NUTECH-2020

Warsaw, 4-7 October 2020

International Conference
on Development and Applications
of Nuclear Technologies

CONFERENCE ABSTRACTS & PROGRAMME

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Wydawca:

Instytut Chemii i Techniki Jądrowej
ul. Dorodna 16, 03-195 Warszawa
tel. :22 504 12 05
e-mail: sekdyrn@ichtj.waw.pl

www.ichtj.waw.pl

ISBN 978-83-946412-4-5

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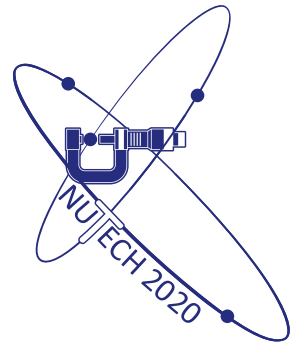

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ABOUT CONFERENCE

The NUTECH-2020 is a continuation of the National Symposia on Applications of Nuclear Techniques in Industry, Agriculture, Medicine and Environment Protection, which have been held in Poland since 1960, almost every three years. From 2008 it attained the international status. With a significant number of foreign participants the NUTECH conference provides a platform for the nuclear science community to share the experience and to learn about the recent developments going on in nuclear research and their practical applications.

Topics of the Conference:

- radiation processing of materials,
- radiation sterilization and health care products development,
- food irradiation,
- industrial application of the nuclear techniques,
- nuclear medicine & radiopharmaceuticals,
- nucleonic control systems,
- radioanalytical and radiotracer techniques,
- radiation technologies in environmental and earth studies applications,
- nuclear technologies in protection and identification of cultural heritage,
- radiation measurements, data processing and acquisition,
- radiation sources (eb, X-ray and gamma) development applications,
- quality control and assurance in nuclear technologies,
- management of nuclear wastes,
- radioprotection and radiobiology,
- present status and future of nuclear energy,
- other topics related to nuclear and radiation related sciences.

ORGANISERS

Institute of Nuclear Chemistry and Technology

AGH University of Science and Technology

Polish Nuclear Society

HONORARY PATRONAGE

Ministry of Science and Higher Education
Republic of Poland

Ministry of Climate and Environment

OFFICE OF TECHNICAL INSPECTION

PAA
NATIONAL ATOMIC ENERGY AGENCY

The project is co-financed under the program Ministry of Science and Higher Education "Excellent Science"

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- Michael Waligórski, Institute of Nuclear Physics, Poland
- Paul Wynne, International Irradiation Association, UK

NUTECH-2020

CONFERENCE SESSIONS

OPENING SESSION

Presenting author	*Title*
	Opening of the conference
Andrzej G. Chmielewski *Institute of Nuclear Chemistry and Technology, Poland*	Opening of the conference and short review of main topics to be presented
Marek Lankosz *AGH University of Science and Technology, Poland*	Nuclear techniques at AGH UST-current status and future developments
	Representatives of the conference honorary patrons
	Łukasz Młynarkiewicz President National Atomic Energy Agency (PAA), Poland
	Tomasz Nowacki Director of Nuclear Energy Department Ministry of Climate, Poland

Session: PLENARY SESSION

Chair: A. G. Chmielewski/ P. Ulański

Presenting author	*Title*
Piotr Ulański *Lodz University of Technology, Poland* *Invited Speaker*	Radiation crosslinking of polymers – facing new paradigms, creating new opportunities
Jerzy Majcher *Nuclear energy expert, Poland,* *Invited Speaker*	Electricity market and power system conditions for financing the construction of a nuclear power plant in Poland
Suresh Pillai *Texas A&M University, USA* *Invited Speaker*	The next frontier for understanding how microorganisms respond to ionizing technologies
Mohamad AL-Sheikhly *University of Maryland, USA* *Invited Speaker*	Electron Beam Synthesis of Novel Fabrics for Extraction of Uranium from Seawater
Bumsoo Han *International Atomic Energy Agency, Austria* *Invited Speaker*	Radiation Technology for Sustainable Development
Patrick Brisset/ Gerardo Maghella-Seminario *International Atomic Energy Agency, Austria* *Invited Speaker*	IAEA Programs in the field of RT, NCS and NDT
	Discussion

Session I: NUCLEAR ENERGY

Chair: M. Dąbrowski/ G. Zakrzewska-Kołtuniewicz

Presenting author	*Title*
Ziemowit Iwański *Ziemowit Iwański Power Systems, Poland* *Invited Speaker*	Modern Power Generation Technologies and Strategy to Achieve Optimal Energy Mix
Wacław Gudowski *KTH, Sweden* *Invited Speaker*	High Temperature Gas Cooled Reactors – good choice for Poland to enter nuclear energy deployment
Piotr Darnowski *Warsaw University of Technology, Poland*	Severe Accident Analyses for Demonstration of the SAMG Decision-Making Tool
Wojciech Kubiński *Warsaw University of Technology, Poland*	Optimization of the Loading Pattern of the PWR Reactor Core Using Genetic Algorithms and Multi-Purpose Fitness Function

Session II: NUCLEAR ENERGY

Chair: M. Dąbrowski/ G. Zakrzewska-Kołtuniewicz

Presenting author	*Title*
Mirco Grosse *Karlsruhe Institute of Technology, Germany* *Invited Speaker*	Thermal Limits of Promising Candidate Materials for Accident Tolerant Fuel Claddings
Bożena Sartowska *Institute of Nuclear Chemistry and Technology, Poland*	Protective multielemental coatings on Zircalloy-2: INCT studies
Leon Fuks *Institute of Nuclear Chemistry and Technology, Poland*	Sorption of Selected Radionuclides from Liquid Radioactive Wastes by Sorbents of the Biological Origin
Wojciech Żurkowski *Warsaw University of Technology, Poland*	Application of genetic algorithms in optimization of the SFR reactor design
Elina Pajuste *University of Latvia*	Thermal properties and oxidation processes of nuclear fusion reactor metallic materials in accidental operational conditions
Zuzanna Krajewska *National Centre for Nuclear Research, Poland*	Raman spectroscopy as a tool of TRISO particle fuel defects examination
	Discussion

Session III: HTR

Chair: W. Gudowski/ G. Zakrzewska-Kołtuniewicz

Presenting author	*Title*
Heinz Nabielek *Consultant, Austria,* *Invited Speaker*	TRISO particle nuclear fuel at the heart of the High Temperature Reactor
Mariusz Dąbrowski/ Agnieszka Boettcher *National Centre for Nuclear Research, Poland* *Invited Speaker*	Polish GOSPOSTRATEG HTR project - what has been done and what to do next?
Janusz Malesa *National Centre for Nuclear Research, Poland*	A brief overview of achievements of the European project GEMINI+
Marcin Brykała *Institute of Nuclear Chemistry and Technology, Poland*	GOSPOSTRATEG: Research and analysis of selected chemical aspect of the production and use of TRISO fuel in the HTR nuclear reactor
Wojciech Starosta *Institute of Nuclear Chemistry and Technology, Poland*	Silver migration in TRISO coated particles - computational studies
Mikolaj Oettingen *AGH University of Science and Technology, Poland*	Numerical modelling of Modular High-Temperature Gas-Cooled Reactor with thorium fuel
Ewelina Chajduk *Institute of Nuclear Chemistry and Technology, Poland*	Development of analytical procedures for chemical characterization of substrates for the production of TRISO coated particles as nuclear fuel in high temperature gas-cooled reactors
Katarzyna Kiegiel *Institute of Nuclear Chemistry and Technology, Poland*	Spent fuel and radioactive waste management in the HTGR fuel cycle
Anna Talarowska *National Centre for Nuclear Research, Poland*	Preliminary computational and experimental design studies of the ISHTAR thermostatic rig for the High-Temperature Reactors materials irradiation
	Discussion

NUCLEAR ENERGY

Chair: I. Herdzik-Koniecko/ M. Łyczko

	Presenting author	Title
1	**Piotr Darnowski** *Warsaw University of Technology, Poland*	Demonstration of the Multiple-Path Event Tree PSA Based Approach Dedicated for E-BEPU for PWR Reactor
2	**Wojciech Starosta** *Institute of Nuclear Chemistry and Technology, Poland*	Studies on sorption properties of UiO-66 type Metal Organic Framework sorbents for selected radiosotopes removal from water solution.
3	**Katarzyna Kiegiel** *Institute of Nuclear Chemistry and Technology, Poland*	The studies on uranium recovery from U-bearing Radoniów dump
4	**Marcin Rogowski** *Institute of Nuclear Chemistry and Technology, Poland*	Encapsulation of graphite-uranium compacts as surrogate of spent High Temperature Reactor fuel
5	**Bożena Sartowska** *Institute of Nuclear Chemistry and Technology, Poland*	Proposed Accident Tolerant Materials (ATM) with increased oxidation resistance; studies in the frame of ACTOF CRP IAEA project
6	**Irena Herdzik-Koniecko** *Institute of Nuclear Chemistry and Technology, Poland*	Optimizing the separation of fission product technetium in the process of recycling actinides from spent nuclear fuel
7	**Dagmara Chmielewska-Śmietanko** *Institute of Nuclear Chemistry and Technology, Poland*	Application of SiEA-KNiFe sorbent for radiocesium removal in three different process configuration: batch, fixed-bed and hybrid membrane process
		Discussion

Session ARIES: ACCELERATOR RESEARCH AND INNOVATION FOR EUROPEAN SCIENCE AND SOCIETY (ARIES)

Chair: A. G. Chmielewski/ U. Gryczka

Presenting author	*Title*
Thomas Edgecock *University of Huddersfield, United Kingdom*	Plans for future electron beam activities in Horizon 2020
Andrzej G. Chmielewski *Institute of Nuclear Chemistry and Technology, Poland*	New Trends in Environmental Radiation Technology Applications
Aleksandr Bryazgin *Budker Institute of Nuclear Physics, Russia*	ILU Electron Accelerators for E-beam and X-ray Treatment
Yongxia Sun *Institute of Nuclear Chemistry and Technology, Poland*	Organic pollutant removal from marine diesel engine off-gases under electron beam (EB) and EB hybrid wet scrubber process
Malgorzata Siwek *University of Huddersfield, United Kingdom*	Application of Electron Beam treatment for microplastics removal from sewage sludge
Simone Schopf *Fraunhofer Institut FEP, Germany*	Effect of Low Energy Electron Beam Irradiation on Bacteria and Viruses in Liquids

Poster session

	Presenting author	*Title*
1	**Andrzej Pawelec** *Institute of Nuclear Chemistry and Technology, Poland*	Plasma technology to remove NOx from off-gases
2	**Marcin Sudlitz** *Institute of Nuclear Chemistry and Technology, Poland*	A method of hygienisation and disintegration of sewage sludges using ionising radiation
3	**Anna Bojanowska** *Institute of Nuclear Chemistry and Technology, Poland*	Degradation of diclofenac in sewage sludge from municipal wastewater treatment plant using ionizing radiation
		Discussion

Session IV: RADIOISOTOPES / MEDICAL APPLICATIONS

Chair: H. Lewandowska

Presenting author	*Title*
Hanna Lewandowska *Institute of Nuclear Chemistry and Technology, Poland*	The influence of irradiation on the physicochemical properties of collagen scaffolds
Anna Mastroberardino *Dipartimento di Fisica, Università della Calabria, Italy*	Development and characterization of novel silicon sensors for neutron detection
Ewelina Chajduk *Institute of Nuclear Chemistry and Technology, Poland*	Activity of INCT in the domain of nuclear forensic
Leon Fuks *Institute of Nuclear Chemistry and Technology, Poland*	Interlaboratory comparison on the determination of radionuclides in water, food and soil conducted by the National Atomic Energy Agency (NAEA), Poland
Tatyana Baptista *Nuclear and Energy Research Institute – IPEN, Brazil*	Assurancy quality system in iodine-125 seeds souces production
Monika Łyczko *Institute of Nuclear Chemistry and Technology, Poland*	Synthesis of multimodal radiobioconjugate Octreotide-PEG-198AuNPs-PEG-DOX
	Discussion

Session: RADIATION TECHNOLOGIES AND APPLICATIONS ISTRA: TRACERS AND RADIOTRACERS APPLICATIONS (ISTRA)

ISTRA International Society for Tracer and Radiation Applications

Chair: T. Smoliński/ C. Nobis

Presenting author	*Title*
Christos Tsabaris *Hellenic Center for Marine Research, Greece*	Progress in radionuclide characterisation in beach sands of Lesvos Island using an underwater gamma-ray spectrometer in 2π geometry
Thorsten Jentsch *Helmholtz-Zentrum Dresden-Rossendorf , Germany*	ISO proposal: Measurement of Fluid Flow Rate in Closed Conduits – Radioactive Tracer Methods

Poster session

	Presenting author	*Title*
1	**Jovan Thereska/ Cezary Nobis** *Institute of Nuclear Chemistry and Technology, Poland*	ISO proposal on leak testing in pressured vessels and underground pipelines using radioactive tracer methods
2	**Ferenc Ditrói** *Institute for Nuclear Research, Hungary*	Visualization of tracer distribution in irradiated samples and traced objects by using Positron Emission Tomography (PET)
3	**Miroslav Pavlović** *Scientific Institution Institute of Chemistry, Technology and Metallurgy, National Institute, Serbia*	Optimization of Injected Radiotracer Volume for Flow Meter Calibration in Closed Conduits
		Discussion

Session V: RADIATION TECHNOLOGIES AND APPLICATIONS

Chair: P. Ulański/ X. Coqueret

Presenting author	*Title*
NIkolay Kuksanov *Budker Institute of Nuclear Physics, Russia* Invited Speaker	Modification of the high power DC electron ELV accelerators for research and industrial application
Colombani Juliette *IRSN, France*	IRSN irradiation facilities
Mark Driscoll *State University of New York College of Environmental Science and Forestry, USA*	Electron Beam Degradation of Microcystin LR
Uliana Pinaeva *Université de Reims Champagne Ardenne, France*	Radiolytic synthesis of HEMA-based hydrogel composites including gold nanoparticles: potentialities for the design of functional 3D-printed materials
Amilcar Antonio *Instituto Politecnico de Braganca, Portugal*	Food irradiation: Where is the Limit?
Urszula Gryczka *Institute of Nuclear Chemistry and Technology, Poland*	Application of low energy electron beam for microbial decontamination of food products
Ivana Sandeva *Ss. Cyril and Methodius University in Skopje, Macedonia*	Interlaboratory comparison for detection of irradiated food by luminescence methods
	Discussion

Session: POSTER SESSION I

Chair: D.Chmielewska-Śmietanko/ U.Gryczka/ M.Walo

IRRADIATION FACILITIES, DOSIMETRY AND PROCESS CONTROLL

Lp.	Presenting author	Title
1	**Zbigniew Zimek** *Institute of Nuclear Chemistry and Technology, Poland*	Characteristics of output systems used in high power electron accelerators equipped with tytanium window
2	**Ivica Vujcic** *Vinca Institute of Nuclear Sciences, Serbia*	Dose Mapping of Products with Different Density Irradiated with Co-60 Irradiatior
3	**Urszula Gryczka** *Institute of Nuclear Chemistry and Technology, Poland*	Dose measurements in liquid flow systems
4	**Zaur Khalilov** *National Nuclear Research Center CJSC, Azerbaijan*	Comparison of the measured and calculated dose maps in gamma facility in Azerbaijan.
5	**Vyacheslav Uvarov** *Kharkiv Institute of Physics and Technology, Ukraine*	On-Line Monitoring System of Processing Regime at an Industrial Electron Accelerator
6	**Renata Majgier** *Jan Dlugosz University in Czestochowa, Poland*	Radiation induced OSL of potassium sulfate
		Discussion

RADIOISOTOPES AND MEDICAL APPLICATIONS

	Presenting author	Title
1	**Kamil Wawrowicz** *Institute of Nuclear Chemistry and Technology, Poland*	Radiobioconjugates of gold nanoparticles with 193m/195mPt conjugated with Trastzumab to targeted Auger therapy
2	**Ulmas MIrsaidov** *Nuclear and Radiation Safety Agency, Tajikistan*	Nuclear technology applications in the Republic of Tajikistan
3	**Patrycja Sliż** *AGH University of Science and Technology, Poland*	Sub-cellular Elemental Imaging of Human Muscle Tissues Affected by Neuromuscular Diseases
4	**Małgorzata Żółtowska** *Radioisotope Centre POLATOM, National Centre for Nuclear Research, Poland*	Studies on new method for accelerator production of ^{99}Mo
5	**Marian Virgolici** *Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Romania*	Validation of the chemical protocol for the determination of lanthanides elemental impurities in uranium oxides
6	**Magdalena Dobrzyńska** *National Centre for Nuclear Research, Poland*	Software for DQE calculation in digital mammography

7	**Adam Cichoński** *National Centre for Nuclear Research, Poland*	Monte Carlo evaluation of ArcCHECK® detector accuracy to reproduce dose distribution from Ir-192 brachytherapy source
8	**Wojciech Grabowski** *National Centre for Nuclear Research, Poland*	Beam Dynamic calculations for modified accelerator systems in the Early Neutron Source project
		Discussion

