



RECENT RADIATION RESEARCH AND TECHNOLOGY DEVELOPMENT IN CROATIA

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ZAGREB, CROATIA



ICARST 2017

1st International Conference on Applications
of Radiation Science and Technology

Overview

1. About RBI & RCDL
2. RCDL expertizes and activities using gamma sources
3. Recent radiation research

RBI IS THE LARGEST CROATIAN MULTIDISCIPLINARY RESEARCH INSTITUTE IN:

> 500 academic stuff

Physics (experimental, theoretical)

Chemistry (organic , physical, biochemistry)

Marine and environmental research and geosciences

Molecular biology

Biomedicine

Computer science

Electronics/engineering

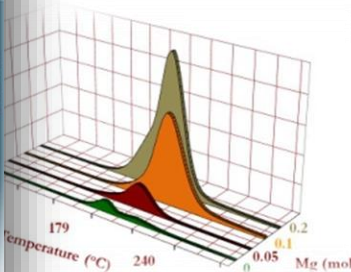
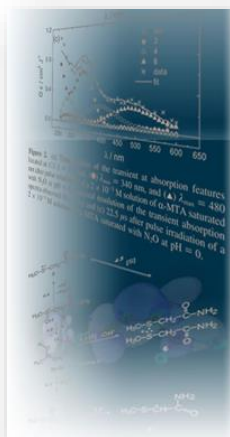
200 RBI scientists involved
in education
(undergraduate, graduate
courses and PhD programs)



