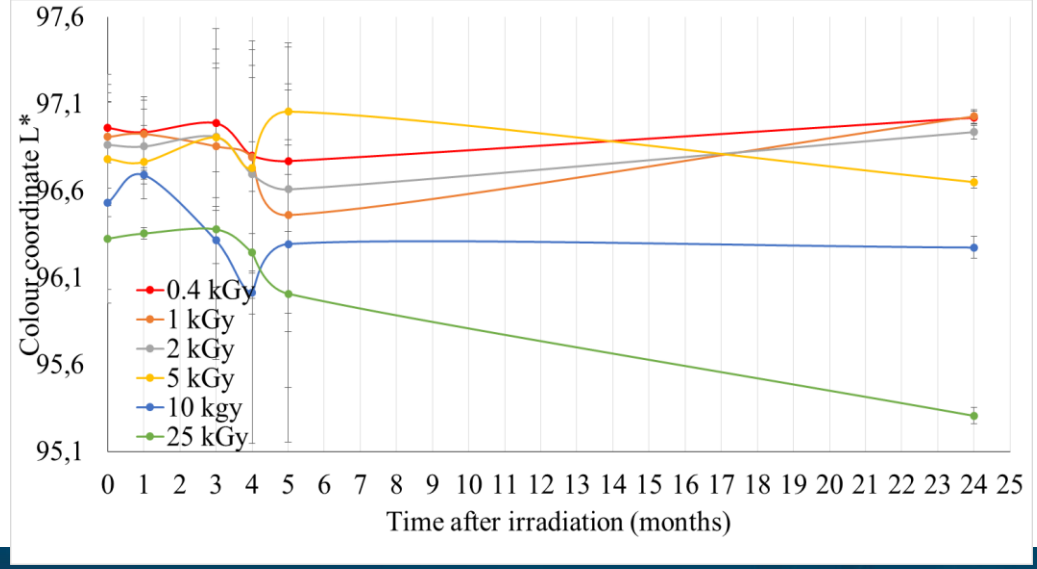
Time [months]	Office paper		Whatman	
	0	3	0	3
Dose [kGy]				
0	8.66	8.47	7.41	6.81
0.4	8.62	8.56	7.38	6.78
1	8.66	8.53	6.97	7.59
2	8.66	8.59	6.97	7.15
5	8.59	8.59	6.86	7.16
10	8.67	8.62	6.94	6.47
25	8.61	8.58	6.38	6.27

Colour parameters – natural aging
ISO 11475:2004 Paper and board -- Determination of CIE whiteness, D65/10 degrees (outdoor daylight)









WHATMAN CHR 1

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Colour parameters – natural aging
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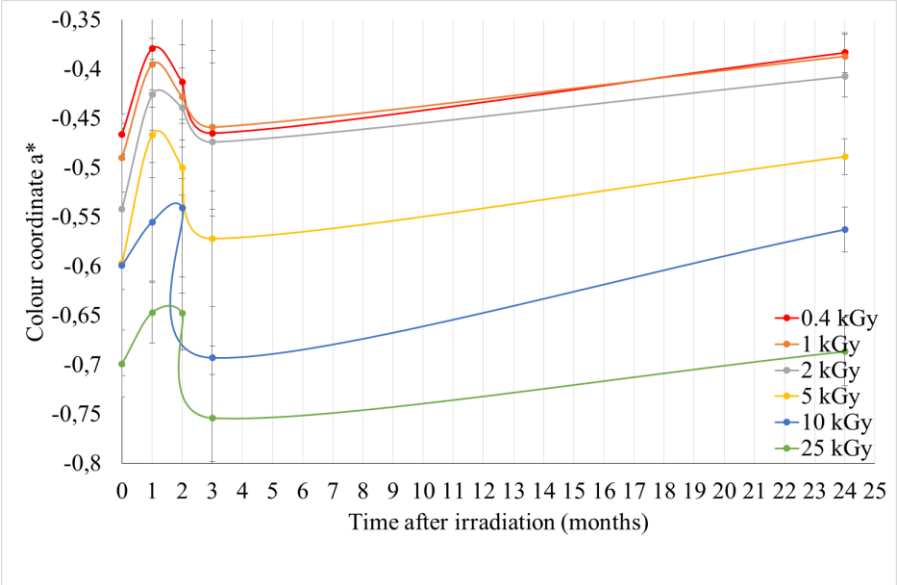