Session: POSTER SESSION II

MATERIALS MODIFICATION

	Presenting author	*Title*
1	**Beata P. Rurarz** *Lodz University of Technology, Poland*	Radiation synthesis of poly(acrylic acid) nanogels for drug delivery applications - post-synthesis product stability
2	**Katsiaryna Dziarabina** *Lodz University of Technology, Poland*	Synthesis and EB-induced modification of poly(hydroxyethyl methacrylate)-based hydrogels
3	**Wojciech Głuszewski** *Institute of Nuclear Chemistry and Technology, Poland*	Radiation stability of high test peroxide (HTP)
4	**Magdalena Rzepna** *Institute of Nuclear Chemistry and Technology, Poland*	Impact of electron beam treatment on copolymers of polylactide and poly(trimethylene carbonate) in an air atmosphere
5	**Marta Walo** *Institute of Nuclear Chemistry and Technology, Poland*	EPR study of gamma irradiated membranes dedicated for gas separation applications
6	**Krystyna Cieśla** *Institute of Nuclear Chemistry and Technology, Poland*	The effect of nanocellulose addition and radiation treatment on the properties of starch-PVA films
7	**Katarina Marusic** *Ruđer Bošković Institute, Croatia*	Influence of the number of double bonds in fatty acids crosslinked on copper on its corrosion inhibition in atmospheric conditions
8	**Tanja Jurkin** *Ruđer Bošković Institute, Croatia*	Rheological, microstructural and thermal properties of magnetic poly(ethylene oxide)/iron oxide nanocomposite hydrogels synthesized using one-step gamma-irradiation method
9	**Ivan Marić** *Ruđer Bošković Institute, Croatia*	A controllable method for the synthesis of magnetic iron oxide and iron oxide/Au nanostructures using γ-irradiation
10	**Wojciech Głuszewski** *Institute of Nuclear Chemistry and Technology, Poland*	The use of GC and DRS to study postradiation phenomena of polypropylene oxidation
11	**Krystyna Cieśla** *Institute of Nuclear Chemistry and Technology, Poland*	Modification of the properties of the films formed in the starch:PVA:nanocellulose system by addition of thymol and ionising radiation

12	**Katarina Marusic** *Ruđer Bošković Institute, Croatia*	Radiation treatment of book covers made from leather
13	**Silvana Vasilca** *Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Romania*	Investigating Cultural Heritage modern materials after gamma irradiation
		Discussion

ENVIRONMENTAL APPLICATIONS

	Presenting author	*Title*
1	**Marko Fulop** *ABRS Ltd, Slovakia*	Combination of methods of thermal and radiation treatment of sediments associated with PCBs – the Delor type
2	**Andrea Sagatova** *Slovak University of Technology in Bratislava, Slovakia*	Improvement of radiation degradation of PCBs in sediments
3	**Tomasz Smoliński** *Institute of Nuclear Chemistry and Technology, Poland*	Ballast water treatment technology for floating "green dock"
4	**Dagmara Chmielewska-Śmietanko** *Institute of Nuclear Chemistry and Technology, Poland*	Inactivation of invasive marine species and harmful bacteria in the process of irradiation of ballast water with electron beam
		Discussion

RADIATION TECHNOLOGIES APPLICATION – FOOD IRRADIATION

	Presenting author	*Title*
1	**Slobodan Masic** *Vinca Institute of Nuclear Sciences, Serbia*	Effect of gamma irradiation on microbiological and nutritional properties of the freeze-dried berries
2	**Magdalena Miłkowska** *Institute of Nuclear Chemistry and Technology, Poland*	Detection of radiation treated vegetal extracts by thermoluminescence method
3	**Grażyna Liśkiewicz, Urszula Gryczka** *Institute of Nuclear Chemistry and Technology, Poland*	Applicability of thermoluminescence for detection of irradiated food treated with low energy electron beam
		Discussion

Session: Closing of the Conference

Session CEI: Accompanying event (CEI and IAEA RER 1021) Closing of the Conference (free and open for all, separate registration for the event required)

Special session under EU Central European Initiative project "Dissemination of the Knowledge on Application of Ionising Radiation for Sterilization of Medical Equipment, Personal Protection Equipment and the other Microbiologically Infected Objects" and under the IAEA technical cooperation project RER1021 "Enhancing the Use of Radiation Technologies in Industry and Environment".

Presenting author	*Title*
Zbigniew Zimek *Institute of Nuclear Chemistry and Technology, Poland*	Ionizing radiation sources used in the process of radiation sterilization
Sylwester Sommer *Institute of Nuclear Chemistry and Technology, Poland*	Microbiological aspects of the process of radiation sterilization with the emphasis of virus sterilization possibility
Krystyna Cieśla *Institute of Nuclear Chemistry and Technology, Poland*	Ionising radiation influence on the physico-chemical and functional properties of the materials
Andrzej Rafalski *Institute of Nuclear Chemistry and Technology, Poland*	Radiation sterilization of medical equipment, personal protection equipment, and the other microbiologically infected objects

PLENARY SESSION

RADIATION CROSSLINKING OF POLYMERS – FACING NEW PARADIGMS, CREATING NEW OPPORTUNITIES

Renata Czechowska-Biskup, Sławomir Kadłubowski, Alicja K. Olejnik, Bożena Rokita, Radosław A. Wach, Agnieszka Adamus-Włodarczyk, Justyna Komasa, Małgorzata Matusiak, Beata P. Rurarz, Piotr Sawicki, Sebastian Sowiński, Kamila Szafulera, Piotr Ulański

Institute of Applied Radiation Chemistry, Faculty of Chemistry, Lodz University of Technology, Poland

Abstract:
Radiation crosslinking of polymers is the oldest large-scale radiation technology, with a history of over 60 years. While crosslinking of commodity plastics, manufacturing of thermoshrinkable materials, curing of coatings, etc. are and will continue to be the mainstream applications due to their importance and usefulness, the radiation processing community is facing changing paradigms, and has to adapt to them. One of them is the social pressure for transforming to green chemistry and technology. While radiation technology in general is already well established in this field (treatment of flue gases [1] and wastewater), in radiation processing of polymers this trend necessitates switching to polymers from sustainable, natural resources and products that are biodegradable and/or easy to recycle. Methods are developed to process new, biocompatible polymers [2] and to circumvent the problems with radiation degradation of the most typical biodegradable polyesters used in medicine, as poly(lactic acid) [3]. Polysaccharides and peptides are among the main building bricks for new materials, and new ways for their radiation processing, including crosslinking, are being developed [4,5]. At least equally promising is the possibility to synthesize, using ionizing radiation, hybrid materials on the nanoscale, that could build upon synergy between natural and synthetic components [6].
Another new paradigm is switching from processing of large-volume commodity materials (consuming a lot of resources, energy and bringing relatively low revenue per unit of processed volume) to radiation synthesis and processing of materials of high added value, for instance for medicine. This trend is already present in radiation processing, the best examples are the mature technologies of hydrogel dressings [7] and hip joint implants [8]. But there are good prospects of going further along this way; a few examples will be discussed including radiation manufacturing of thermoresponsive materials for cell layer engineering and scaffolds for tissue engineering [9] as well as nanocarriers for controlled delivery of drugs, genes and radiopharmaceuticals [10]. Another promising option is synthesizing micro- or nanosized materials for medicine by patterning, either by UV or EB [11]. Developing these new technologies requires the underlying radiation chemistry and physics to be known in considerable detail. Some new experimental approaches to studying radiation effects on polymer systems will be briefly discussed [12].
Acknowledgements: This work has been supported in part by the National Science Centre, Poland (UMO-2017/25/B/ST4/01110 and UMO-2019/33/B/ST5/02125) and by the International Atomic Energy Agency (CRP F22070).

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ELECTRICITY MARKET AND POWER SYSTEM CONDITIONS FOR FINANCING THE CONSTRUCTION OF A NUCLEAR POWER PLANT IN POLAND.

Jerzy Majcher

(Consultant)

Abstract:
In this presentation, I explain the reasons for the long-term lack of new investments in large-scale power generation projects by conventional and nuclear power plants. I also explain the paradox of the liberal energy market and its consequences in the form of not covering the fixed costs of the reserve sources of electricity generation.
The presentation contains real examples of the functioning of the liberal energy market, showing the advantage of nuclear energy over other electricity generation technologies.
I also discuss the current situation in Poland in the power generation sub-sector in conventional power plants burning fossil fuels and their limited development prospects due to greenhouse gas emission standards.
Large and long-term investments requiring high financial outlays are usually perceived as risky. For this reason, in the presentation I show an example from the UK of principles of financing the construction of a nuclear power plant based on a contract for difference (CfD). Graphically on the plate of risk, I also explain the methods of reducing investment risk by mutual compensation of changes in energy prices against market prices.
Finally, I present arguments proving the advantage and attractiveness of nuclear power plants in the operation of the power system, unmatched in any so far available electricity generation technology.

THE NEXT FRONTIER FOR UNDERSTANDING HOW MICROORGANISMS RESPOND TO IONIZING TECHNOLOGIES

Suresh D. Pillai

Texas A&M University, Department of Food Science & Technology, National Center for Electron Beam Research, USA

Abstract:
Ionizing technology whether it is via cobalt-60 gamma rays or electron beam technology via commercial electricity has benefitted mankind in many ways. The food industry is one industry where this technology can find a variety of applications not only in pasteurizing foods but also for modifying and strengthening packaging materials. The pasteurization of food by ionizing technologies is one corner stone of the food industry because of this technology's versatility in inactivating microbial pathogens and spoilage organisms. It is well documented that when the appropriate doses are applied to microbial cells whether pathogens or spoilage organisms, the target organisms are inactivated and they are unable to repair and multiply. However, thanks to the spectacular development of analytical techniques and instruments our ability to investigate the molecular state of these ionizing technology-inactivated organisms has not been better. These techniques provide us the opportunity to study these inactivated microorganisms at molecular levels that were hitherto impossible. Studies in my laboratory are starting to reveal that though microbial cells are inactivated (and will not grow), they are still metabolically active. There appears to be defined metabolic pathways at least a few days post exposure to lethal ionization doses. Given that ionizing technologies are now being used for developing vaccines from such inactivated microbial states, it is imperative that we focus our efforts to understand, at a molecular level, the ionization-inactivated microbial cells.

ELECTRON BEAM SYNTHESIS OF NOVEL FABRICS FOR EXTRACTION OF URANIUM FROM SEAWATER

Mohamad Al-Sheikhly

Department of Materials Science and Engineering, University of Maryland, USA

Abstract:
The world's oceans contain more than 4.5 billion tons of uranium; however access to this resource is limited by the ability to extract uranium from seawater efficiently. Lacing fabric substrates with chemical functionalities specific for uranium adsorption is one approach to meeting this challenge. Advanced adsorbent materials are being developed using polymeric substrates with high chemical stability, excellent degradation resistance and improved mechanical properties. Fabrics include polypropylene, nylon and advanced Winged Fibers from Allasso industries featuring extremely high surface areas for improved grafting density. Using 10 MeV electron beam linear accelerator, the various fabrics have been irradiated over a wide range of dose rates, total doses and temperatures.
Innovative vinyl phosphate and oxalate exhibiting high distribution coefficients and selectivity for uranium along with excellent potential for free radical polymerization have been utilized in the functionalization of the fabric substrates. Azo compounds with higher selectivity have also been utilized but have required the use of a grafted chemical precursor. Attachment of the chelating adsorbent or its precursor to the substrate polymer is maximized through the optimization of numerous variables including monomer concentration, dose rate, total dose, solvent and temperature.
Following irradiation, fabrics are washed, dried and weighed to determine the degree of grafting (DoG). The presence of monomer in the fabrics is verified using numerous experimental techniques including X-ray photoelectron spectroscopy (XPS), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), and Fourier-transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR). Zeta potential measurements allow for surface charge measurements to confirm the negative charge required for uranium chelation. The fabric capacity for uranium extraction was tested by rotating samples for 7 days in a rotary agitator with actual seawater spiked with 0.2 or 1.0 mg·L-1 uranium. The fraction of uranium in the solution which was removed due to uptake on the fabrics was found to rise with increasing DoG at both uranium concentrations. SEM-EDS measurements are used to map the distribution of adsorbed uranium on the polymeric fibers.
Current work includes optimization of grafting density in addition to material characterization on the molecular level and analysis of the sample microstructure. Further testing in synthetic seawater will be conducted to compare the selectivity of each adsorbent fabric towards uranium compared to that of other species, in addition to determining the loading and adsorption rates under various conditions such as pH, temperature and salt concentration. Experiments in real seawater will consider effects of organics on the adsorbent materials, test for durability and reusability and determine kinetics and efficiency of the uranium extraction as a function of degradation.

RADIATION TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Bumsoo Han, Celina Horak, Valeriia Starovoitova, Joao A Osso Jr

Department of Nuclear Sciences and Applications,
International Atomic Energy Agency, Vienna, Austria

Abstract:
Since the discovery of X-rays and radioactivity more than 100 years ago, the ways to produce radiation and radioactive materials artificially were found. The first use of radiation was in medical diagnosis, within six months of the discovery of X-rays. The discovery of ionizing radiation and radioactive materials has led to dramatic advances in medical diagnosis and treatment, and they are used for a wide range of procedures in industry, agriculture, and research. Radioisotopes and other radiation technologies have been promoted for their merit in addressing important human needs such as improving food security through enhanced crop production, food safety and shelf life in a sustainable manner, better managing scarce fresh water resources, improving human health, improving industrial production and processes, preserving cultural heritages and protecting our environment.

The IAEA helps Member States strengthen their capacities in adopting radiation-based techniques that support cleaner and safer industrial processes and for the compositional analysis of materials and objects. It also supports them in applying radiation technology for advanced materials development, nanoscience and the processing of natural polymers into such products, as well as for the management of industrial and agricultural waste and effluents and the decontamination of biological agents.

The IAEA is organizing the Second International Conference on Applications of Radiation Science and Technology (ICARST-2021), following the success of the first ICARST in 2017 (ICARST-2017). The IAEA, working in close partnership with its Member States as well as with professional scientific bodies and the industry, has striven to maximize the contribution of radiation sciences and technologies towards the achievement of the Member States' development priorities in a safe manner.

Session I: NUCLEAR ENERGY

MODERN POWER GENERATION TECHNOLOGIES AND STRATEGY TO ACHIEVE OPTIMAL ENERGY MIX.

Ziemowit Iwański

Ziemowit Iwański Power Systems, Poland

Abstract:
Presentation will discuss forecast of changes in climate, natural resources, demography, power demand and energy policies and challenges driven by the changes in the future.
There will be presented modern power generation technologies, including these using fossil fuels, renewable energy resources and nuclear power.
Main focus will be given to technical limits and challenges in the future development of each of todays' power generation technology leaders.
In order to mitigate CO2 emission growth on the way to achieve sustainable energy mix - specifically hydrogen fuel option and other low emission power generation techniques will be discussed.
Definition of an optimal energy mix – will be set with use of local and global influencing factors, there will be considered as well long term economic aspects of availability of energy resources and social context of technical and economic solutions to illustrate positives and constraintes of an opitimum solution.
There will be included as well discussion on available low scale technologies and future emerging technologies able to be employed on local community level to build local energy independence on micro economic basis. Main economic drivers and factors supporting such local energy independence approach will be discussed.

HIGH TEMPERATURE GAS COOLED REACTORS – GOOD CHOICE FOR POLAND TO ENTER NUCLEAR ENERGY DEPLOYMENT

Wacław Gudowski

National Center for Nuclear Research, Poland

Abstract:
The recently announced "Program of Nuclear Energy in Poland" (PPEJ) reveals the governmental plans to base this program on deployment of large PWR units. While the envisioned pace of nuclear energy development in Poland is pretty ambitious the technical choice of PWR units is a very conservative one and do not correspond well to needs of the polish energy market and ignores rather rapid development of nuclear technology in recent years. An ambitious and well tailored for polish needs nuclear energy program must not ignore rapid development of small and medium reactors (SMR) and by no means must exploit possibilities of Combine Heat and Power (CHP) generation. No reactor should be built in XXI century without CHP. Looking at these constraints High Temperature Gas Cooled Reactors are a very good choice for Poland offering not only electrical power generation but also industrial heat of right thermodynamical parameters, district heat and or rather before all - a rapid entry to hydrogen system economy. HTGRs can be built today at power range starting at few MW_{el} and ending at few hundreds of MW_{el}, using highly modular design and having exceptional safety features, which enable co-location of nuclear and other industrial facilities.

SEVERE ACCIDENT ANALYSES FOR DEMONSTRATION OF THE SAMG DECISION-MAKING TOOL

Piotr Darnowski[a], Piotr Mazgaj[a], Ivica Bašić[b], Ivan Vrbanic[b], Janusz Malesa[c], Maciej Skrzypek[c], Ari Silde[d], Jarno Hiittenkivi[d], Luka Štrubelj[e]

[a]Institute of Heat Engineering/Warsaw University of Technology
[b]APOSS d.o.o
[c]National Centre for Nuclear Research
[d]VTT – Technical Research Centre of Finland
[e]Gen-Energija

Abstract:
The paper presents severe accident analyses used to generate a database of Nuclear Power Plant (NPP) states to be applied with Severe Accident Management Guidelines (SAMG) Decision Making (DM) Tool. The novel software is being developed in the framework of the NARSIS Horizon-2020 research project. The tool will be useful in support of SAMGs implementation and selection of proper Severe Accident Management (SAM) strategies. Analyses presented in this paper were performed with MELCOR 2.2 integral computer code for generic NPP with Gen-II Pressurized Water Reactor (PWR). The database covers results for phenomena and parameters important for both in-vessel and ex-vessel phases of different accident scenarios. Two general types of scenarios were considered, low-pressure sequences and high-pressure sequences. In the case of low-pressure, several variants of a Large Break Loss of Coolant Accident (LB-LOCA) were studied, including cold-leg and hot-leg breaks with and without recovery. In the case of high-pressure scenarios, mainly Station Blackout (SBO) type events were considered and different variations which cover additional seal LOCA, steam generator tube rupture, surge line rupture, different safety valves positions and recovery setup. In this paper, selected plant parameters for different scenarios were compared and assessed quantitatively and qualitatively. The landscape of scenarios in the database creates space of plant states being large enough for DM tool demonstration. Finally, the database applicability was evaluated, its limitations and areas of application were estimated.