**...Scientific Discoveries for
Innovative Economy and Society...**



RADIATION CHEMISTRY AND DOSIMETRY LABORATORY

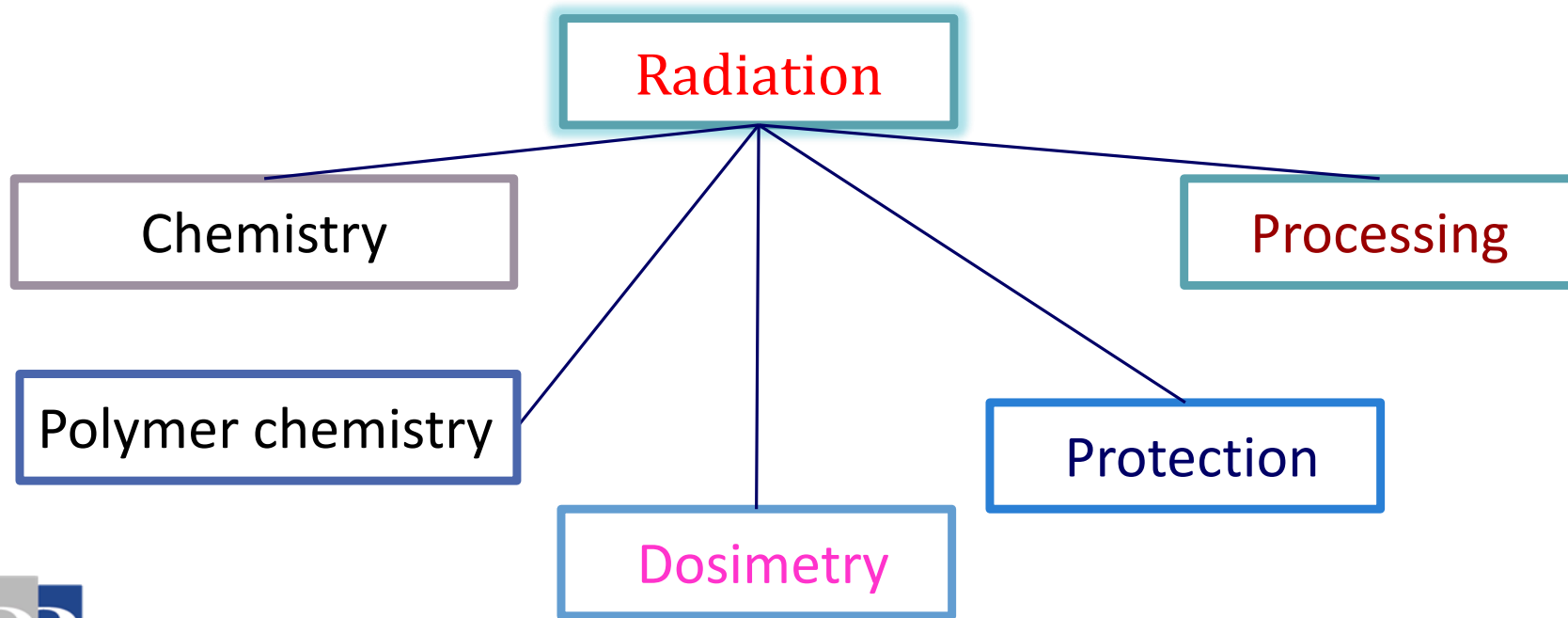


Radiation Chemistry and Dosimetry Laboratory (RCDL)

Founded in 1958 by dr. Igor Dvornik (1923 – 2010)

Focused on two avenues of research:

- (a) investigations into fundamental mechanisms of the interactions of ionizing radiation and matter, and
- (b) investigations of the possibilities to apply physical, chemical and biological effects of irradiation



Polymer chemistry

Synthesis and modifications of polymers by irradiation and/or with additives.



Radiation Chemistry

Phenomenology of gamma radiolysis (& laser flash photolysis) for the study of biologically relevant fast reactions (biomimetics, lipidomics). Graduate and postgraduate courses on the subject.

Projects: CSF (Croatian Science Foundation), IAEA, COST

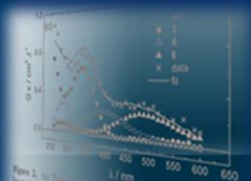
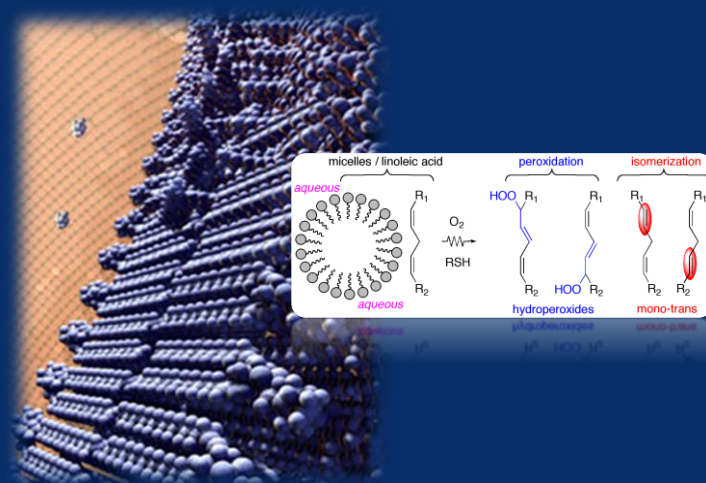
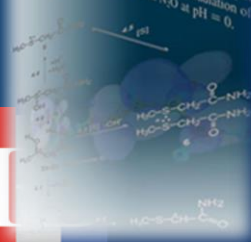


Figure 2. (a) Time evolution of the transient at absorption feature located at $\lambda = 340$ nm, (b) $\lambda = 340$ nm, and (c) $\lambda = 410$ nm. The photochemical reaction was initiated by irradiation with Nd at pH = 7.0. The concentration of α -MTA saturated solution was 2×10^{-4} M. The observed relaxation of the transient absorption of α -MTA saturated with N_2O at pH = 7.0 is shown in (d). The concentration of α -MTA saturated with N_2O at pH = 7.0 was 2×10^{-4} M.



Fields of expertise:

Radiation Metrology and Dosimetry

Research on radiation dosimetry of a broad range of doses (μGy - MGy) and dose rates, over a broad range of radiation qualities (electromagnetic radiations, neutrons and charged particles over a range of LET values) and over a broad range of applications (environmental monitoring, public exposure, professional exposure, accidental exposure, radiation processing, radiation damage). Education.