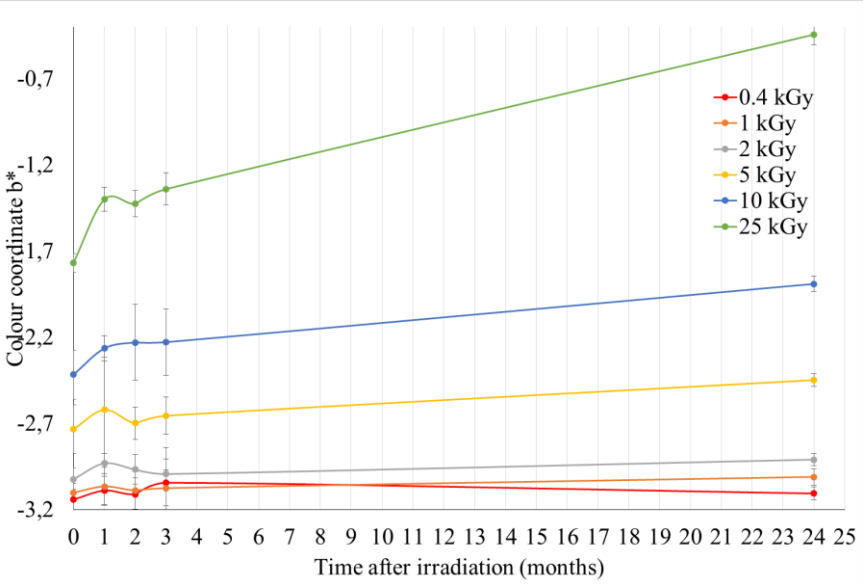

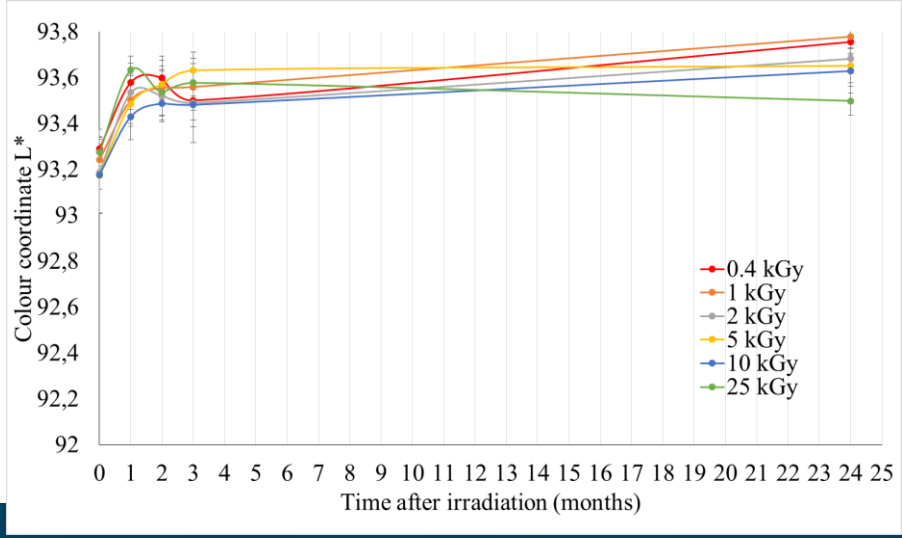

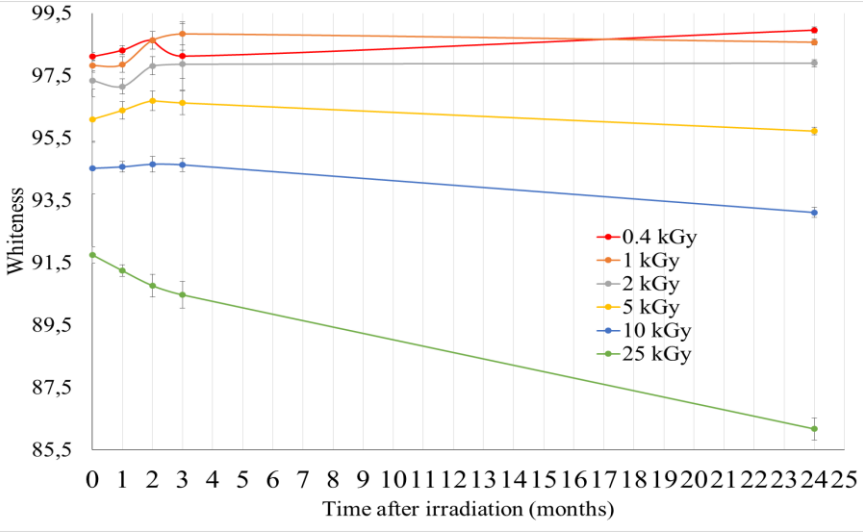

OFFICE PAPER

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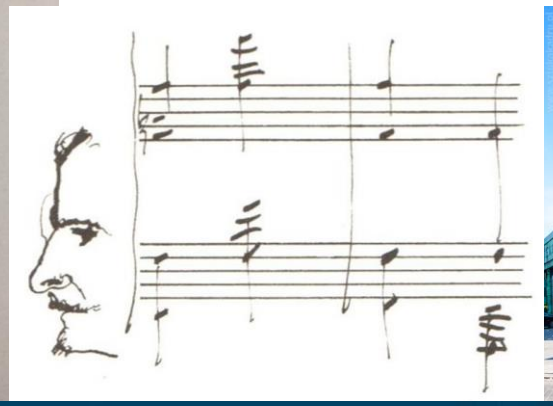
Application of radiation for paper objects preservation in Poland