OPTIMIZATION OF THE LOADING PATTERN OF THE PWR REACTOR CORE USING GENETIC ALGORITHMS AND MULTI-PURPOSE FITNESS FUNCTION

Wojciech Kubiński, Kamil Chęć, Piotr Darnowski

Warsaw University of Technology

Abstract:
The study presents a demonstrative application of genetic algorithms in the optimization of the initial configuration of PWR nuclear reactor core, on the example of the MIT BEAVRS model. Optimizing the initial core configuration is an important problem from the point of view of the economics of the nuclear reactor operation. However, this is a complicated multidimensional issue, due to several hundred assemblies that build up the core. The assemblies vary in different geometry, enrichment, burn up, different amounts of burnable absorbers and other properties. Due to the number of combinations, it is not possible to check subsequent configurations and choose the best one, therefore it is necessary to use specialized algorithms.

One of such may be genetic algorithms (GAs), used in this study. GAs are optimization methods based on genetics and the theory of evolution. These methods are based on generations of coded specimens corresponding to the optimized system. GAs have been successfully used in many nuclear engineering problems such as core geometry optimization and fuel configuration. In many cases, however, these analyses focused on optimizing only a single parameter, such as the effective neutron multiplication factor (k-eff), neutron flux, burn up, often limited to the simplified core model or limiting the number of used types of assemblies.

However, the computing power resources available today can take it a step further. As part of the analyses presented, optimization of the full 3D core was performed using the PARCS code coupled with the genetic algorithm. Using the multi-purpose fitness function, the initial arrangement of the core was optimized, maximizing the cycle length by applying additional assumptions such as the k-eff range, power peaking factor, the amount of fissile material, burnable absorber and number used assemblies of a given type. In addition, an innovative method of controlling the variance of the population was used, which increased the efficiency of GAs compared to standard methods.

In the best of the analysed scenarios, it was possible to extend the core cycle by 152 days (or 46%), while maintaining the previously mentioned core constraints. Thus, it has been shown that GAs are tools that can be successfully used in solving this type of problems.

Session II: NUCLEAR ENERGY

THERMAL LIMITS OF PROMISING CANDIDATE MATERIALS FOR ACCIDENT TOLERANT FUEL CLADDINGS

Mirco Grosse

Karlsruhe Institute of Technology, Germany

Abstract:
Since the Fukushima disaster, efforts are made worldwide to improve the accident performance of nuclear fuel. The development of the so called accident tolerant fuel (ATF) comprises both, new fuels and new cladding materials.
Main goal of the fuel development are the increase of thermal conductivity to reduce the thermal capacity of the fuel after termination of the nuclear chain reaction. Examples are developments of UN and U_3Si_2 fuel.
The goal of the cladding developments are materials releasing less heat and hydrogen if they react with hot steam in the case of an accident. They can be divided into three groups:
- Coated zirconium alloys for instance chromium coatings
- New metallic materials for instance FeCrAl
- SiC
Even the investigations were initiated to found materials with better severe accident performance than the classical zirconium alloys used, most studies were performed under operational or design basis accident conditions. The research at KIT is focused on the high and very high temperature behavior of promising cladding materials. Experiments on laboratory scale as well at fuel rod simulator bundle scale were and will be performed.
In the presentation, an overview about the work done at KIT on this field will be given. The thermal limits of promising candidate materials for ATF claddings chromium coated Zircaloy, FeCrAl and SiC will be discussed.

PROTECTIVE MULTIELEMENTAL COATINGS ON ZIRCALLOY-2: INCT STUDIES

Bożena Sartowska[a], Wojciech Starosta[a], Lech Waliś[a], Jerzy Smolik[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Institute for Sustainable Technologies, Poland

Abstract:
Zirconium and its alloys is commonly used as cladding material for fuel elements in nuclear reactors. This is connected with their good water corrosion and radiation resistance at normal working conditions. In the case of LOCA conditions, the possible very fast oxidation of zirconium at steam or/and air atmosphere may result in intense hydrogen generation and hydrogen-oxide mixture explosion.
The development of the solution to minimize mentioned risk is needed/ in interest. One of actual concept is to improve oxidation resistance of Zr alloy cladding with produce/form protective coatings as for example: Cr, MAX phases, multielemental (Zr, Cr, Si), FeCrAl.

Coatings with elemental composition with Cr, Si and Zr were formed using PVD method on Zircalloy-2 (Zry-2). Long-term corrosion - oxidation test were carried out in standard conditions for PWR reactors with parameters: 360oC/195 bar/21 days period/water simulating water used in PWR.
Initial, modified and oxidized materials were characterized with SEM (morphology observations), EDS (elemental composition determination), and XRD (phase composition). Obtained results showed that $Zr_{40}Si_{24}Cr_{36}$ coatings protected the base material (here: Zry-2) from oxygen migration what confirmed protective role of the coatings in defined limited range.

SORPTION OF SELECTED RADIONUCLIDES FROM LIQUID RADIOACTIVE WASTES BY SORBENTS OF THE BIOLOGICAL ORIGIN.

Leon Fuks[a], Irena Herdzik-Koniecko[a], Agata Oszczak-Nowińska[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Institute of Chemistry, Military University of Technology, Poland

Abstract:

Introduction

Radioactive waste-waters that contain radioactive metal ions, e.g. Cs(I), Sr(II), Co(II), and/or Am(III) are dangerous for people and for the environment. There are several methods to remove them from the wastewaters. Sometimes, several of these methods are combined to form a so-called hybrid method, e.g. complexation with ultrafiltration. An alternative method of eliminating the radioactive metals from waste-water is sorption by low-cost natural materials of the biological origin.

Among major advantages of sorption over conventional treatment are: low cost, easy regeneration of biosorbent, and the possibility of metal recovery [1, 2].

Experimental

In presented studies, batch sorption of Cs(I), Sr(II), Co(II) and Am(III) on different natural materials of the biological origin (calcium alginate, powdered vegetables) was studied as a function of contact time, initial pH of aqueous solution and mass of the sorbent and concentration of the radionuclide, respectively.

All potential sorbents have been characterized by different physicochemical methods.

An attempt to revitalize the Cs(I)-, Sr(II)-, Co(II)- and Am(III)-loaded sorbents was done by shaking the material at room temperature with different types of desorbing agents.

Results

Decontamination Factor - the ratio of specific activity before and after decontamination has been calculated and analyzed. Values of the Factor show that, in most cases, the radionuclides may be effectively removed from aqueous solutions.

Thermogravimetric analyzes of the materials show that sorbents studied in our laboratory decompose at the relatively low temperatures. This means that the energy necessary to reduce the mass of the solid wastes obtained in the course of decontamination of liquid aqueous radioactive wastes may be relatively low, which decreases the cost of the process.

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APPLICATION OF GENETIC ALGORITHMS IN OPTIMIZATION OF THE SFR REACTOR DESIGN

Wojciech Żurkowski, Piotr Sawicki

Warsaw University of Technology, Poland

Abstract:
Fast spectrum nuclear reactors have been developed for many years. Space of solutions for research, analysis and modifications is broad; thus, they seem to be the ideal material to check whether, in the design process, it is possible to use analytical tools such as genetic algorithms. The purpose of this work was to create a software implementing a genetic algorithm which would optimize two selected aspects of the liquid sodium-cooled fast reactor core. Tested core was a 3600MWth carbide core which design comes from a publication issued by the OECD/NEA in February 2016. The models were created and then simulated in SERPENT Monte Carlo neutron transport code. The first problem was the optimization of the fuel composition in terms of minimizing the volume share of long-lived actinides in the fuel composition while maximizing the effective neutron multiplication factor. The second task was the optimization of the boron shield location around the reactor core to minimize the sodium void reactivity effect. Received optimized fuel assembly cassette stands out by lower share of actinides in the fuel composition and a high effective neutron multiplication factor and the core model filled with boron shields is characterized by the lower value of the void coefficient of reactivity, thus reducing the significance of the potentially dangerous sodium void reactivity effect. Therefore, the realized simulations showed the efficiency and universality of genetic algorithms even in multidimensional optimization problems, and thus the possibility of their application in reactor physics issues.

THERMAL PROPERTIES AND OXIDATION PROCESSES OF NUCLEAR FUSION REACTOR METALLIC MATERIALS IN ACCIDENTAL OPERATIONAL CONDITIONS

Elina Pajuste[a], Liga Avotina[a], Arturs Zarins[b,c], Rudolfs Janis Zabolockis[b]

[a]University of Latvia, Institute of Chemical Physics, Faculty of Chemistry,
[b]University of Latvia, Institute of Chemical Physics,
[c]Daugavpils University, Faculty of Natural Sciences and Mathematics

Abstract:
Both beryllium (Be) and tungsten (W) are key components of fusion reactor vacuum vessel first wall. The choice of Be is based on its low-Z and good thermal conductivity, whereas W - due to its high thermal stress resistance, thermal conductivity, low erosion by light projectiles and low retention hydrogen isotopes.
In this study, thermal processes and oxidation processes of Be and W have been studied regarding the accidental operation conditions such as loss of vacuum and loss of coolant accidents, LOVA and LOCA, respectively.
In case of LOVA, materials can be exposed to hot air, whereas in LOCA - water vapour. If exposed to oxygen and/or water at high temperature a highly toxic beryllium oxide (BeO) is formed from Be, whereas W oxidation would lead to formation of mobile tritiated flakes. Both type of particles must be considered as important safety issues.
Oxidation rate and thermal properties have been measured for both, Be and W, during thermal treatment in a temperature range from ambient temperature to 1600 K both in dry air and moistured air. Size and structure of the formed particles has been studied by the means of scanning electron microscopy. For Be also the neutron irradiation effects has been assessed by performing the same experiments for irradiated samples.
The results show, that oxidation in presence of water vapour, when relative humidity is >90%, gives significantly higher amounts of oxide. This indicates different oxidation mechanisms of first wall metallic materials at elevated humidity. This should be taken into account for further analysis of Be and W as well as predicting of LOVA and LOCA risks in fusion reactors.

RAMAN SPECTROSCOPY AS A TOOL OF TRISO PARTICLE FUEL DEFECTS EXAMINATION.

Zuzanna Krajewska

National Centre for Nuclear Research, Poland

Abstract:
Development of High Temperature Gas-cooled Reactors could open new horizons for nuclear power in Poland. Good understanding of the failure-free performance of the Tri-structural ISOtropic (TRISO)-particle fuel, is a key aspect of safe and efficient operation of such a reactor. That is why it is so important to find the most optimal properties of TRISO fuel particles, which would have the lowest degree of damage at the production stage and during the irradiation process in the reactor. This presentation focuses on the description of an experiment whose starting point is a comparative analysis of different types of TRISO produced in different periods. The analysis of the occurrence of damage in the examined material is performed using the Raman spectroscopy method.
It is assumed that the illustrated differences in damage, including understanding of the aging process and its impact on damage, will allow to choose the optimal TRISO fuel for HTGR program in Poland.

Session III: HTR

TRISO PARTICLE NUCLEAR FUEL AT THE HEART OF THE HIGH TEMPERATURE REACTOR

Heinz Nabielek

Consultant, retired from the Forschungszentrum Juelich, Germany

Abstract:
The Gas-Cooled High-Temperature Reactor – HTR or HTGR – was conceived with an all ceramic core and an inert helium single-phase coolant. Two HTR concepts exist: the pebble-bed employs a cylindrical core of spherical fuel elements surrounded by graphite reflectors; and the prismatic HTGR employs hexagonal graphite-blocks stacked into an annulus with internal and external graphite reflectors. The blocks contain axial coolant holes surrounded by fuel holes, filled with compacts.
The fundamental unit of the HTR fuel element is the ceramic TRISO coated particle of ~1 mm diameter. The fuel kernel is surrounded by four successive ceramic coating layers consisting of a porous buffer and tri-structural isotropic (TRISO) dense coating layers that provide near complete retention of internal gas pressure and fission products. HTR cores contain ~10^9 such coated particles.
Two distinct events in HTR history championed development of the modern coated fuel particle: (i) world-wide proliferation concerns 1977-80 led to adopting low-enriched fuel for use in all nuclear facilities; and (ii) in early 1980's, development of small, modular HTRs whereby a tall and slim core guarantees self-acting heat removal under all accident conditions. The first event led to new and more efficient fuel particle designs. Implementing the second event through small MODUL reactors limits fuel temperatures below 1600°C under depressurised loss-of-forced coolant accidents. This requirement necessitated developing a fuel system that remains intact and retains all safety-relevant fission products throughout such accident sequences.
This led to improved TRISO-coated particle and fuel element manufacturing and quality control methods. Their application has resulted in present-day near-zero manufacturing defects, near-zero irradiation-induced failures and near-zero accident-induced particle failures.
In-reactor and accident testing ended in Germany in 1995, and at the European level in 2005. The German HTR fuel materials development effort resulted in establishing an extensive UO_2 fuel element data base.
South Africa successfully repeated the German development from 1999 to 2009. And, in China, 700,000+ modern LEU UO_2 TRISO spherical fuel elements have been manufactured, and will be loaded into the two 250 MW_{th} HTR-PM reactors at the end of 2020.
Recent successful U.S. development with UCO TRISO particles in cylindrical compacts began in 2000+ with UCO fuel production and irradiation testing, followed by post-irradiation examinations and accident simulation tests, some still on-going. Results to-date are outstanding and have been achieved with efficient modern instrumentation and advanced analysis methods.

POLISH GOSPOSTRATEG HTR PROJECT – WHAT HAS BEEN DONE AND WHAT TO DO NEXT?

Agnieszka Boettcher, Mariusz Dąbrowski

National Centre for Nuclear Research, Poland

Abstract:
GOSPOSTRATEG-HTR: Preparation of legal, organizational and technical instruments for the HTR implementation is a national project implemented under the strategic Polish program of scientific research and development. The goal of this project is the preparation of Poland for the HTR technology implementation on every level. In this presentation, the summary of the research phase of the project which terminated in July 2020 as well as the short insight into the implementation phase are going to be presented. Main up-to-date achievements of the project such as the identification of materials for testing, the identification of standards for testing materials, Irradiation System for High TemperAture Reactor (ISHTAR) design, the survey of the Polish industry capabilities, screening the legal gaps to impose HTR, and the review of the awareness of HTR among public will be discussed. Finally, the future challenges such as the research HTR reactor design and its licensing plan, more laboratory tests, Polish industry involvement, the legal framework implementation, and the stakeholders consensus will also be highlighted.

A BRIEF OVERVIEW OF ACHIEVEMENTS OF THE EUROPEAN PROJECT GEMINI+

Janusz Malesa

National Centre for Nuclear Research, Poland

Abstract:
GEMINI + is a project carried out by members of the European Nuclear Cogeneration Industrial Initiative (NC2I) and financed by the European Horizon 2020 / Euratom programme. Since 2014 the NGNP Industry Alliance (USA) and the NC2I have been joining forces to promote and work on the industrial development of HTGR cogeneration by creating the GEMINI Initiative. To support the Initiative in the area of research and development the GEMINI+ project was prepared. The project launched in September 2017. Its main goal was to provide a conceptual design of a high temperature nuclear cogeneration system with ability to supply process steam to industry. Equally important objectives are providing a licensing framework for this system and a business plan for a full scale demonstration. The project's results are expected to be applied in the deployment of the first novel European HTGR cogeneration plant in Poland. The project is organized into 6 work packages: Safety approach and licensing framework, Configuration for an industrial high temperature nuclear cogeneration system, Innovative and long-term perspectives, Demonstration project of industrial high temperature nuclear cogeneration, Communication and dissemination, Coordination and quality management.
Selected achievements of the project will be presented. First of all the conceptual design of the HTGR and configuration for industrial applications is proposed. The licensing requirements for the reactor and for coupling with industrial plant were examined to ensure that the proposed design meet all the criteria. Further, residual technology gaps were identified to point out necessary R&D actions. Selected applications of GEMINI+ system were analyzed including economical competitiveness.
The presentation will conclude with suggestions of further steps that can help in deployment of HTGR in Poland.

GOSPOSTRATEG: RESEARCH AND ANALYSIS OF SELECTED CHEMICAL ASPECT OF THE PRODUCTION AND USE OF TRISO FUEL IN THE HTR NUCLEAR REACTOR

Marcin Brykała, Danuta Wawszczak, Tadeusz Olczak, Renata Laskowska

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
The works of the Sol-Gel Laboratory at the Institute of Nuclear Chemistry and Technology (ICHTJ) have focused on synthesis of ceramic microspheres by the sol-gel method since decades. The widely used ceramics oxides materials are obtained in spherical shapes with various diameters. To the all synthesis - the Complex Sol-Gel Process (CSGP), which is modifications of the classic sol-gel method, is applied. This method with combination with method of gelation to spherical kernels - Internal Gelation allows obtaining final product in the shape of microspheres with diameter above 400 μm. The experience on the sol-gel synthesis and characterization of uranium dioxide kernels, which are potential precursors of nuclear fuels for High Temperature Reactor (HTR), will be presented.

Acknowledgement
This work is one portion of the studies in the strategic Polish program of scientific research and development work "Social and economic development of Poland in the conditions of globalizing markets GOSPOSTRATEG" part of "Preparation of legal, organizational and technical instruments for the HTR implementation" financed by the National Centre for Research and Development (NCBiR) in Poland.