Fields of expertise:

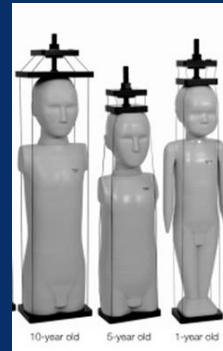
- *Medical dosimetry*

The determination of out-of-field doses in radiotherapy treatments using various photon/proton techniques (identification of a list of clinical situations and treatment protocols which lead to healthy-tissue doses of concern, evaluation of different dosimeters for out-of-field measurements, estimation of secondary cancer risk, joint clinical measurements with partners at selected hospitals).

Projects: EURADOS, EUROFusion, EURAMET, IAEA

Radiobiology

Expertise and consultancy related to radiobiological experiments. Irradiation services for radiobiology experiments.



Fields of expertise:

Food irradiation

Research of radiation chemical effects in irradiated foods.
Research and application of the identification methods for irradiated foods. Irradiation services for food irradiation.
Education.

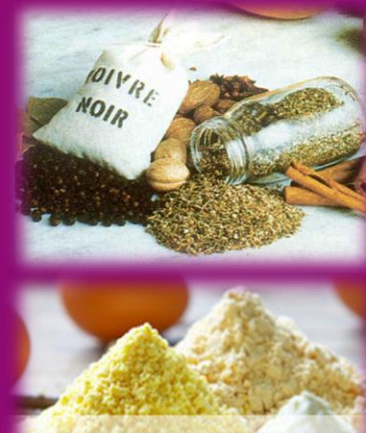
Croatian experience

Foods:

of botanical origin: *dry tea herbs, dry and liquid herbal extracts, seasonings, dry spices and vegetables etc., oils*
of animal origin: *egg powder, egg products*

More than 50 papers and 50 congress presentations

RCDL members (1994): Regulation on the Conditions for the Conservation by Ionizing Radiation of Food and Items for General Use



Fields of expertise:

Radiation Sterilization

Irradiation of different materials at high doses. Education.

Croatian experience

(medical devices and supplies (syringes, needles, scalpels, blades, catheters), implants, medical & cosmetic products etc)

Pharmaceuticals

Low volume + high value of irradiated pharmaceuticals warrant research attention

(pharmaceutical packages (hard gelatine capsules, eye droppers), raw materials for pharmaceutical industry (starch, plant extracts)

Review: Ražem & Katušin Ražem: The effects of irradiation on controlled drug delivery/ controlled drug release systems. *Rad.Phys.Chem.*, 77(2008)288.

(For 2 years since publication No. 1 among Top 25 in *Radiat. Phys. Chem.*)



Bank tissue : human skin cells (for the skin transplantation, plastic surgery)

Peat soil or other materials: agriculture (related biotechnologies)

Fields of expertise:

Radiation treatment of cultural heritage

Expertise and consultancy related to disinfestation and desinsection of cultural heritage artefacts.

Croatian experience

More than 8.000 wooden sculptures, parts of altars, furniture, tools, musical instruments, other wooden, paper, straw, textile, leather, etc. Items

(2014-2016): 22 publications related to irradiation applications, exhibitions and lectures



Gamma irradiation facility at the RCDL

Only of the kind in Croatia!

Applications:

- suitable for a variety of applications
from medium dose range used in radiobiology (solid state physics, biophysics etc) to the high doses pertaining to radiation processing and radiation chemistry

Irradiation:

- for research and radiation processing

Ražem, *Rad Phys Chem* 71 (2004) 595-600



The source rack construction allows for the fast and safe travel of the source assemblies. The travel time of the source between end positions (3 m apart) is about 2 seconds. The safety is maintained by sources being at all times within their respective guide tubes.