- **University of Warsaw Library** (books, archives, 40 m^3)
- **Faculty of Modern Languages Library University of Warsaw**(books, archives, 150 m^3)
- **The Fryderyk Chopin University of Music Library** (documents, original music notation composed by Ignacy Paderewski)
- **The Sejm (Polish Parliament) Library** (books, archives, 4 m^3)
- **The Office for Registration of Medicinal Products, Medical Devices and Biocidal Products** (documents, archives, 30 m^3)
- **State Archaeological Museum in Warsaw** (collection of leather shoes and documents)
- **Diocesan Libarary in Sandomierz** (collection of XV/XVI century manuscripts and old prints)



Conclusions

- The colour of the paper is the most sensitive to the irradiation parameter of the paper samples.
- EB irradiation of different kinds of paper with doses up to 5 kGy doesn’t influence their colour noticeably and only for the samples of office paper irradiated with a dose of 25 kGy changes of the paper colour can be noticed by the experienced observer.
- Mechanical parameter like tensile strength of paper samples is not sufficiently sensitive to electron beam irradiation in applied dose ranges to indicate paper degradation.
- EB irradiation enables the treatment of huge quantities of paper-based objects in a short time.

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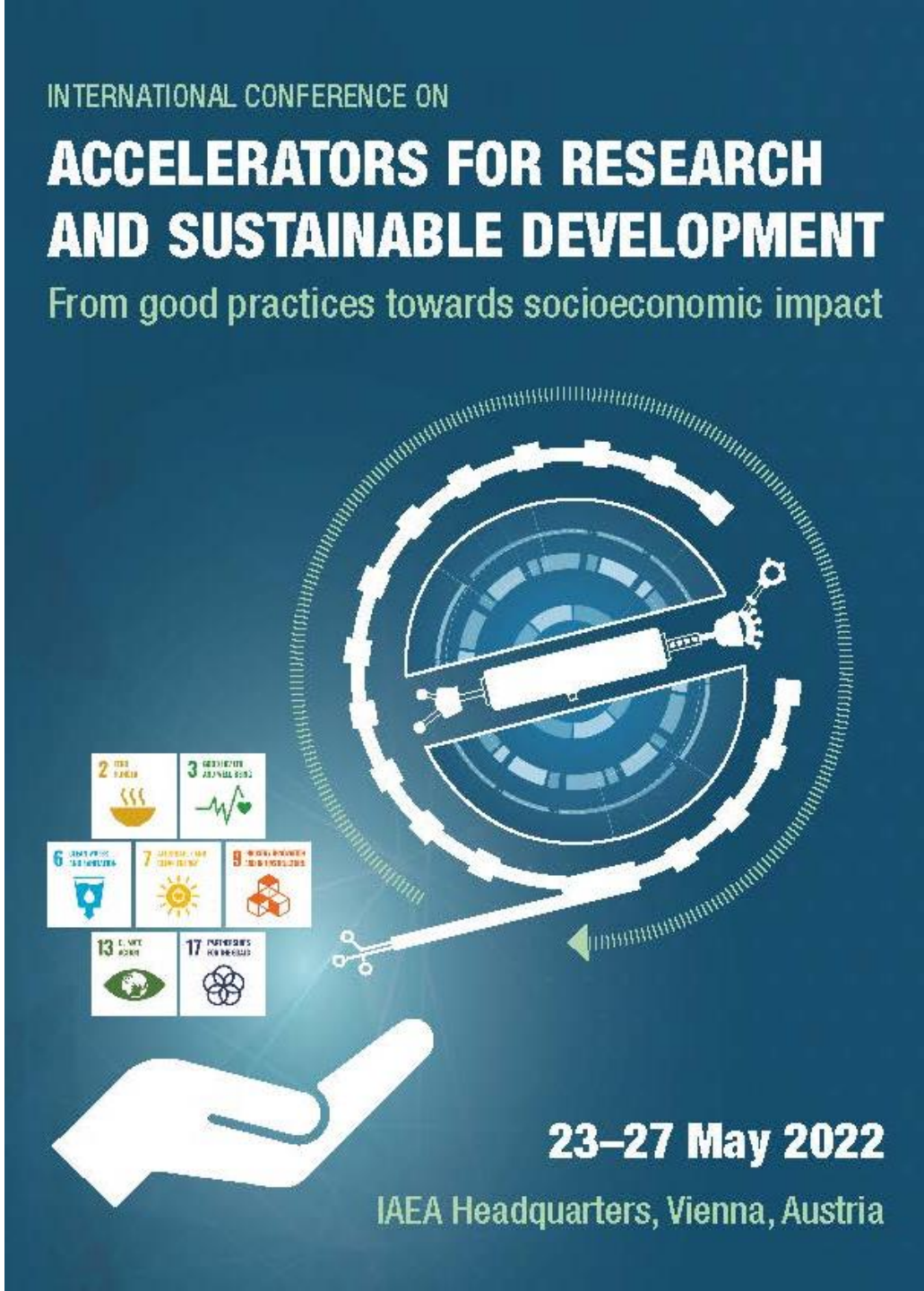
Thank you

Acknowledgements:

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