SILVER MIGRATION IN TRISO COATED PARTICLES – COMPUTATIONAL STUDIES

Wojciech Starosta[a], Vera K. Semina[b], Lech Waliś[a], Tomasz Płociński[c]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Flerov Laboratory of Nuclear Reactions, JINR, Russia
[c]Warsaw University of Technology, Faculty of Materials Science and Engineering, Poland

Abstract:
TRISO fuel has been developed for high temperature reactors to provide retention for uranium fission products at any reactor conditions. Studies on the fuel behavior in the reactor carried out at the stage of development of this technology confirmed the possibility of fission products retention inside spherical capsule made of silicon carbide sandwiched between two isotropic pyrolytic graphite layers. It was also found that the silver retention is variable and depends on the operating temperature and the quality of the silicon carbide layer [1]. Despite of about forty years of studies the mechanisms of silver (and palladium) migration had not yet been determined. However, some hypothesis have been formulated on the basis of critical literature review and the results of the experimental studies performed so far [2]. They underline the importance of knowledge of the microstructure of silicon carbide layer – grains dimensions, grains morphologies and their mutual angular orientation as grain boundaries diffusion may be mostly responsible for the radionuclides migration. The detailed knowledge of the mechanisms of fission products migration, like silver and palladium through TRISO fuel coatings is of great importance for ensuring nuclear safety in the case of an accident, for the license conditions fulfillment and for the further development of this technology, especially for planned VHTR reactors.
For the identification of the mechanisms that makes the greatest contributions to fission products migration computer simulations can be helpful. The aim of this contributions is to review the available results of selected radionuclides migration (Ag, Pd) through the silicon carbide layer of TRISO fuel obtained so far by applying computational modelling. The results of the own computer simulation obtained by ab-initio and molecular dynamic modelling methods will be presented for the selected grain boundaries geometries of silicon carbide.

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This work is one portion of the studies in the strategic Polish program of scientific research and development work “Social and economic development of Poland in the conditions of globalizing markets GOSPOSTRATEG” part of “Preparation of legal, organizational and technical instruments for the HTR implementation” financed by the National Centre for Research and Development (NCBiR) in Poland.

NUMERICAL MODELLING OF MODULAR HIGH-TEMPERATURE GAS-COOLED REACTOR WITH THORIUM FUEL

Mikolaj Oettingen, Jerzy Cetnar

AGH University of Science and Technology, Poland

Abstract:
In the study the parametric analysis of the Modular High-Temperature Gas-Cooled Reactor core with thorium-uranium fuel is shown. The numerical model of the reactor was developed using the Monte Carlo Continuous Energy Burnup Code (MCB) developed at the AGH University, Krakow, Poland. The numerical simulations were performed using supercomputer Prometheus available at the Academic Computer Centre CYFRONET AGH. The simplified method for the fast modelling of the double-heterogeneity of the MHTR core, i.e. volumetric homogenisation of the TRISO fuel in the fuel compact was applied. The method significantly facilitates the complexity of the three dimensional numerical model and decreases the calculation time. Therefore, it is useful for the parametric analysis towards development of the final configuration of the reactor core. The results of the study comprise the time evolutions of reactivity and concentrations of chosen isotopes for a few configurations of the initial reactor core. The particular attention was given to the production of fissionable ^{233}U from fertile ^{232}Th and ^{239}Pu from ^{238}U to estimate breeding capabilities. The parametric study includes variation of the geometrical and material parameters of the TRISO fuel in the initial core, i.e. kernel radius and fuel isotopic composition. The study presents the first step in the design process of the final core configuration of the MHTR, which focuses on the specification of the general characteristics of the graphite core with thorium-uranium fuel.

DEVELOPMENT OF ANALYTICAL PROCEDURES FOR CHEMICAL CHARACTERIZATION OF SUBSTRATES FOR THE PRODUCTION OF TRISO COATED PARTICLES AS NUCLEAR FUEL IN HIGH TEMPERATURE GAS-COOLED REACTORS

Ewelina Chajduk, Paweł Kalbarczyk, Anna Bojanowska-Czajka, Marta Pyszynska, Zbigniew Samczyński

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
High temperature gas-cooled reactors have recently gained importance as a source of electricity. Nuclear fuel used in these reactors consists of TRISO coated particles, where spherical grains of uranium kernel are covered with four successive layers consisted of pyrolytic carbon and silicon carbide. Of great importance is chemical purity of reagents and substances used for the production of TRISO coated fuel particles. Analytical techniques ensuring the determination of elements at trace levels are inductively coupled plasma mass spectrometry (ICP-MS) and neutron activation analysis (NAA). They were applied in this work for chemical characterization of substrates used for TRISO fuel production. Two analytical procedures were developed. Separate, where materials are analyzed by ICP-MS and separate using NAA. Successive stages of these procedures are described with details. Results of quantitative chemical analysis of examined substances are reported as well as detection limits for the investigated elements. Moreover, the expanded uncertainties estimated for the determined elements while employing the devised analytical procedures are presented.

This work is one portion of the studies in the strategic Polish program of scientific research and development work "Social and economic development of Poland in the conditions of globalizing markets GOSPOSTRATEG" part of "Preparation of legal, organizational and technical instruments for the HTR implementation" financed by the National Centre for Research and Development (NCBiR) in Poland.

SPENT FUEL AND RADIOACTIVE WASTE MANAGEMENT IN THE HTGR FUEL CYCLE

Katarzyna Kiegiel, Irena Herdzik-Koniecko, Leon Fuks, Grażyna Zakrzewska-Kołtuniewicz

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Nuclear reactors are increasingly used not only for the production of electricity, but also for the production of heat and have the potential for further development in this respect.
Gas-cooled high temperature reactors (HTGRs) are one of the Gen IV reactors in the future market, with efficient power generation and high temperature process heat supply used in many industrial processes. Recently, it was confirmed that no fuel damage would occur even in the event of a beyond design basis accident such as multiple losses of reactor shutdown functions. Spherical fuel elements (60mm outer diameter; 50mm inner diameter) contain about 8300 triple-coated UO_2 particles of 0.92mm in diameter surrounded by graphite coating [1].
Poland is the country that is considering the HTGR technology starting the operation by 2033 for supporting Polish industry [2]. The launch of a new reactor must be preceded by thorough analysis and resolution of a number of problems related to the safety of its operation. Therefore, it will be required to find the radioactive waste and spent fuel management methods to obtain all necessary permissions for the expected HTGR to operate.
Activity of the staff of the Institute of Nuclear Chemistry and Technology is focused on physical and chemical characterization of the radionuclides present in the radioactive wastes and on development the procedures suitable in the HTR waste management. Improving currently used extractive methods of spent nuclear fuel and fission materials recycling strategies, it is possible to implement them in the 4th generation of reactors.
The main results of the studies, both the literature analysis and the experiments carried out at the INCT, will be presented.

Acknowledgment:
This work is one portion of the studies in the strategic Polish program of scientific research and development work "Social and economic development of Poland in the conditions of globalizing markets GOSPOSTRATEG" part of "Preparation of legal, organizational and technical instruments for the HTR implementation" financed by the National Centre for Research and Development (NCBiR) in Poland.

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PRELIMINARY COMPUTATIONAL AND EXPERIMENTAL DESIGN STUDIES OF THE ISHTAR THERMOSTATIC RIG FOR THE HIGH-TEMPERATURE REACTORS MATERIALS IRRADIATION.

Anna Talarowska, Maciej Lipka, Grzegorz Wojtania

National Centre for Nuclear Research, Poland

Abstract:
The ISHTAR (Irradiation System for High-Temperature Reactors) thermostatic rig will be used to irradiate advanced core materials samples in conditions corresponding to those prevailing in the high-temperature reactors: stable temperature up to 1000°C in the helium atmosphere. Computational and experimental studies concerning the design have been conducted, proving the possibility of these conditions' fulfillment inside the capsule while maintaining the safety limits for MARIA Research Reactor. The outcome is the thermostatic rig design that will be implemented in the MARIA reactor. Appropriate irradiation temperature will be achieved by a combination of electric heating with the control system, gamma heating, and a helium insulation gap with precisely designed thickness. The irradiation will be placed inside the vertical irradiation channel, located in the reactor pool. The device is being developed from scratch at the Nuclear Facilities Operation Department of the National Centre for Nuclear Research as a part of GOSPOSTRATEG program.

Poster session

DEMONSTRATION OF THE MULTIPLE-PATH EVENT TREE PSA BASED APPROACH DEDICATED FOR E-BEPU FOR PWR REACTOR

Aleksej Kaszko[a], Piotr Darnowski[b], Piotr Mazgaj[b], Javier Hortal[c], Miloard Dusic[c], Rafael Mendizabal[c], Fernando Pelayo[c]

[a]National Centre for Nuclear Research, Poland
[b]University of Technology, [c]Nuccon

Abstract:
The paper presents the novel Multiple-Path Event Tree (MPET) approach, based on the Probabilistic Safety Analysis (PSA) methodology, which is being developed in the framework of the Horizon 2020 NARSIS research project. The new approach is applied in the Extended Best Estimate Plus Uncertainty (E-BEPU), which is an innovative risk-informed combined deterministic and probabilistic methodology dedicated to Nuclear Power Plant design verification. In the new approach, event trees are not designed to studying success/failure as in typical PSA, but they are allowed to have more than two branches. The modified probabilistic methods are applied in EBEPU, which has a basically different purpose than the PSA. However, the typical Fault Trees are applied in parallel with PSA models created in Risk Spectrum and Sapphire codes. In the paper, the conversion procedure between PSA dedicated event tree and EBEPU event trees is presented. The proposed methodology is defined and demonstrated for the representative Generation III Pressurized Water Reactor (defined in NARSIS project) in case of Large Break Loss of Coolant Accident (LB-LOCA). Obtained results will be used in the further development of the Extended-BEPU methodology.

STUDIES ON SORPTION PROPERTIES OF UIO-66 TYPE METAL ORGANIC FRAMEWORK SORBENTS FOR SELECTED RADIOSOTOPES REMOVAL FROM WATER SOLUTION.

Wojciech Starosta[a], Jianwei Ren[b], Xoliswa Dyosiba[b], Rafał Walczak[a], Paweł Kalbarczyk[a]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Council for Scientific and Industrial Research, Pretoria, South Africa

Abstract:
Metal-organic frameworks (MOFs) emerged in the last years as a new generation of porous materials. MOFs are made by interconnecting metal or oxo-metal clusters by coordination bonds using organic, polytopic, mainly carboxylate ligands. Their unique properties are: possibility of tailoring the structure parameters as pore size, pore structure in wide range and grafting of the functional chemical groups on the pore walls using linkers possessing functional backbone group. It is believed that by careful selection of metal and linker MOF type sorbent selective for the ion under considerations can be obtained. The low interest to this topic at the earlier period can be explained by low stability of the first MOFs in water. They were synthesized mainly using low valence metals for which metal-carboxylate bonds is prone to hydrolysis in water environment.
But for the MOFs built with higher valence metals like aluminum, chromium, iron (MIL series) and four valence metals like zirconium (UiO-66 series) strength of metal-carboxylate bonds is higher and hydrolysis effects should be limited. Therefore, using these materials, studies on hazardous metals ions removal (heavy metals, radioisotopes) from water solution became possible.
Recently, we have synthesized the range of zirconium terephthalate UiO-66 type sorbents using so called modulating synthesis method. In the ideal case UiO-66 structure has chemical formula $Zr_6O_4(OH)_4(BDC)_6$, where BDC- 1,4-benzenedicarboxylate. By monocarboxylate ligand addition to the reaction mixture terephthalate bifunctional linker can be substituted partially by this monofunctional ligand. As the result porosity increases due to the structural defects introduced and rather inert UiO-66 structure can be functionalized with monofunctional linker's backbone groups. We have applied as modulators 2-aminobenozic acid, 3-aminobenzoic acid, 4-aminobenzoic acid, 3,5-diaminobenzoic acid. At the same time the UiO-66_NH_2 structure has been synthesized using 2-aminoterephtalic ligand.
The preliminary results of the sorption kinetics and sorption capacities for the case of pertechnetate anion and uranyl ion sorption from water using modified UiO-66 type sorbents will be presented. The results obtained may be beneficial to the further development of nuclear technologies, particularly in the field of the immobilization of pertechnetate anion and uranyl ion recovery from water solutions.

Acknowledgments
The financial support from The National Centre for Research and Development PL-RPA/02/ PET-MOF-CLEANWATER project" The studies on waste PET-derived metal-organic framework (MOFs) as cost-effective adsorbents for removal of hazardous elements from polluted water" is gratefully acknowledged

THE STUDIES ON URANIUM RECOVERY FROM U-BEARING RADONIÓW DUMP

Katarzyna Kiegiel[a], Otton Rubinek[b] Dorota Gajda[a], Paweł Kalbarczyk[a], Grażyna Zakrzewska-Kołtuniewicz[a], Andrzej Chmielewski[a]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Faculty of Chemistry, Warsaw Technology of University, Laboratory of Technological Processes-Park Technology, Poland

Abstract:
The constant interest in development of nuclear power is leading to the inevitable growing demand for uranium. New sources of primary uranium will originate from exploration and exploitation of low-grade ore bodies, and also secondary resources as potential raw materials [1]. In addition to well-developed methods that are applied already in the technology of recovery of uranium, the bioleaching of uranium from raw materials and industrial waste containing less than 0.1% w/w of uranium could also be used. The bioleaching is the extraction of metals from their ores or other sources using living organism such as bacteria, fungi and archaea [2].
The aim of the present studies was to investigate of possibility of uranium recovery from the post-mining uranium dump by bioleaching method.
The studies were proceeded in the dump leaching model with the mass of 570 kg of uranium bearing mineral material from Radoniów pile and in the periodic bioreactor with mixing and aeration of the charge. The uranium concentration in examined material was about 800 ppm. In this process the consortium of microorganisms isolated from former mines was used. It was composed of following microorganism: Bacillius, Pseudomonas, Sphingomonas, Thiobacillus, Halothiobacillus, Thiomonas, Geothrix The efficiency of the uranium bioleaching process was high. Uranium was leached with 98% yield in the reactor and with 70% yield in the dump leaching model. The post leaching solution contained significant amounts of iron ions that were separated in two stages: in the ion chromatography column and then by precipitation. The resulting solution was a source of ammonium diuranate, the precursor of uranium oxide.

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Acknowledgment:
The authors acknowledge the financial support of this work from NCBiR Strategic Research Grant "Technologies supporting the development of safe nuclear energy (research task No 3: Basics for securing the fuel needs of the Polish nuclear energy, stage 11: Research on bioleaching on a quarter technical scale)

ENCAPSULATION OF GRAPHITE-URANIUM COMPACTS AS SURROGATE OF SPENT HIGH TEMPERATURE REACTOR FUEL

Marcin Rogowski, Tomasz Smoliński

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
In general, three paths can be distinguished in the management of spent HTGR fuel - direct disposal of fuel elements; separation of fuel compacts from block or with the further separation of TRISO particles from the compacts; and separation of graphite, coatings, and fuel particles together with UO_2 fuel processing. The next stage of waste treatment process is their immobilization. It involves permanent binding of waste components to prevent them from entering the environment. In our experimental work, one of immobilization methods of spent nuclear fuel and radioactive wastes was studied. For this purpose, sol-gel methods developed at INCT were used to obtain glass and Synroc ceramic material. Glass composed of 65% SiO_2, 12% B_2O_3, 8% Al_2O_3, 10% Na_2O, and 5% CaO by weight and perovskite $CaTiO_3$ were obtained. The idea of the project was to enclose a graphite pellet, containing UO_2 with or without neodymium, simulating fuel compacts with TRISO particles, in glass or Synroc ceramics. The next step was to study the leaching of elements from these materials with solutions having different pH and temperature.

Acknowledgement
The work is carried out within the framework of GOSPOSTRATEG Project "The preparation of law, organization and technical instruments to deploy the HTR reactors" financed by The National Centre for Research and Development.

PROPOSED ACCIDENT TOLERANT MATERIALS (ATM) WITH INCREASED OXIDATION RESISTANCE; STUDIES IN THE FRAME OF ACTOF CRP IAEA PROJECT

Bożena Sartowska[a], Mirco Grosse[b], Sami Penttila[c], Martin Sevecek[d], Mikhail Veshunov[e]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Karlsruhe Institute of Technology, Germany
[c]VTT Technical Research Centre of Finland Ltd.,
[d]Czech Technical University in Prague,
[e]International Atomic Energy Agency, Austria

Abstract:
Zirconium and its alloys are commonly used as cladding material for fuel elements in nuclear reactors. This is connected with their good water corrosion and radiation resistance at normal working conditions. But in the case of severe accident conditions, the possible very fast oxidation of zirconium at steam or/and air may result in intense hydrogen generation and hydrogen-oxide mixture explosion. Minimization of the mentioned risk and prolongation of the time for personnel reaction is very important point of the nuclear reactors' safety. Accident Tolerant Fuels (ATF) and Accident Tolerant Materials (ATM) concept has been considered and investigated. The CRP IAEA project: Analysis of Options and Experimental Examination of Fuels for Water-Cooled Reactors with Increased Accident Tolerance - ACTOF was carried out (2015-2019).
Standard and modified zirconium alloys (Zry-2 and Zry-4) with different coatings and AISI 348 steel were investigated. Materials were produced and tested in different laboratories according to Round Robin Test (RRT) rules. Project partners were involved in sample production, long-term corrosion tests in PWR/VVER conditions and high-temperature steam oxidation tests. Samples were characterized before, during and after testing. Materials were characterized with SEM, EDS, XRD, metallography, weight changes, hydrogen pickup measurements.
Obtained results allow authors to make preliminary recommendations for the best zirconium alloys modification method (here: Cr coatings) as well as propose improvements for coating processes optimization in the case of MAX and Cr-Si-Zr coating.