Historical objectives

Establishment of an essential radiation research facility of RCDL

Upgrading experimental infrastructure of the RBI

Technology transfer - service to society

*pilot-scale irradiation plant enabling technology transfer by
providing first hand experience in irradiation services*

Actions:

1962 Construction of a panoramic irradiator

1966 First loading with ^{60}Co (3.000 Ci)

1982 Reconstruction of electromechanical parts

1983 Replenishment with 50.000 Ci of ^{60}Co

1988 Reconstruction of safe storage position

1990 Replenishment with 100.000 Ci of ^{60}Co

2000 Replenishment with 80.000 Ci of ^{60}Co

2015 Replenishment with 86.000 Ci of ^{60}Co

IAEA TC-IAEA CRO1006 (2014-2015). : Upgrading of ^{60}Co panoramic irradiation facility in Croatia (3.4 PBq)

November 18, 2015



DOSIMETRY

Routine dosimetry monitoring has been performed by using ECB dosimetry

Dosimetric solutions on the basis of chlorobenzene (developed in RBI)

Chlorobenzene in ethanol and trymethylpentane: system CET

- “Low” doses (0.1 – 12 Gy): accidental dosimetry, radiobiology, radiotherapy
- Emergency personel CET dosemeter (DL-M4)

Chlorobenzene in ethanol: system ECB

- High doses (10 Gy – 10 MGy): radiation processing
- Characterized for 4, 10, 20, 25 and 40% CB (by vol.)

ECB: a practical and an original solution to the needs!
Adoption of the ECB dosimetry system as a reference
standard dosim. system by ASTM (ISO/ASTM 51538).

Contributions of other researchers
(Hungary: oscillometric readout)



DOSIMETRY

The source rack has a squirrel cage shape and the radiation field has a cylindrical symmetry.

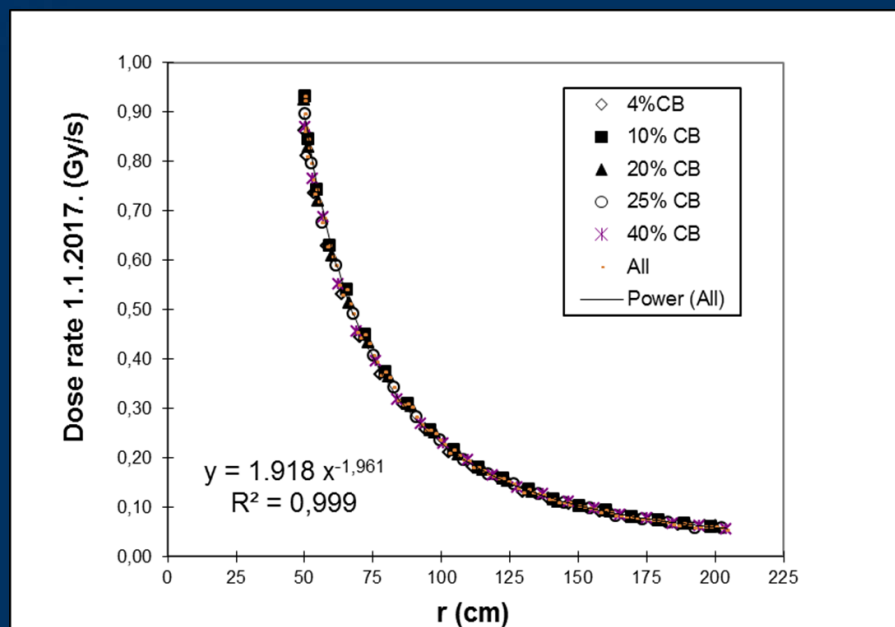
The new dose mapping

- Dose rates were measured at different distances from the source at the level of the axis of the position when source is in „working position“.
- Dose rates were also measured at different heights at specified distance from the source.
- Reference dosimetry was performed using NE 2571 ionisation chamber and UNIDOS electrometer
- Dose specified as “absorbed dose to water”



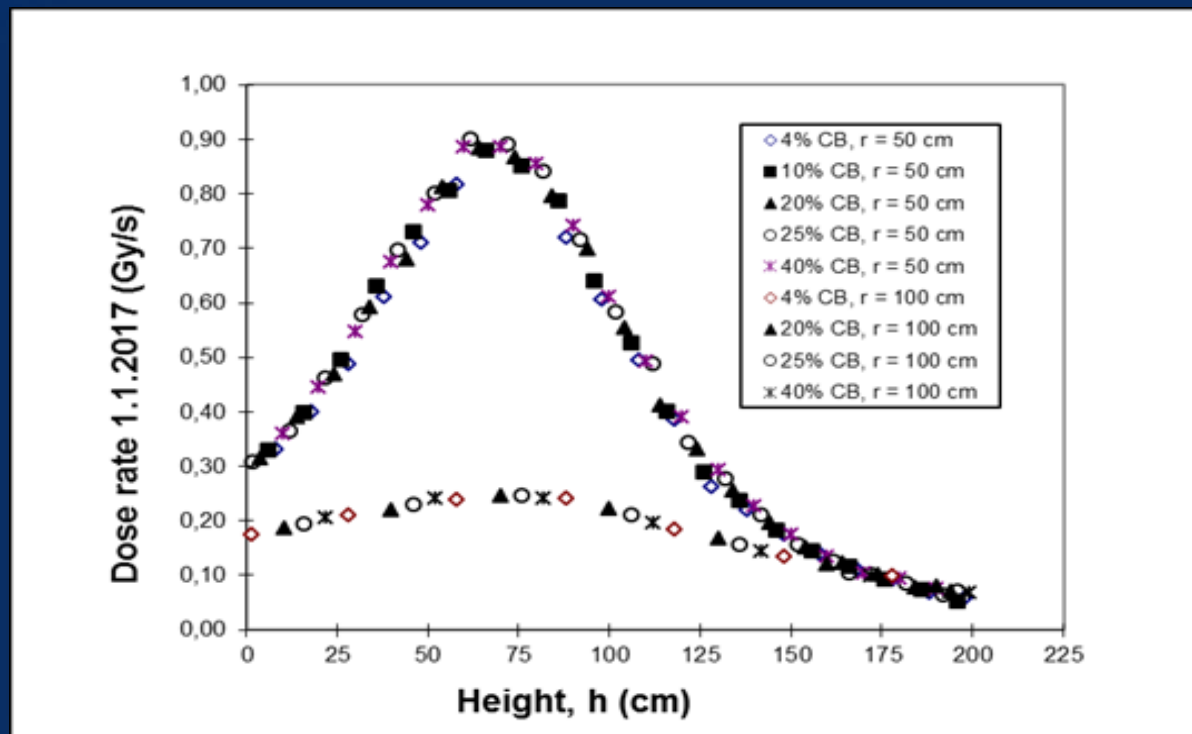
The dependence of the dose rate on the radius r was determined using previous measurements with various formulations of ECB dosimeter at distance h from the reference horizontal plane (horizontal plane through the centre of the source cylinder).

If the source were a point source, the dose rate would decrease with distance from the centre of the source in the reference horizontal plane $h = 0$ as an inverse quadratic function of r . ($80 \text{ cm} < r < 300 \text{ cm}$)



Results: The decrease is slightly slower than with the square of the distance.
(publication in preparation)

Source cylindric symmetry



Dependence of dose rate on the height from the floor at $r = 50$ cm and $r = 100$ cm measured with various formulations of ECB dosimeter as indicated.

(publication in preparation)

RECENT RADIATION RESEARCH (2012-)

National and international collaborations

Ruđer Bošković Institute

University of Zagreb

Croatian Conservation Institute & RBI

Department of Restoration of the Academy of Fine Arts & RBI

Croatian State Archives & RBI

Central Conservation Institute Beograd, Serbia, National University
Library, Zagreb & RBI

Restoration Centre, Institute for the Protection of Cultural Heritage of
Slovenia, Ljubljana & RBI

Vinča Institute of Nuclear Science, Beograd, Serbia & RBI

*International co-operation through the IAEA regional development
programs*

- 2006-
- Nuclear Techniques for the Characterisation and Preservation of Cultural Heritage Artefacts,
 - Introducing and Harmonizing Standardized Procedures for Radiation Technologies,
 - Coordinated research programs
- Developing Radiation Treatment Methodologies and New Resin Formulations for Consolidation and Preservation of Archived Materials and Cultural Heritage Artefacts

RADIATION MODIFICATION OF POLYMERS

γ -IRRADIATION OF PEO IN THE SOLID STATE, MELT AND AQUEOUS SOLUTION

Goal: to improve properties of PEO for application in polyelectrolites, hydrogels (drug delivery) etc.