OPTIMIZING THE SEPARATION OF FISSION PRODUCT TECHNETIUM IN THE PROCESS OF RECYCLING ACTINIDES FROM SPENT NUCLEAR FUEL

Irena Herdzik-Koniecko, Magdalena Rejnis-Strzelak, Jerzy Narbutt

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Technetium-99, one of the major long-lived fission products, must be separated from the actinides in hydrometallurgical reprocessing of spent nuclear fuel (SNF) to avoid its negative impact on the process. The separation is not an easy task because the most stable form of technetium under these conditions is the pertechnetate anion, $^{99}TcO_4^-$, eagerly coextracted with the actinides from nitric acid solutions to the organic phase used in the solvent extraction EURO-GANEX process.[1] The separation processes based on Tc(VII) reduction and formation of unextractable hydrophilic complexes are slow. The method of reducing Tc(VII) to Tc(II) using acetohydroxamic acid (AHA) of high concentrations at a high temperature[2] is fast but hardly acceptable for large scale hydrometallurgical SNF reprocessing. We examined the possibility of alleviating the harsh conditions of this process and selected the stage of the counter-current EURO-GANEX process of actinide separation, in which the Tc(VII) reduction with AHA can be carried out.

This work was supported by the European Commission under project GENIORS - „GEN IV Integrated Oxide fuels Recycling Strategies": HORIZON 2020; grant No 755171; and co-financed by the Ministry of Science and Higher Education of Poland from the funds for science.

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APPLICATION OF SiEA-KNiFe SORBENT FOR RADIOCESIUM REMOVAL IN THREE DIFFERENT PROCESS CONFIGURATION: BATCH, FIXED-BED AND HYBRID MEMBRANE PROCESS

Dagmara Chmielewska-Śmietanko[a], Marek Henczka[b], Agnieszka Miśkiewicz[a], Pavel Apel[c], Oleg Orelovich[c]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Faculty of Chemical and Process Engineering, Warsaw University of Technology, Poland
[c]Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Russia

Abstract:
Liquid radioactive waste (LRW) must meet very strict standards before their safe discharge into environment. Level of radioactivity, the concentration of heavy metals, organic compounds etc. in LRW is precisely regulated by the national standards, therefore, to reach them LRW has to be treated to reduce its volume and to decrease radioactivity level and harmful substances content. Cesium radioisotopes are produced by nuclear fission in high yield, contribute strongly low-level radioactive waste (LLRW) activity and are characterized with a long half-life. Moreover, cesium radioisotopes due to its high solubility can easily migrate to the environment. Therefore, effective methods for radiocesium removal from LLRW are still highly appreciated. This work presents synthesis of the new nanocomposite sorbent SiEA-KNiFe based on silica modified with cobalt-nickel hexacyanoferrate and ethanolamine. Due to fast and simple synthesis method SiEA-KNiFe sorbent is obtained in the form of "cake", that can be grinded and sieved according to the need in order to be suitable for the use for radiocesium removal in different engineering process configuration as sorption in column or in slurry or hybrid membrane process. These methods require the application of a sorbent of the proper size distribution and morphology. Therefore, a very valuable property of the sorbent is the possibility of the controlled modification of particle size and morphology to apply it in different process configurations.

Acknowledgements
This research was supported by the Plenipotentiary Representative of Poland on Cooperation Program between Polish Scientific Institutions and JINR in the frame of the project No 75/50/2020 (theme 04-5-1131-2017/2021, regulation number 75 on 03 February 2020).

Session ARIES: ACCELERATOR RESEARCH AND INNOVATION FOR EUROPEAN SCIENCE AND SOCIETY (ARIES)

PLANS FOR FUTURE ELECTRON BEAM ACTIVITIES IN HORIZON 2020

Thomas Edgecock

University of Huddersfield, UK

Abstract:
Electron beam activities in Europe have been supported by a number of projects in FP7 and H2020, most recently by ARIES. If it is approved, this will continue in IFAST, the successor to ARIES. However, what is really needed is a dedicated electron beam project with sufficient funding to make significant progress. The latest. and last, H2020 call, the EU Green Deal, may provide an opportunity for such a project.
This talk will decribe briefly what has been achieved in ARIES and the plans for IFAST and a possible proposal in response to the Green Deal call.

NEW TRENDS IN ELECTRON BEAM ENVIRONMENTAL APPLICATIONS

Andrzej G. Chmielewski, Zbigniew Zimek, Yongxia Sun, Andrzej Pawelec, Marcin Sudlitz, Urszula Gryczka, Dagmara Chmielewska-Śmietanko, Tomasz Smoliński, Marcin Rogowski, Sylwester Bułka

Institute of Nuclear Chemistry and Technology (IAEA Collaborating Centre), Poland

Abstract:
Due to high emission of SO2 and NOx, the process of fossil fuel combustion created a major world environmental problem to be solved at the turn of 20th and 21st centuries. INCT was a leader in development of EBFGT technology. In a recent century, new man-made problems have become a priority in terms of their importance for the protection of the environment. The major cargo transportation mode is maritime transport, which is also responsible for approximately 90% of world trade by volume. Accordingly, worldwide emission from shipping has grown significantly, which contributes directly to the global anthropogenic emissions of SO_2, NO_x and other pollutants and it poses a serious threat to the ecosystem and public health. Institute has developed and studied eb laboratory system tested at pilot scale for diesel ship engine off-gases at Riga's, Latvia Shipyard. The project was executed in the frame of PoC project in the frame of EU ARIES project. The positive results of tests are the basis of on board demonstrator design. The other problem which concern marine industry is related to ballast water discharge safety. In 2004, the International Maritime Organization developed the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), which entered into force globally on 8 September 2017. It provides a uniform legal regulation of the ballast water handling in order to prevent the spread of potentially harmful aquatic organisms and pathogens around the world. Laboratory tests have proofed possibility of eb application. Continuous flow system is under development to be applied on a floating dock. Finally eb is tested for sludge waste originated from wastewater treatment plants (WWPs) stabilization and hygenization. Waste Framework Directive 2008/98/EC lays down some waste management principles: it requires that waste must be managed without endangering human health and harming the environment, in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odours, and without adversely affecting the countryside or places of special interest. The main problem for agriculture application is contamination by human and animal parasites, their eggs, and also pathogenic bacteria. According to conception of 'zero energy' technology for sludge hygenization, biomass originating from wastewater treatment plant after its fermentation in the process of anaerobic digestion and separation is irradiated with electron beams.

Acknowledgements.
NCBiR TANGO2/341079/NCBR/2017; EU H2020 Research and Innovation programme No 730871 ARIES; NCBiR (INNOship) POIR.01.02.00-00-0007/18; „BBNawOrg" POIR.04.01.04-00-0078/17".

ILU ELECTRON ACCELERATORS FOR E-BEAM AND X-RAY TREATMENT

Aleksandr Bryazgin

Budker Institute of Nuclear Physics, Russia

Abstract:
A report describes powerful industrial pulse radio frequency electron accelerators type ILU, their beam power is up to 100 kW and energy range is 1-10 MeV. Working frequencies of ILU radio frequency systems are between 115 and 185 MHz, RF power is supplied by self-excited generators based on triodes. The self-excitation scheme distinguishes these accelerators from most other machines and improves accelerators usage in production lines. These machines can treat products by electron beam and X-rays (braking radiation). Their basic parameters and features are given.

Keywords
Electron accelerator, X-ray, E-beam

ORGANIC POLLUTANT REMOVAL FROM MARINE DIESEL ENGINE OFF-GASES UNDER ELECTRON BEAM (EB) AND EB HYBRID WET SCRUBBER PROCESS

Yongxia Sun[a], Andrzej G. Chmielewski[a], Andrzej Pawelec[a], Gösta Mattausch[b], Toms Torims[c]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology, FEP, Germany
[c]Riga Technical University, Latvia

Abstract:
SO_2, NOx, volatile organic pollutants (VOCs)' emission from marine diesel engine off-gases caused serious problem to the environment and human health, some VOCs are ozone-depleting substances or precursor for ozone depletion. The strict regulation concerning SO_2 and NOx emission from ship exhaust gas has been enacted accordingly. Based on MARPOL air pollution Annex VI, sulphur emission from ship exhaust gas can't exceed 0.1% (wt/wt) sulphur content in sulphur emission control areas (SECA), 0.5% sulphur content limits in global marine area.
Limits of NOx emission will be valid from 2021, between 3.4 and 2g/kWh depending on the engine speed based on TIER III requirement.
SO_2 and NOx removal using EB hybrid wet-scrubber process was first tested in a real maritime environment. The pilot plant set-up and results of SO_2 and NOx removal have been described in details [1]. In this work, we studied VOCs removal from ship emission using two processes, EB and EB hybrid wet scrubber process. 5000 Nm^3/hr flue gas emitted from a tugboat "Orkāns" in Riga Shipyard was treated using a mobile accelerator unit WESENITZ-II. 3 M^3 sea water containing 0-3.3 mg/L $NaClO_2$ oxidant was used as a wet scrubber solution. VOCs were collected at 3 different sampling points, before irradiation vessel, after irradiation vessels, and after wet-scrubber unit. They were collected with glass sampling bottles, tedlar bags, Coconut Charcoal (CC) sorbents and XAD-2 sorbents. CH_3OH and CH_3OH/CH_2Cl_2 (1:1) were used to extracted VOCs from CC and XAD-2 sorbents, respectively. The solid-free extraction solutions were obtained by using syringe filters to separate extraction solution from sorbents, and they were concentrated using a micro-extractor under continuously blowing high-purity Ar. A GCMS-QP5050 was used for analysis. We identified organic compounds emitted from exhaust gases. They were aliphatic hydrocarbons (Dodecane $C_{12}H_{26}$ to Eicosane C_{20} H_{42}), aromatic hydrocarbon (toluene), esters ($C_3H_7COOCH_3$, $(C_4H_9OCO)_2C_6H_4$), nitro compounds ($C_3H_5NO_3$, $C_4H_7NO_2$), acid ($C_7H_{15}COOH$). After 5 kGy EB irradiation, around 80% aliphatic hydrocarbons, 90% toluene, 50% $(C_4H_9OCO)_2C_6H_4$) were removed from the off-gases, after EB hybrid wet-scrubber process, most organic compounds were removed and the cleaned off- gas might be emitted into atmosphere.

Acknowledgements:
This work was partly financed by European ARIES PoC project (H2020 GA No 730871) and by Polish Ministry of Science and Higher Education (INCT statutory task 4.3).

Reference
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APPLICATION OF ELECTRON BEAM TREATMENT FOR MICROPLASTICS REMOVAL FROM SEWAGE SLUDGE

Malgorzata Siwek, Thomas Edgecock

University of Huddersfield, UK

Abstract:
The interest in using high energy electrons for wastewater purification has been rising for the last several decades. Starting from the early 70s', there have been many laboratory- and industrial-scale plants investigating not only wastewater but also sludge, and sewage sludge disinfection with the high effectiveness [1]. Furthermore, the electron beam has been proven to be a successful approach to various pathogens, pharmaceuticals and persistent organic pollutants disposal [2]–[4]. Nevertheless, before 2000, there were concerns about the perceived high capital costs of the accelerator and with public acceptance of the usage of irradiation for treatment purposes. Nowadays, with increased knowledge and technological development, it may not only be possible but also justified to use the electron beam technology for risk-free sewage sludge treatment, pharmaceuticals decomposition, and bio-friendly fertiliser production.
In this research, the electron beam has been investigated as the potential tool for microplastics removal from wastewater and/or sewage sludge. Microplastics (MPs) can be of primary (purposefully manufactured to be of microscopic size) or secondary (derived from the fragmentation of microplastic items) origin and they are defined as particles in the size range 1nm to <5 mm [5], [6]. Wastewater treatment plants (WWTPs) can act as a barrier but also as entrance routes for microplastics to the aquatic environment. Conventional wastewater treatment with primary and secondary treatment processes can remove MPs from the wastewater over 90%, and most of the MPs are removed already during the pre-treatment phase [7]. Despite the high reduction ability, conventional WWTPs are officially recognised in the UK as a significant source of MPs given the large volumes of effluents that are discharged daily [7]–[9].
The most common plastics such as PP, PE, PET, PS and PVC have been irradiated with various doses up to 200kGy in tap water. The materials before and after the irradiation were studied by infrared spectroscopy (IR), laser diffraction particle size analyser (Mastersizer), thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Additionally, the high-resolution pictures have been taken using the digital microscope to observe the possible material degradation signs such as commonly reported yellowing.

EFFECT OF LOW ENERGY ELECTRON BEAM IRRADIATION ON BACTERIA AND VIRUSES IN LIQUIDS

Simone Schopf, Jana Beckmann, Gaby Gotzmann, Javier Portillo Casado, Frank-Holm Rögner, Volker Kirchhoff, Ulla König

Fraunhofer-Institut für Organische Elektronik, Elektronenstrahl- und Plasmatechnik FEP, Germany

Abstract:
Low-energy electron-beam irradiation (LEEI) with acceleration voltages below 300 kV has already been successfully used for surface functionalization and the sterilization of innovative medical devices. The technology allows surface treatment under ambient conditions, without significant heat input, and with a precise determination of the electron penetration depth. Recently, it has been shown that LEEI is also a versatile tool for inactivation or sterilization of viruses and bacteria in liquid solutions. The major drawback with this method, however, seems to be the low penetration depth of the electrons. Therefore, an experimental setup for the reproducible irradiation of thin liquid films using LEEI was developed. Since no functional liquid dosimetry for low-energy applications existed at that time, a novel dosimetry system based on a simple and reproducible colorimetric assay was established. The functionality of the experimental setup in combination with the new liquid dosimetry system to monitor the applied dose will be demonstrated. The killing kinetic of different bacterial suspensions as a function of the low-energy irradiation dose will be presented. Beyond this, current research activities focus on the development of a novel concept for LEEI of stirred liquids. This will enable us to treat larger amounts of liquids in an ongoing biotechnological production process. Preliminary results on this novel development will be presented.

PLASMA TECHNOLOGY TO REMOVE NOX FROM OFF-GASES

Andrzej G. Chmielewski, Yongxia Sun, Andrzej Pawelec, Sylwester Bułka, Zbigniew Zimek

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Operation of marine diesel engines causes serious emission of sulfur and nitrogen oxides, that is a serious problem especially in harbor areas and sea routs. It was noticed worldwide and the regulations concerning SO_2 and NO_x emissions were introduced. There are several solutions of this problem as fuel desulfurization or sea water scrubbing in the case of SO_2 and fuel combustion process modification (engine modification) or selective catalytic reduction (SCR) process application in the case of NO_x. All of these processes has its limitations. Low sulphur fuel is much more expensive and may be harmful for older engines. Similarly, fuel combustion process modification has limited NO_x emission reduction potential. Therefore the most popular solution for marine industry is combination of sea water scrubbing with SCR. They are two separate processes realized in separate devices, that is problematic due to limited space on ship board. One process allowing for simultaneous removal of both pollutants may be an alternative.
The response may be electron beam flue gas treatment (EBFGT) technology. It was applied in the power industry and further research on its development is carried on. The process was adopted to marine Diesel off-gases treatment conditions. In this solution called hybrid EBFGT process, two main processes are combined. Flue gas is first irradiated for oxidation of NO and SO_2 to higher oxides, then followed by wet scrubbing to remove both SO_x and NO_x with high efficiency.
Laboratory test showed that hybrid EBFGT process is very promising to remove SO_2 and NOx from diesel engine off-gases. Different compositions of absorbing solution with three different oxidants (NaClO, $NaClO_2$ and $NaClO_3$) were tested The highest NO_x removal efficiency (>96%) was obtained when sea water-$NaClO_2$-NaOH was used as scrubber solution at 10.9 kGy dose. The process was further tested in Riga shipyard, Latvia. More than 45% NO_x was removed at 5.5 kGy dose for 4800 Nm^3/h off-gases from ship emission. The operation of the plant was the first case of examination of the hybrid electron beam technology in the real conditions. Taking in account the experiment conditions, good agreement was obtained with laboratory tests. The results obtained in Riga shipyard provided very valuable information for this technology application for control of large cargo ship emission.

Acknowledgements:
This work was partly financed by Tango 2 Project (TANGO2/341079/NCBR/2017), European ARIES project (H2020 GA No 730871), and by Polish Ministry of Science and Higher Education (INCT statutory task 4.3).

A METHOD OF HYGIENISATION AND DISINTEGRATION OF SEWAGE SLUDGES USING IONISING RADIATION

Marcin Sudlitz, Andrzej G. Chmielewski

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Sludge obtained from municipal and industrial wastewater was always a problematic waste to utilize and nowadays growing year by year amount of sewage sludge produced in Wastewater Treatment Plants (WWTP) intensifies this problem. One of the possible ways is to use it as an biomass for anaerobic fermentation process to produce biogas and to use digestate obtained in the process as a fertilizer. But due to its origin sewage sludges contains pathogens dangerous for humans health and which are able to survive processes applied in WWTPs. Thus hygienization process is required before using sewage sludge in agriculture.
In literature there are examples of experiments with hygienization and disintegration of sewage sludges using ionizing radiation. Tests shown increase in SCOD after irradiation of secondary sludge and higher biogas production during anaerobic fermentation of irradiated sewage sludges in comparison to untreated samples.[1] Another experiments also shown parasite eggs and pathogenic bacteria removal after the irradiation of sewage sludges.[2]
Experiments with irradiated sewage sludges obtained from aerobic digestion were carried out in laboratory scale using DIN 38414/8 eudiometers and lasted 21 days. Methane fermentation of irradiated sludges (in range of 2-10 kGy) shown, that during first period of the process biogas yield was higher approximately 1,15 – 1,3 times for irradiated sludges (depending on the ionizing radiation dose) in comparison to non treated sample. Also after the irradiation of examined sludges SCOD was higher.
Aerobically treated sludge were tested for living parasite eggs content after the irradiation. Results shown, that dose of 3 kGy eliminates completely living eggs of Trichuris sp., Toxocara sp. and Ascaris sp.

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Acknowledgement

Ministry of Science and Higher Education Project: nr. 411946: „A Method for Hygienisation of Sewage Sludge Based on Electron Accelerator Application" W48/IAEA/2018

IAEA RC 22642 "A Method for Hygienisation of Sewage Sludge Based on Electron Accelerator Application" in framework of CRP F23033 "Radiation Inactivation of Bio-hazards Using High Powered Electron Beam Accelerators"

DEGRADATION OF DICLOFENAC IN SEWAGE SLUDGE FROM MUNICIPAL WASTEWATER TREATMENT PLANT USING IONIZING RADIATION

Anna Bojanowska-Czajka, Andrzej G. Chmielewski, Marcin Sudlitz, Paweł Kalbarczyk

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Diclofenac belongs to nonsteroidal anti-inflammatory drugs (NSAIDs) for treating painful disease. In all European countries the consumption of pharmaceuticals still increase, especially NSAIDs. The massive consumption of pharmaceuticals resulted in the discharge of these substances into the environment. Although their concentration in aquatic environments are very low, they can caused unfavorable and irreversible changes in ecosystem. It is well known, that diclofenac is resistant to biodegradation, and its elimination in conventional wastewater treatment is limited and incomplete [1]. Hence a strong attention is focused in recent years on the development of efficient radical methods of decomposition, described as advanced oxidation processes (AOPs). Especially efficient process is the radiolytic decomposition by the use of ionizing radiation (γ or electron beam EB). The aim of presented work was investigation of the yield of the radiolytic decomposition of diclofenac in sewage sludge from municipal wastewater treatment plant. Based on our previous work [2] the sludge was subsidizes with diclofenac up to 50 mg L^{-1} and then irradiated separately with gamma radiation and electron beam. After irradiation the concentration of diclofenac in sludge was carried out using extraction procedure and HPLC analysis. It was found that applied dose 5 kGy (γ or electron beam EB) is not sufficient to decompose 50 mg L^{-1} diclofenac in sewage sludge. Only 50% of the initial amount of diclofenac is decomposed at the dose used. It was shown that matrix composition has a great influence on the efficiency of diclofenac degradation.

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Acknowledgements

This research was supported by the project NCBiR POIR 04.04-0078/17-00 „BBNawOrg" POIR.04.01.04-00-0078/17 "Zero-energy technology for the manufacturing of biologically safe organic fertilizers based on sewage sludge"

Session IV:
RADIOISOTOPES / MEDICAL APPLICATIONS

THE INFLUENCE OF IRRADIATION ON THE PHYSICOCHEMICAL PROPERTIES OF COLLAGEN SCAFFOLDS

Grażyna Przybytniak, Wojciech Głuszewski, Hanna Lewandowska

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Much effort is made to find effective dressings for patients suffering from skin injuries and to develop adequate scaffolds that could be seeded with stem cells. Skin allografts fully meet most clinical requirements. Their microbial contamination is one of the important problems requiring an appropriate sterilization method. Usually for biomedical products radiation sterilization is recommended. An important variable is the procedure of tissue treatment before irradiation, which affects the structure of transplants and further modifications introduced during sterilization [1,2].
The grafts were irradiated with a high-energy electron beam to a dose of 35 kGy, in the air at dry ice temperature (195K). Immediately after sterilization, the samples were placed in liquid nitrogen (77K). Some EPR measurements required irradiation at 77 K, using a ^{60}Co gamma chamber (10 kGy). The X-band EPR measurements were performed at selected temperatures in the range from 100 to 340 K. The H_2 production and O_2 consumption were measured by gas chromatography (GC).
The produced radicals were relatively stable because at 340 K traces of paramagnetic species were observed. At 195K, radicals decay slowly and are present in the collagen matrix even after 38 hours. The most intense EPR pattern, overlapped with an unknown broad singlet, consisted of five lines. The hyperfine splitting was 1.95 mT and the g-factor was 2.0031, suggesting the -CH_2-$^{\bullet}CH_2$ secondary alkyl radical formation as a result of cleavage of the C-C or C-N bond. Hydrogen release observed by GC suggests the formation of other alkyl radicals. Free hydrogen was also visible in the EPR spectra as doublet lines separated by 50.2 mT. The radiation efficiency of hydrogen emission is 0.026 μM H2/J, while that of oxygen consumption was 4.6 times higher (0.12 μM O_2/J). Some alkyl radicals produced by the scission of the C-H bond are rapidly oxidized even under cryogenic conditions. Consequently, the asymmetric singlet attributed to peroxy radical RCOO$^{\bullet}$ was observed by EPR, even at 100K. The peroxy radicals were more thermally stable than the alkyl radicals and only a part of them was converted to -NH- • CH-CO-, observed as the doublet formed above 280 K. Other radicals may recombine to form dialkyl peroxides.
Summarizing, EPR spectra show the intensive radical-induced oxidation, which affects the chemical structure of collagen allografts and their morphology.

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DEVELOPMENT AND CHARACTERIZATION OF NOVEL SILICON SENSORS FOR NEUTRON DETECTION

Anna Mastroberardino

Dipartimento di Fisica, Università della Calabria, Italy

Abstract:
The planned final upgrade of the LHC accelerator at CERN, namely the high luminosity phase of the LHC (HL-LHC), foreseen beyond 2026, will mean unprecedented radiation levels, Due to the radiation damage limitations of the silicon sensors presently used, new radiation-hard tracking detectors will be required by the physics experiments 3D silicon pixel detectors are among the radiation-hard solutions designed for the extreme radiation levels expected for the vertexing layers at the HL-LHC.
The 3D technology features electrodes penetrating inside the silicon bulk. While keeping a high carrier collection efficiency in heavily irradiated detectors, this configuration minimizes the detector dead border region.
Neutron detectors fabricated with 3D technologies and coupled to different neutron converter materials have recently been the object of an increasing interest for possible replacement of 3He detectors.
In the framework of the INFN DEEP_3D (Detectors for neutron imaging with Embedded Electronics Produced in 3D technology) project, a new monolithic detector for neutrons coupled with boron, lithium or their combination, is presented.
The talk will cover aspects relevant to the electronics design, layout and validation of the key technological steps of these innovative 3D pixel sensors

ACTIVITY OF INCT IN THE DOMAIN OF NUCLEAR FORENSIC

Ewelina Chajduk, Paweł Kalbarczyk

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
This work shows the possibility of Institute of Nuclear Chemistry and Technology on the field of nuclear forensic. Nuclear forensic is a scientific discipline that aims to aid in criminal investigations concerning illicit trafficking and use of nuclear material or other radioactive substances. Application of analytical methods: gamma-ray spectrometry, SEM-EDS, ICP-MS, INAA to the characterization of "unknown" radioactive materials has been demonstrated. The complementary application of all methods allows a thorough knowledge of the chemical composition of the material, which is necessary in nuclear forensics. On the basis of obtained results it should be concluded, that INCT possess the capability to categorize nuclear or other radioactive materials to assess their threat.

Acknowledgement:
This work was partially supported by IAEA (CRP J02013, contract numer No. 23061/R0)

INTERLABORATORY COMPARISON ON THE DETERMINATION OF RADIONUCLIDES IN WATER, FOOD AND SOIL CONDUCTED BY THE NATIONAL ATOMIC ENERGY AGENCY (NAEA), POLAND

Leon Fuks, Paweł Kalbarczyk, Halina Polkowska-Motrenko

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Proficiency tests (PT) on the determination of radionuclides in food and environmental samples have been organized each year by the National Atomic Energy Agency (NAEA), Poland, since 2004. The activity of the following radionuclides: ^{241}Am, ^{137}Cs, ^{3}H, ^{239}Pu, ^{226}Ra, and ^{90}Sr were determined in water, food, and soil.
The PTs have been conducted by the Institute of Nuclear Chemistry and Technology (INCT), Warsaw, Poland, and the procedure adopted by the INCT is presented in the paper. The test materials: water, milk and milk powder, powdered vegetables, wheat flour, and soil, were prepared by spiking blank materials with a standard solution of the radionuclide of interest. The activity concentrations were calculated and associated uncertainties were evaluated before sending the test materials to the laboratories.
The results provided by the participants were statistically evaluated by means of z and zeta scores as well as using the International Atomic Energy Agency (IAEA) criteria for trueness and precision. Observed trends and some benefits for the participants have been presented.

Organizers invite further laboratories to participate in the PT'2021.

ASSURANCY QUALITY SYSTEM IN IODINE-125 SEEDS SOUCES PRODUCTION

Tatyana Baptista, Anselmo Feher, João Moura, Carlos Zeituni, Maria Elisa Rostelato

Nuclear and Energy Research Institute – IPEN, Brazil

Abstract:
There is a great challenge the implantation on assurance quality system in the brachytherapy sources production. It involves to fulfill the Good Manufacturing Practices (GMPs) requirements, involving the process validation and of all supporting activities such as cleaning and sanitization. Much more than compliance with regulatory guidelines, required for certification and inspections, a validation builds large process knowledge, provides possibilities for optimization and improvement, increasing the degree of maturity of all people involved and the quality system. The aim of this work was to evaluate the all steps that involve the implantation on assurance quality system in the brachytherapy sources production on Radiation Technology Center located at IPEN- Brazil. Briefly, the sanitization was to evaluate the effectiveness of different surface cleaning products, determining the best to reduce radiological contamination to acceptable levels during the sources production, according to legislation. The fabrication process was performed three times for evaluation (process validation). The parameters evaluated in this study were: the source welding efficiency and the leakage tests results (immersion test). The welding efficiency doesn't have an established parameter, since is visually evaluated by the operator, and the leakage detection has to be under 5 nCi / 185 Bq, accordingly with the ISO 9978. In the relation of sanitization, it was established a cleaning program for three production lots of iodine 125 seeds using three types of sanitizers: Lot 1 with extran 1/1 (v/v), Lot 2 with hydrogen peroxide 6% and Lot 3 with sodium hydroxide 1M. Each lots contained seven iodine 125 seeds and was immersed in the sanitizer for 1 hour and then two washes with distilled water. An activity detected in each lots does not exceed 0,2 kBq (=5nCi). The observed values on process validation were: 75% welding efficiency and 32% leakage detection. Although established values for the global efficiency aren't available in the literature, the results showed high consistency and acceptable percentages, especially when other similar manufacturing processes are used in comparison (average 85-70% found in the literature for other similar metallic structures). According to results of sanitization, the best choice for remove de surface contamination was peroxide hydrogen. Further testing should ensure the sanitizer's choice is based not only on the removal of surface contamination, but also this sanitizer does not leave residues requiring further rinsing with distilled water. Those values will be important data when drafting the validation document and to follow the Good Manufacturing Practices (GMPs).

SYNTHESIS OF MULTIMODAL RADIOBIOCONJUGATE OCTREOTIDE-PEG-^{198}AUNPS-PEG-DOX FOR TARGETED CANCER THERAPY

Monika Łyczko, Kinga Żelechowska-Matysiak, Emilia Górzyńska, Aleksander Bilewicz, Agnieszka Majkowska-Pilip

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Over the last decade, interest in the use of radioactive nanoparticles for diagnosis and medical therapy has increased significantly. The development of targeted therapy using radioactive nanoparticles is caused by the necessity to increase the effectiveness and selectivity of treatment, which is particularly important due to the high resistance of cancer cells to standard methods of treatment, such as chemo-, radio- and immunotherapy.
In medicine, the synergistic effect of chemotherapy and external radiotherapy is widely known and contributes to the increase of therapeutic effects.
The aim of our research was to synthesize of a multimodal radiobioconjugate. We propose innovative targeted brachytherapy applying radioactive gold nanoparticles (^{198}AuNPs) in connection with chemotherapeutic - doxorubicin and guiding vector – octreotide, for the treatment of locally-advanced neuroendocrine tumors.
The synthesis of gold nanoparticles (^{198}AuNPs) was carried out with the use of radioactive precursor ^{198}Au, obtained by the neutron capture reaction $^{197}Au(n,\gamma)^{198}Au$ in the Maria reactor in Otwock (Poland). The irradiated target was dissolved in aqua regia to obtain $H^{198}AuCl_4$. Finally, to obtain 30 nm size ^{198}AuNPs the simplest method discovered by Turkevich was applied [1]. In order to avoid contamination of the testing apparatus, the physicochemical parameters of ^{198}AuNPs were characterized using non-radioactive ^{197}AuNPs.
The stability of obtained nanoparticels in human blood serum, PBS and NaCl solutions was confirmed. The physicochemical parameters were characterized based on measurements carried out on the non-radioactive AuNPs-PEG-DOX-Octreotide bioconjugate. The hydrodynamic diameter and zeta potential were determined using the DLS method, and the efficiency of octreotide and doxorubicin attachment reactions was determined using UV-Vis spectrophotometry. The synthesis of bioconjugate was controlled using size exclusion chromatography.
The cytotoxicity assay was performed on the AR42J cell line for the ^{198}AuNPs-PEG-DOX-Octreotide radiobioconjugate, ^{198}AuNPs-PEG-DOX radioconjugate and ^{198}AuNPs.

This work was supported by SONATA grant 2018/31/D/ST4/01488 from the National Science Centre of Poland.

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Session: RADIATION TECHNOLOGIES AND APPLICATIONS ISTRA: TRACERS AND RADIOTRACERS APPLICATIONS (ISTRA)

PROGRESS IN RADIONUCLIDE CHARACTERISATION IN BEACH SANDS OF LESVOS ISLAND USING AN UNDERWATER GAMMA-RAY SPECTROMETER IN 2Π GEOMETRY

Christos Tsabaris[a], Filothei Pappa[a], Dionisis Patiris[a], Evaggelia Krasakopoulou[b]

[a]Hellenic Center for Marine Research, Greece
[b]University of Aegean, Greece

Abstract:
The study of natural radioactivity levels at the sandy beaches of Tsonia and Anaxos located in the North-Eastern and North-Western part of Lesvos island was carried out. A mapping method based on the use of gamma-ray spectroscopy was applied. In particular two detection systems were used: the KATERINA II detection system for in-situ measurements and the GeoMAREA medium resolution detector for calibration purposes. The values of natural radioactivity was recorded their gamma-ray emitters together with the activity concentration of of ^{214}Bi and ^{228}Ac. The maximum values seem to be attributed to the presence of a small stream that feeds the beach with material having the mineralogical and radiological characteristics of the volcanic formation of Sykaminea. The concentrations recorded on the Lesvos beaches of Tsonia and Anaxos are comparable to those observed in Mediterranean regions with strong presence of volcanic rocks. Estimates of the absorbed dose rate and of the annual active dose did not show increased radiological risk for the people using the two beaches for recreation. Typical values of the ratio of ^{214}Bi/^{228}Ac are also reported for identifying erosion and deposition processes in the areas of study.

ISO PROPOSAL: MEASUREMENT OF FLUID FLOW RATE IN CLOSED CONDUITS – RADIOACTIVE TRACER METHODS

Thorsten Jentsch[a], Jovan Thereska[b], Patrick Brisset[c], Joon-Ha Jin[d], Mohd Amirul Syafiq Mohd Yunos[e], Stanslaus Masinza[f], Hannah Affum[g]

[a]HZDR - Helmholtz-Zentrum Dresden-Rossendorf e.V. Germany
[b]ISTRA - International Society for Tracer and Radiation Applications,
[c]IAEA - International Atomic Energy Agency
[d]KAERI - Korea Atomic Energy Research Institute,
[e]MNA - Malaysian Nuclear Agency,
[f]KENAS - Kenya Accreditation Service,
[g]GAEC - Ghana Atomic Energy Commission

Abstract:
Radioactive tracer methods are very competitive and sometimes unique for online measurement of flow rate in single phase flows flowing inside closed conduits. Radioactive tracer methods are already well accepted from industrial end users and established in routine service worldwide.

ISO standards are basic elements of quality control and accreditation for recognition and cooperation in national and international market. There have been proposed several ISO standards dealing with radioactive tracer methods for measurement of water and gas flows in closed conduits during last five decades:

ISO 2975/VII Measurement of water flow in closed conduits -Tracer methods: Transit time method using radioactive tracers
ISO 4053 Measurement of gas flow in conduits -Tracer methods

The ISO standards ISO2975 and ISO4053 issued in 1975-1977 addressed radioactive tracer methods respectively for water and gas flows. The ISO2975 is limited to water phase only, while ISO4053 dealt with gas phase, was withdrawn in 2001 leaving a void on this subject. The proposed ISO standard will replace both of them.

This ISO proposal defines the use of radioactive tracer methods in the measurement of single-phase fluid (gas or liquid) flows in closed conduits. This method of measurement is applicable only to single-phase homogeneous fluid mixtures. This ISO proposal is developed to fill the need for a generalized reference based on fundamental principles to measure fluid flow using radioactive tracer methods. It defines the terms and principles needed for intelligent consideration of radioactive tracer methods for any single-phase fluid flow flowing in closed circuits.

Experts from different countries – so called P member states of ISO TC30 SC5 – will discuss the ISO proposal, and finalize it as new international standard in this field in coming years.

ISO PROPOSAL ON LEAK TESTING IN PRESSURED VESSELS AND UNDERGROUND PIPELINES USING RADIOACTIVE TRACER METHODS

Jovan Thereska[a], Patrick Brisset[b], Cezary Nobis[c]

[a]*ISTRA*
[b]*IAEA*
[c]*Institute of Nuclear chemistry and Technology, Poland*

Abstract:
Radioactive tracer methods are very competitive in testing pressured vessels, heat exchangers and underground pipelines for eventual leaks. Radioactive tracer methods for leak testing in industry, have been the subject of continuous development for over 40 years and the experience built up in the application of this technology exists in developed and developing countries. Radioactive tracer methods for leak testing are already established in routine service to many end users worldwide and are mature for the ISO standard.