Radiat. Phys. Chem. 81 (2012) 1303–1308; 1426–1429.

SYNTHESIS AND MODIFICATION OF PEO/SiO₂ NANOCOMPOSITE FILMS AND HYDROGELS

Polym. Eng. Sci. 53 (2013) 2318–2327.

PEO/IRON OXIDE NANOCOMPOSITE HYDROGELS AND MAGNETIC SUSPENSIONS synthesized by gamma-irradiation of PEO + Fe³⁺ aq. solutions

Goal: to synthesize in a „clean” way, in one step, magnetic PEO hydrogels and/or stable ferrofluids for possible application in biomedicine (with superparamagnetic magnetite or other iron oxide particles).

Radiat. Phys. Chem. 124 (2016) 75–83

MICROEMULSION SYNTHESIS OF GOLD NANOPARTICLES BY γ -irradiation and other reducing agents

Goal: Au nanoparticle size, aggregation, dispersion and stability

Gold Bull. 49 (2016) 21–33.

FOOD IRRADIATION

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont



Aflatoxin B₁ occurrence in maize sampled from Croatian farms and feed factories during 2013



Jelka Pleadin^{a,*}, Ana Vulić^a, Nina Peršić^a, Mario Škrivanko^b, Brankica Čanek^c

Željko Č

Croatian Vet
Croatian Vet
Ministry of A



Food Control

Volume 54, August 2015, Pages 79–85



Inactivation of aflatoxigenic fungi and the reduction of aflatoxin B₁ *in vitro* and *in situ* using gamma irradiation

Ksenija Markov^a,  , Branka Mihaljević^b, Ana-Marija Domijan^c, Jelka Pleadin^d, Frane Delaš^a, Jadranka Frece^a

- Effect of gamma irradiation on aflatoxigenic moulds AFB₁ level was tested.
- Gamma irradiation effectively stopped moulds' germination, sporulation and growth.
- Level of AFB₁ in maize and feed samples was reduced by gamma irradiation.
- Gamma irradiation can be used to control AFB₁ level in various commodities.

Reduction of ochratoxin A in dry-cured meat products using gamma-irradiation

Ana-Marija Domijan^a, Jelka Pleadin^{b*}, Branka Mihaljević^c, Nada Vahčić^d, Jadranka Frece^d and Ksenija Markov^d

^aFaculty of Pharmacy and Biochemistry, University of Zagreb, Zagreb, Croatia; ^bLaboratory for Analytical Chemistry, Croatian Veterinary Institute Zagreb, Zagreb, Croatia; ^cRuder Bošković Institute, Zagreb, Croatia; ^dFaculty of Food Technology and Biotechnology, University of Zagreb, Zagreb, Croatia

(Received 2 March 2015; accepted 27 April 2015)

This study investigated the efficiency of gamma (γ)-irradiation in the reduction of ochratoxin A (OTA) present in dry-cured meat products prepared from intentionally contaminated raw materials from OTA-treated pigs. OTA concentrations determined in the samples ($n = 24$) ranged from $25.8 \mu\text{g kg}^{-1}$ in bacon to $17.8 \mu\text{g kg}^{-1}$ in smoked ham. After γ -irradiation at doses of 3, 7 and 10 kGy (i.e. the doses used in the food industry), a dose-dependent OTA reduction was observed; however, it was not statistically significant. The mean OTA reduction achieved with 3-, 7- and 10-kGy γ -doses was approximated to 8.5%, 13.9% and 22.5%, respectively. The storage of irradiated samples (1 month, 4°C) did not significantly affect OTA levels. Based on the correlation between the OTA reduction level and basic chemical composition of dry-cured meat samples, OTA reduction may be linked to the samples' fat content. The results indicate that γ -irradiation