The ISO proposal aims to finalize a long and extended experience in leak testing in pressured vessels and underground pipelines using radioactive tracer methods. Having an ISO standard in this field, will help radioactive tracer service providers and their end users to work in partnership, improve acceptance and understanding for making better use of the technology. ISO standard will facilitate the radioactive tracer laboratory accreditation and promote the international and regional trade and services among countries.

Radioactive tracer methods are the most competitive for online leak testing of pressured vessels, heat exchangers and underground piping; leaks of less than 1% may be identified and localized at early phase, thus reducing shutdown time, ensuring safe operation and protecting the environment from pollution. According to the methods and targets, radioactive tracers for leak testing are grouped in two categories:

1. Leak testing in plant processing units, pressured vessels, heat exchangers, valves, flares, boilers, heating water distribution network. Leaks in these units can be developed mostly as:
• release to atmosphere from a pressurized system,
• penetration from the tube side to shell side of a heat exchanger.

2. Leak testing in underground pipelines (oil and gas transporting pipes, urban water distribution network, cables).

VISUALIZATION OF TRACER DISTRIBUTION IN IRRADIATED SAMPLES AND TRACED OBJECTS BY USING POSITRON EMISSION TOMOGRAPHY (PET)

Ferenc Ditrói

Institute for Nuclear Research, Hungary

Abstract:
The application of radioactive tracers in medicine, agriculture and industry has a long history. The use of these tracers in medicine is continuously developing but their industrial use is in an uprising period again only in the last decades. The reason is, among others the automobile industry, which can widely exploit the capability of radioactive tracers in wear measurements by using Thin Layer Activation (TLA) in following industrial processes and also in investigation of different lubricants, surface treatments, etc..
When the radioisotopes for tracing are introduced into the sample surface by irradiation (e.g by TLA) it is very important to confirm the lateral distribution of the radioactive atoms, especially when a large and complicated area is irradiated. The 3rd dimension, i.e. the depth distribution is usually calculated or measured by using stacked foil technique of the same material. The tracer distribution is also important when the tracer is introduced into the system in liquid solution.
For this purpose, a technique having long history in medicine, can be applied. This is the positron emission tomography (PET). In our institute a several versions of small animal PETs (mini-PET) have been developed and it is capable to visualize the distribution of radioactive isotopes in the irradiated samples, or in small volume processes. The spatial resolution of the min-PET is less than 1 mm in metallic samples, which is suitable to check the proper spatial distribution. For depth distribution this resolution is not enough, because the usual activation depth is far under 1 mm. The volume to be able to investigate with mini-PET (view field) is about 10x10x10 cm, for larger samples and parts a human PET can also be used.
During our TLA studies and process control several irradiated samples and traced processes have been investigated by using our mini-PET scanner. The strongest condition to be able to use the mini-PET for process visualization is that the radioisotope in question should be positron emitter. It is not always the case, e.g. not by one of the most frequently used ^{57}Co tracer. Fortunately, in this case the always co-produced ^{55,58}Co positron emitter radioisotopes can do the job in a limited time after the irradiation. Their depth distribution (which cannot be investigated with mini-PET) is different from that of the ^{57}Co but their lateral distribution is the same.

This work is partly supported by IAEA CRP No: 22490 and IAEA RER1020

OPTIMIZATION OF INJECTED RADIOTRACER VOLUME FOR FLOW METER CALIBRATION IN CLOSED CONDUITS

Miroslav Pavlović[a], Pavel Bartl[b], Marijana, Pantović Pavlović[a], Jasmina Stevanović[a], Bojan Radak[c]

[a]University of Belgrade, Institute of Chemistry, Technology and Metallurgy, Department of Electrochemistry, Serbia,
[b]Department of Nuclear Chemistry – CTU in Prague, Czech Republic,
[c]Serbian Radiation and Nuclear Safety and Security Directorate, Serbia

Abstract:
In chemical processes it is of essential for flow in the process to be accurate and well defined. Fluid velocity measurements are important for fluid flow quality performance in the systems. This study focuses on determination of volumetric flow rate measurement and on calibration of conventional flowmeter using industrial radiotracer approach. In this work, the application of radiotracer method for RTD measurement in flow meter calibration for chemical industry is described. The experiments in pilot-scale flow rig were performed using Technetium-99 m (^{99m}Tc) as a radiotracer in the form of pertechnetate ion ($^{99m}TcO_4^-$) to calibrate flow meter. The data were evaluated using plug flow with axial dispersion model of RTD software.
The optimization of the parameters included input signal of radiotracer, concentration of radiotracer and position of detectors. The measured data were analyzed, and precision of experimental setup was investigated under two different approaches. A plug flow with axial dispersion was used to simulate the measured RTD curves and investigate flow dynamics of the flowing water. The results of the study, showed that there might be an optimum injection volume range of the tracer for each specific application.
The optimum range in this study was determined from 300 to 700 μL. In this range, relative standard deviation was around 1% for both calculation methods, which is lower than with other available injection volumes. Bias of the initial flow rate was lower using summation approximation, resulting in ca 9% in the area of interest. In case of RTD software, bias values were between 10 and 11%. For the first time the variation of standard deviation of calculated flow rate with injection volume and activity of radiotracer was determined. The results of the study may help in injection volume optimization as well as give a guide on how to process data without RTD software, as the results obtained by both methods were in great agreement. They also revealed a slight dependency of the precision of output results on the injection volume as well as similar results for manual and specialized RTD software data processing. The study that investigated the change of standard deviation of calculated flow rate with injection volume and activity of used radiotracer was conducted for the first time in literature.

Keywords:
Radiotracers; Flow meter; calibration; RTD; Technetium-99m.

Session V:
RADIATION TECHNOLOGIES AND APPLICATIONS

MODIFICATION OF THE HIGH POWER DC ELECTRON ELV ACCELERATORS FOR RESEARCH AND INDUSTRIAL APPLICATION

Nikolay Kuksanov, Yury Golubenko, Rustam Salimov, Sergey Faadeev, Petr Nemytov, Alexey Korchagin, Alexander Lavruchin, Alexey Semenov, Viktor Cherepkov, Dmitry Kogut, Evgeny Domarov, Denis Vorobiev, Mikhail Golkovsky

Budker Institute of Nuclear Physics SB RAS, Novosibirsk Russia

Abstract:
Electron-beam technologies have been used extensively in radiation treatment of polymer compositions. The use of these technologies enabled to develop the manufacture of a wide range of wires, cables and heatshrinking goods, films, bands, etc. The powerful industrial electron accelerators are perfect instruments for radiation treatment of polymers. This paper reviews the development and current status of ELV electron accelerators. ELV electron accelerators are DC machines which were designed and produced by the Budker Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of Science. Over 180 accelerators have been supplied from 1973 to date. 120 accelerators are still under operation. One of the advantages of ELV is high-efficiency conversion of electrical power to electron beam power (70-80%). Main parameters of the accelerator are energy and beam power. The subject of modification are energy range, beam power, the set of under beam supplementary devices. The ELV accelerator can be equipped with a wide set of additional devices that extend its application and improve the quality of electron beam treatment. Such devices include 4-side irradiation systems, ring irradiation and transportation systems for cables, films and grain. Some special devices can be used for extraction of focused beam into atmosphere with a power density of the beam of about 5 MW/cm^2
The maximum beam power of a regular accelerator is 100 kW and the maximum beam current is 130 mA. The accelerators cover the energy range from 0.2 to 2.5 MeV. The accelerator with energy range of 0.6 -1.0 MeV and beam power 400 kW was developed for environmental applications.
The accelerator with energy of less than 1 MeV only can be equipped with a local steel shielding weight is about 50 T.

IRSN IRRADIATION FACILITIES

Juliette Colombani

IRSN, France

Abstract:
The irradiation processing obtained from ionizing radiation sources is a nuclear technique widely used both in academic research and in industrial area, as for instance : sterilization of objects; nuclear medicine including diagnostic imaging, radiation oncology and radiological protection; development of innovative electronic materials; harmful effects on solid materials and so on.
As a French public industrial and commercial establishment, IRSN (Institut de Radioprotection et de Sûreté Nucléaire) contributes to public nuclear security and safety policies, as well as health, environmental and crisis management policies. So, in the frame of its missions, IRSN carries out research, analysis and expert work in the fields of nuclear safety and radioprotection. One key topic concerns more especially the ionizing radiations as used in industry and medicine or naturally present in the environment. Thus, IRSN owns several irradiation facilities to perform its basic and applied research and to enhance its expertise in this specific area.
This communication presents an overview of the irradiation facilities available in IRSN as well as the linked skills and expertise, especially covering the fields of medicine, environment and industry. These experimental facilities are designed to address all kinds of ionizing radiations such as alpha, beta gamma, X-ray and nucleons (proton, neutron) and over very wide ranges of dose rate and energy. The samples that can be studied thanks to them can cover from micro to macro scales and for both inert and living matters. For instance, irradiations can be applied in one hand from the biological cell to the full organism (animal or plant) and on other hand from nanomaterial up to equipment as large as several cubic meters. Moreover, some of these facilities are also able to perform online measurements during the irradiation process. The main technical features of the irradiation facilities are detailed hereafter: type of radiation, dose rate, energy, irradiation conditions (temperature, pressure, type of atmosphere, etc.) and size of samples. The experimental sensors linked with the facilities allowing on-line measurements during the irradiation phase are also presented. Finally, the skills and expertise of IRSN are pointed out by showing some major outcomes coming from the R&D, Industry or nuclear fields. Through this communication, IRSN aims to promote its irradiation facilities and to share its skills and knowledge with both the national and international networks and with both the scientific and industrial communities having potential needs in irradiation processing.

ELECTRON BEAM DEGRADATION OF MICROCYSTIN LR

Mark Driscoll[a], David Kieber[a], Cornelius Murphy[a], David Kiemle[a], Fred Bateman[b]

[a]State University of New York College of Environmental Science and Forestry, USA
[b]National Institutes of Standards and Technology, USA

Abstract:
Harmful algal blooms (HAB) are becoming more frequent and are growing in size and toxicity worldwide due to increasing nutrient pollution, increasing storm intensities (runoff) and rising temperatures. These blooms include freshwater cyanobacteria, or blue-green algae. One of the most common freshwater blue-green algal HAB species, Microcystis aeruginosa, produces a group of toxins known as microcystins. Microcystin toxins have been found in every continent including Antarctica. Microcystins are cyclic heptapeptides and hepatotoxins to both humans and animals. Microcystins inhibits protein phosphatase type 1 and type 2A activities in the cytoplasm of liver cells. Of the 80+ variants of microcystin, microcystin LR is the most abundant and most toxic.

It is believed that the toxicity of microcystin LR can be reduced by disrupting or removing the Adda side chain, reacting the methylene group of microcystin-LR's N-methyl-dehydroalanine residue and/or opening the main ring of the compound. Microcystins are difficult to degrade by conventional drinking water treatment methods including chlorination, ultraviolet radiation and ozone treatment. Advanced oxidation methods, such as electron beam irradiation, are needed to treat drinking water to remove microcystins. This presentation will focus on the degradation of microcystin LR by electron beam irradiation at different doses.

RADIOLYTIC SYNTHESIS OF HEMA-BASED HYDROGEL COMPOSITES INCLUDING GOLD NANOPARTICLES: POTENTIALITIES FOR THE DESIGN OF FUNCTIONAL 3D-PRINTED MATERIALS

Uliana Pinaeva[a], Katsiaryna Dziarabina[b], Xavier Coqueret[a]

[a]Université de Reims Champagne Ardenne, France
[b]Lodz University of Technology, Poland

Abstract:
In view of the increased demand of photo-patternable functional polymeric 3D objects, we are currently evaluating methods allowing in situ formation of gold nanoparticles (AuNPs) into 2-hydroxyethyl methacrylate (HEMA)-based hydrogels using high energy radiation.
Radiolytic method is an effective technique for the synthesis of metal nanoparticles in aqueous media via generation of hydrated electrons, hydrogen atoms and free radicals, which can easily reduce metal ions such as Au(III) down to zero valent state. The presence of polymeric solutes may induce a more complex reduction mechanism involving short-lived and long-lived polymeric species. Transposing this approach to polymeric hydrogels requires a good control over changes occurring within the system.
Disk-shaped xerogels and patterned 2D structures on glass substrates were prepared by photo-polymerization of 2-hydroxyethyl methacrylate (HEMA) and ethyleneglycol dimethacrylate (EGDMA) as cross-linker under 365 nm radiation.
Aqueous solutions of Au(III) (0.1, 0.5 and 1 mM) were used to investigate the reduction process inside polyHEMA matrix. Preliminary experiments showed that the samples, when used as prepared, were able to form AuNPs upon Au(III) sorption, likely due to the presence of occluded reducing species within the vitrified matrix. This undesirable effect was suppressed by pre-swelling the material in water and drying.
Different approaches were explored to synthesize the nanocomposites: direct Au(III) reduction within the matrix at various doses and pre-irradiation of dry or water-swollen disks followed by soaking in Au(III) solutions. The reduction efficiency was evaluated by UV-vis spectroscopy. Lead masks were used to spatially control the irradiated areas in samples exposed to 10 MeV EB at 5 kGy. The typical color change to purple-red assigned to the presence of AuNPs was precisely localized in irradiated areas of Au(III)-swollen hydrogels and not around. Furthermore, pre-irradiation of water-swollen disks and subsequent soaking in Au(III) solution resulted in a well-defined colored spot, yet much smaller in intensity. To improve the latter approach, one needs to characterize and quantify the long-lived polymeric species responsible for Au(III) reduction.
The effect of network mesh size which is dependent on the cross-linking content (0.5, 1, 2 and 5 wt.%) was shown to modify the UV-vis. spectra of the nanocomposites, presumably by controlling the nanoparticle size via the diffusion rate of Au(III) ions, of reducing species and/or of nanoparticles formed upon radiolytic synthesis. Sub-millimeter 2D hydrogel patterns were successfully converted into nanocomposites using the direct reduction method. Aging of the obtained polyHEMA-AuNPs composites is currently being examined.

FOOD IRRADIATION: WHERE IS THE LIMIT?

Amilcar L. Antonio[a], Sandra Cabo Verde[b]

[a]Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Portugal
[b]Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

Abstract:
Food irradiation persist as an underused technology in several countries, namely in Europe region, where scientific misconceptions about the technology are wide spread in the population, including in more educated persons. Also, EU regulations are quite old (from 1999) and contribute, in some way, to maintain this status quo. On the last years we have been validating the use of this technology in several food products (chestnut fruits, edible wild mushrooms, different fresh fruits, wild edible plants, etc), limiting our studies to a commercial-technological purpose, focusing on the low dose to attain the desired effect, without compromising the nutritional characteristics of the processed products. Recently, we have moved to a more scientific point of view, to test how far we can go, how high is the dose we could apply. Again, we re-started this scientific approach using chestnut fruits as a first case study. For that we have started to measure two physical parameters that are easily assessed (colour and texture), for doses up to 10 kGy. And the results shown that, for this specific case, colour changes and texture variation can easily be used to check at what dose to stop. Further studies are ongoing to assess other parameters (chemical composition and molecular structure) to check where is the "trigger" point to define the dose limit for this food product. With this work, extended to other food matrices, we expect to give a scientific contribute for a critical revision of current EU legislation for food irradiation limits and limited food products included in that list.

Keywords:
Food irradiation, dose limit, chestnut fruits, colour, texture

Acknowledgements:
Foundation for Science and Technology (FCT, Portugal) and FEDER, under Program PT2020 for financial support to CIMO (UIDB/00690/2020) and C2TN (UIDB/04349/2020). The authors are also grateful to the International Atomic Energy Agency (IAEA) for financial support through the Coordinated Research Project D61024 "Development of New Applications of Machine Generated Food Irradiation Technologies".

Reference
Ferreira, I. C. F. R., Antonio, A. L., & Cabo Verde, S. (Editors) (2018). Food Irradiation Technologies: Concepts, Applications and Outcomes. Cambridge, U.K.: Royal Society of Chemistry.

APPLICATION OF LOW ENERGY ELECTRON BEAM FOR MICROBIAL DECONTAMINATION OF FOOD PRODUCTS

Urszula Gryczka, Sylwester Bułka, Wojciech Migdał

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Currently for food irradiation highly penetrating ionizing radiation sources are used. New approach to radiation processing of food and agricultural products is related to limited penetration of electrons having energy below 300 keV. The advantage of such solution is that low energy electrons do not penetrate the whole volume of food products thus interacting less with food components. Additionally low energy e-beam machines do not require thick shields and can be applied for in-line irradiation or as mobile unites.
The scope of presented work was to investigate effectiveness of microbial decontamination process of pepper grains using low energy electron beam. In the experiments pepper grains were analyzed to determine process parameters ensuring high efficacy of microorganisms reduction. To ensure uniformity of the dose absorbed in the external layer of each food item, the grains were irradiated in rotating drum which allows to control dose of irradiation by control of irradiation time. For beam characteristic and dose measurements B3 dosimetric foil was used.
The results show reduction in number of microorganisms depending on the energy of electrons and doses of irradiation. The electron beam of energy 200 keV reduced number of microorganisms, however it penetrates the layer less than 150 μm thick which was not sufficient to penetrate the whole layer of pepper grains inhabited by microorganism. Application of higher energy electron beam resulted in increasing effectiveness of microbial decontamination process and for 300 keV electron beam it was comparable with high energy electron beam.

The work was support by the IAEA under the CRP D61024 DEXAFI (POL19000) and by the Polish Ministry of Science and Higher Education (project Nr 3671/FAO/IAEA/2017/0).