γ -irradiation is a method of limited effectiveness for ochratoxin A reduction

RECENT INTERDISCIPLINARY STUDY ON TOXICITY OF IRRADIATED AFLATOXIN B₁ AND OCHRATOXIN A *in vitro*

Analysis:

- HPLC-MS/MS analysis revealed that even at 5 kGy AFB₁ and OTA molecules were degraded.
- AFB₁ has greater susceptibility than OTA to gamma irradiation.
- Results on cytotoxicity tested on three different cell lines (Pk15, HepG2 and SH-SY5Y; MTT assay, 24 h exposure) demonstrated that radiolytic products of AFB₁ and OTA are less toxic than parent compounds to all cell lines tested.

PROTECTION OF CULTURAL HERITAGE OBJECTS BY IRRADIATION

A case study on an oil canvas painting from the 18th century - desinsection

RCDL & Faculty of Pharmacy and Biochemistry &
Croatian Conservation Institute, Zagreb



Disinfection could be achieved with 10 kGy, without negative consequences on the materials that are present on the painting (textiles, wood, pigments, binders, wax).

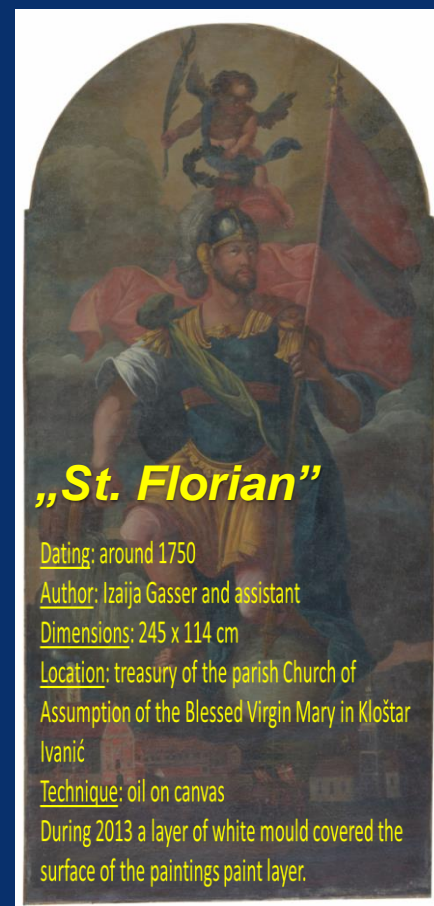
Biodecontamination by gamma irradiation of cultural heritage object containing nacre

RCDL & Academy of Fine Arts, University of Zagreb
Radiat. Phys. Chem. 124 (2016) 62-67

Radiation treatment against fungi on cultural heritage textiles-archaeological and model silks

RCDL & Institute for the Protection of Cultural Heritage of
Slovenia & University of Ljubljana

- γ -radiation is an excellent biocide that also partially inactivates fungal enzymes
- irradiation of silk to doses for fungi control causes no radiation-specific damage (publication in preparation)



„St. Florian”

Dating: around 1750

Author: Izaija Gasser and assistant

Dimensions: 245 x 114 cm

Location: treasury of the parish Church of
Assumption of the Blessed Virgin Mary in Kloštar
Ivanić

Technique: oil on canvas

During 2013 a layer of white mould covered the
surface of the paintings paint layer.



RADIATION PROCESSING ON PANORAMIC GAMMA IRRADIATOR

FUTURE ACTIVITIES:

- Establishment of traceability of high dose dosimetry;
- Harmonization of pertaining rules and regulations with EC;
- Establishment of a comprehensive quality assurance system of service gamma irradiations (ISO 13485)

National and regional development programs related to radiation technologies

RBI EU project – in progress: *Open scientific infrastructural platforms for innovative applications in economy and society*: The Radiation Technology Platform

LINAC included:

- possibilities both for interdisciplinary scientific research and for commercial applications.
- to supplement and substitute the decaying cobalt of the present gamma facility.

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The support of the IAEA in ensuring the timely supplies of the radioactive ^{60}Co over the years is gratefully acknowledged.

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Thank you for your attention!