INTERLABORATORY COMPARISON FOR DETECTION OF IRRADIATED FOOD BY LUMINESCENCE METHODS

Ivana Sandeva[a], Aleksandar Krleski[a], Lihnida Stojanovska-Georgievska[a], Margarita Ginovska[a], Grażyna Liśkiewicz[b], Sandra Kerbach[c], Hristina Spasevska[a]

[a]Ss. Cyril and Methodius University in Skopje, Faculty of Electrical Engineering and Information Technologies, Macedonia
[b]Institute of Nuclear Chemistry and Technology, Independent Laboratory for Detection of Irradiated Food, Poland
[c]Eurofins Analytik GmbH

Abstract:
The main aim of this interlaboratory comparison is the investigation of the comparability of results produced under possibly different laboratory protocols for detection of irradiated food. The interlaboratory comparison ensures the highest quality results by identification of possible sources of variation and tests the reliability and reproducibility of routine measurements, thus forming an important part of a laboratory quality assurance program.
In the process of accreditation of the Laboratory for Detection of Irradiated Food at the Ss. Cyril and Methodius University in Skopje, the interlaboratory comparison was done with world-renowened laboratories in order to validate the already established protocols for detection of irradiated food by luminescence methods, including thermoluminescence and photostimulated luminescence. Measurements were done according to two standard physical methods for detection of irradiated food: Foodstuffs - Detection of irradiated food using photostimulated luminescence EN 13751:2009 and Foodstuffs - Thermoluminescence detection of irradiated food from which silicate minerals can be isolated EN 1788:2001. In the interlaboratory trial, the intensity of photostimulated luminescence, defined as amount of light detected during photostimulation and the intensity of thermoluminescence, defined as amount of light detected per unit temperature interval at a given heating rate, were analyzed. Measurements were done on different samples of food treated with different doses of ionizing radiation. One part of the samples was tested in the Laboratory for Detection of Irradiated Food in Skopje and the other parts were tested in the other laboratories that took part in the interlaboratory trial.
All tested samples were correctly identified as irradiated or unirradiated. Regression analysis shows good linearity, thus confirming consistency of results obtained in different laboratories.

Session: POSTER SESSION I

CHARACTERISTICS OF OUTPUT SYSTEMS USED IN HIGH POWER ELECTRON ACCELERATORS EQUIPPED WITH TYTANIUM WINDOW

Zbigniew Zimek

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
The electron beam in industrial applications is a form of energy that, when introduced into the irradiated object, enables the achievement of specific physico-chemical transformations. The efficiency of electron accelerators and electron beam spatial distribution determines the economic effects of radiation treatment. Understanding the factors affecting the amount of electron beam energy losses allows them to be reduced by optimizing the design of devices and the geometry of the irradiation process. Depending on the needs and capabilities, thin films of beryllium, aluminum, titanium-aluminum composite as well as films of titanium and titanium-based alloys are used as a window material in the accelerators. The basic requirements are a low atomic number to limit the amount of losses and appropriate mechanical parameters, allowing the thin film to withstand the stress caused by the pressure difference on both sides. To a significant extent, the electrical efficiency of accelerators depends on the principle of their operation. A common feature of all accelerators is the need to transfer the electron beam to the atmosphere through an output window possibly transparent for accelerated electrons. In industrial electron accelerators, thin films made of titanium are the most often used as the exit window due to the low atomic number and good mechanical properties. Low-electron accelerators (0.1-0.3 MeV) require film thickness to be limited to 6-20 μm due to loss of electron beam energy. This forces the search for optimal construction solutions to compensate for the limited mechanical strength of such a film. The high intensity beam requires the use of solutions aimed at the effective removal of thermal energy deposited in the window material by electrons. At higher electron energies, 50 μm thick titanium foils are commonly applied. Sometimes, for technological reasons, it is necessary to use a second window connected directly to the reaction chamber (e.g. radiation treatment of gases, liquids), which duplicates the level of losses and complicates the radiation treatment process. The construction solutions and failure frequency of the output devices with high-power electron accelerators equipped with titanium windows were discussed.

DOSE MAPPING OF PRODUCTS WITH DIFFERENT DENSITY IRRADIATED WITH CO-60 IRRADIATIOR

Ivica Vujcic[a], Slobodan Masic[a], Bojan Rankovic[b]

[a]Vinca Institute of Nuclear Sciences, Serbia
[b]Faculty of Technology and Metallurgy of the University of Belgrade, Serbia

Abstract:
The distribution of the absorbed dose of irradiation within the irradiated product is a complex function of the product density and homogeneity, as well as the position, and shape of the radiation source, and the design of the irradiator. In this paper, a complete dose mapping in products with different density (gauze, plastic, and soil), irradiated in the industrial Co-60 irradiator is provided. The positions of minimum and maximum absorbed radiation doses in different products are established. It is concluded that the irradiation dose absorbed in the material decreases almost linearly with increasing density of the material. Also, the homogeneity of the absorbed dose increases with increasing product density. For the lower density of products, the absorbed radiation dose is more properly distributed within the product.

DOSE MEASUREMENTS IN LIQUID FLOW SYSTEMS

Urszula Gryczka[a], Marcin Sudlitz[a], Sylwester Bułka[a], Marta Walo[a], Andrzej G. Chmielewski[a], Henryk Woźniak[b], Dariusz Wakuluk[b], Artur Kozdra[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Remontowa Shiprepair Yard S.A., Poland

Abstract:
The growing emphasis on environmental protection and reduction of pollutants emissions caused that industry is looking for a new solutions. The increase is observed in environmental research of ionizing radiation, which has been already applied for flue gas treatment to eliminate harmful sulfur and nitrogen compounds, water treatment to eliminate chemical contaminates or wastewater and sludge treatment thus eliminating bioburden.
One of the new areas where ionizing radiation can be applied is treatment of ships ballast water. The International Convention for The Control and Management of Ships Ballast Water Ballast Water and Sediments established by International Maritime Organization has introduced requirements to minimize the transfer of harmful aquatic pathogens in ships' ballast water. Currently applied solutions involve hybrid systems combining filtration with UV-irradiation, chemical treatment, electrolysis systems or ozone sterilization. The new approach is to use ionizing radiation in order to reduce the level of biological contamination. In proposed solution the sources of ionizing radiation is electron beam accelerator, working at the energy level 1 MeV. For this special conditions it is necessary to develop dosimetric procedures allowing to measure average absorbed dose.
Number of dosimetric system can be used to measure dose absorbed for flowing water e.g. temperature measurements, liquid dosimeters, TL or EPR dosimetry solids. The criteria for selection of dosimetric systems which can be used are insensitivity to humidity and the dose range.
In presented work the selected dosimetric systems were verified to evaluate their applicability for dose measurements in installations of liquids irradiation. The two systems tested were: conductivity measurements of alanine solutions [1] and EPR measurements of alanpol [2]. The tests performed for water irradiation in batch and continuous mode proved their applicability in tested system.

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Acknowledgement
The project is founded by POIG project POIR.01.02.00-00-0007/18 implemented under Measure 1.2 Sectoral R&D programs (INNOship) under the Operational Program Intelligent Development 2014-2020, co-financed by the European Regional Development Fund.

COMPARISON OF THE MEASURED AND CALCULATED DOSE MAPS IN GAMMA FACILITY IN AZERBAIJAN

Zaur Khalilov[a], Volodymyr Morgunov[b], Aygun Suleymanova[a]

[a]National Nuclear Research Center CJSC, Azerbaijan
[b]Progresa Final SK

Abstract:
Radiation technologies are widely used in modern life in many areas: medicine, industry, ecology, agriculture and etc.
The knowledge of dose (dose rate) maps inside the irradiation room is very important, especially for gamma facilities. Direct measurement of these maps is time consuming and costly. The numerical simulation can accelerate the process and decrease the cost of the dose mapping.
We compare the measured and calculated dose maps. The measurements were made by using alanine, ECB and B3 dosimeters. We used the Spectrophotometer UVmini-1240 and Spectrometer MiniScope MS400 for measurements.
The calculation was made using of Monte-Carlo simulation toolkit GEANT4. The accuracy of numerical simulation compared to the measured doses is up to 11 %.
The numerical simulation can be used for the dose map calculation.

ON-LINE MONITORING SYSTEM OF PROCESSING REGIME AT AN INDUSTRIAL ELECTRON ACCELERATOR

Vyacheslav Uvarov, Roman Pomatsalyuk, Valentin Shevchenko

National Science Centre "Kharkov Institute of Physics and Technology"(NSC KIPT), Ukraine

Abstract:
A LU-10 electron linac (10MeV, 10kW) operating in NSC KIPT provides by now above 70% of all services in radiation sterilization of medical devices, row materials and products of pharmaceutical and food industry in Ukraine. QA/QC of such technology requires keeping of absorbed dose in every unit of processed product within the specified limits. In the report, a system is described for continuous monitoring and archiving of critical parameters of the treatment regime (the electron energy, beam current, width and offset of the beam scan, the conveyor speed and the absorbed dose). Contact-free measurement of beam energy, and also of absorbed dose in every processed load is carried out by "radiation shadow" technique with the use of expanded stack-monitor positioned behind the irradiation zone.
The control system has been designed on the basis of EPICS package. The hardware comprises a set of primary sensors, a data acquisition subsystem using a multi-functional USB module, a single-board mini-computer to control the mode of the beam scanner, a kit of measuring instruments, connected to a local network, an automated operator workstation, and also a database server of radiation treatment parameters. The characteristics of the system as well as the procedures and results of its calibration are presented.

RADIATION INDUCED OSL OF POTASSIUM SULFATE

Renata Majgier, Mikhail Tsvirko, Arkadiusz Mandowski

Department of Experimental and Applied Physics,
Jan Dlugosz University in Czestochowa, Poland

Abstract:
The optically stimulated luminescence (OSL) method is widely used in dosimetry of ionizing radiation. The OSL phenonenon consists of two stages: excitation by ionizing radiation and stimulation. It results in emission of luminescence with intensity proportional to the absorbed dose. In the OSL method the stimulating factor is the light of appropriate wavelength. The OSL usually occurs in crystalline dielectric materials with a wide energy band gap. Until now only two materials, aluminium oxide dopped with carbon (Al_2O_3:C) and beryllium oxide (BeO), were recognized as OSL detectors. Much more materials have found use in the OSL-like thermoluminescence (TL) method. Dysprosium doped calcium sulphate phosphor is one of the most efficient phosphors in thermoluminescence. However, OSL properties of sulphates is much less known. The aim of this work is to study the dosimetric properties of selected sulfate salts using OSL method. Potassium sulfate was chosen due to the small number of reports about its OSL properties. Samples were prepared from analytical quality material. For the preparation of doped samples (K_2SO_4:Ce), the powder (potassium sulfate) was dissolved in distilled water. Then the dopant - cerium sulfate was added. The obtained crystals were then fabricated in the form of pellets (5 mm diameter x 1 mm thickness) by pressing crystalline powders at 2 ton/cm^2. To increase the luminescent signal, the pellets were annealed in a porcelain crucible in high temperature furnace. Potassium sulfate based detectors were irradiated using ^{90}Sr/^{90}Y beta source. Continuous wave OSL (CW-OSL) measurements were performed using custom made OSL reader HELIOS-1 with green light stimulation. The following dosimetric features were investigated: repeatability of the OSL signal, dose response and signal stability after irradiation. The material was tested for potential use in dosimetry of ionizing radiation. Investigation of pellets annealing temperature showed the largest increase in signal at 1000 ^{o}C. Therefore, this annealing temperature was found to be optimal for the preparation of highly sensitive K_2SO_4:Ce detectors. K_2SO_4:Ce pellets show linear dose response for dose range from 10 mGy to at least 12 Gy. The minimum detectable dose is estimated as 31 μGy. The OSL signal decreases to c.a. 30-40% of the initial value within first day, after which it tends to stabilize at least until one month. Strong luminescent signal (higher than for the standard Al_2O_3:C detector), good measurement repeatability, reusability and linear dose response up to 12 Gy makes K_2SO_4:Ce a promising material for radiation dosimetry applications.

RADIOBIOCONJUGATES OF GOLD NANOPARTICLES WITH $^{193M/195M}$PT CONJUGATED WITH TRASTZUMAB TO TARGETED AUGER THERAPY

Kamil Wawrowicz

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Heterogeneity of cancer cells and related to that different mechanisms of diseases makes impossible to find one, versatile way to carry on effective therapy. Growing interest of scientists is focusing on Auger electrons,, which have very short range in tissue (effective range between 1-20 nm) and are able due to their high linear energy transfer to cause double-strand DNA brakes Auger electrons characteristics, however, implicates many restrictions on scientists, among which most important is to synthetize bioconjugate in a such way that Auger electron emitters internalize into cell and next into the cell nucleus, locating as close to DNA as possible.

The purpose of this study is synthesis and in vitro evaluation of radiobioconjugate Au@$^{193m/195m}$Pt-PEG-Trastuzumab. We expect, the platinum radionuclides will dissolve in cytoplasm of SKOV-3 cells (which has high oxidative potential due to H_2O_2 presence), then internalize to nucleus and intercalate into the DNA. As part of current research synthesis of Au@Pt has been developed and Trastuzumab was successfully conjugated. Analysis of process have been performed with HR-TEM, DLS and ICP-MS techniques. In vitro receptor binding, internalization and toxicity studies for this bioconjugate have been performed with HER2+ cells (SKOV-3) and HER2- cells (MDA-MB-231).

Au@Pt nanoparticles have been covered with monolayer of platinum with >90% efficiency. Using labelling of Trastuzumab with ^{131}I method it was calculated, that one nanoparticle is conjugated with 22,4 +/- 1,4 Trastuzumab. In vitro results showed specific receptor binding and high (>93%) internalization into the cell. Obtained results are promising for next studies including both non-radioactive and radioactive $^{193m/195m}$Pt bioconjugates.

NUCLEAR TECHNOLOGY APPLICATIONS IN THE REPUBLIC OF TAJIKISTAN

Ulmas MIrsaidov, Zhahon MIrsaidov

Nuclear and Radiation Safety Agency, Tajikistan

Abstract:
The Republic of Tajikistan became a member of IAEA in 2001, and according to the Law of the Republic of Tajikistan "On Radiation Safety", Nuclear and Radiation Safety Agency (NRSA) of the National Academy of Sciences of Tajikistan is the State regulatory authority in the field of radiation safety, which pursues a unified state policy and coordinates the activity of relevant authorities and it is a focal point to the IAEA.
Currently, Tajikistan has received technical assistance from the IAEA more than 5 million euros for the implementation of national and regional projects.
According to the IAEA Technical Cooperation Project "Modernization of the Radiotherapy Service at the Oncology Research Center" a number of unique equipment had been installed. It should be noted, that after the development of the concept and plan for the modernization of the radiology department, it was overhauled on bases of state budget investments. Currently, the Teragam gamma-therapeutic apparatus and planning system have been installed. In the framework of this project, a number of radiologists and physicists of the Oncology Research Center had been trained at European countries for a period of one week to six months. It allowed using qualitatively new level of radiation therapy for cancer treatment in compliance with international standards. This project continues in 2020 as well with the purpose of updating the radiotherapy equipment of the Oncology Research Center. The cost of this project is more than 1.7 million euros in the city of Khujand (Northern Tajikistan).
Within the framework of the IAEA Technical Cooperation Project "Development of the Nuclear Medicine Service" the Institute of Gastroenterology of the NAST received equipment worth for more than 500 thousand euros including a Gamma-Spectrum camera (single-photon emission computed tomography), Biological Laboratory - Biohazart, Dose calibrator, etc. for the radionuclide diagnosis of patients. This equipment allows to determine higher technical indicators for the diagnosis of individual parts of the human body. Nowadays, diagnosis using the Gamma-Spectrum camera is one of the modern methods for vascular diseases of the brain, diseases of the cardiovascular system, kidneys and liver and oncological diseases. On the basis of the received equipment, the Center for Radionuclide Diagnostics and Therapy had been established at the Institute of Gastroenterology of the NAST, which is currently functioning successfully.

SUB-CELLULAR ELEMENTAL IMAGING OF HUMAN MUSCLE TISSUES AFFECTED BY NEUROMUSCULAR DISEASES

Patrycja Śliż[a], Marek Lankosz[a], Joanna Dudała[a], Dariusz Adamek[b], Borys Kwinta[b], Edyta Radawańska[b], Milko Jaksic[c], Iva Božičević Mihalić[c], Georgios Provatas[c]

[a]AGH-University of Science and Technology, Poland,
[b]Jagiellonian University Medical College, Poland,
[c]Ruđer Bošković Institute, Croatia

Abstract:
Myopathies are diverse group of muscle diseases. This is a sizable group of sickness with diverse grounds, various course and prognosis, but their common trait is a weakness of muscles. Myopathy can be divided because of the underlying background: inherited - which are separately classified as dystrophy, and acquired diseases. The lack of effective therapies for this disease results in a large amount of research done in this direction. The samples designed to the elemental analysis were prepared and diagnosed at the Department of Neuropathology of Collegium Medicum Jagiellonian University. Tissue materials were shock-frozen with liquid C_3H_8. For each specimen two adjacent tissue slices were cut into 8 micrometers on the cryo-microtome and placed on the microscope slice and Silicon Nitride Window (nitride thick: 200 nm, window size:2x2 mm^2). The samples for elemental measurements were freeze dried. Subsequently the adjacent slides was placed onto the standard slides for histological purposes (histochemical and immunohistochemical staining). There were four samples (control group, dystrophic and myopathic sample types) measured during experiment. The samples were measured at the cellular level with the use of fine focused ion microbeam. with protons energy up to 2 MeV. For elemental analysis Particle Induced X-ray Emission (PIXE) was applied. The sample was mounted on a cold finger and cooled using a liquid nitrogen cryostat. The PIXE measurements were combined with the registration of the energy of particles after passing through the sample, which is performed using Scanning Transmission Ion Microscopy (STIM) and provides information on the surface density. The sample was excited with a beam dimensions ca. 1 x 1 square μm. In each sample several areas ranging from 100x100 μm^2 to 500x500 μm^2 were scanned with steps of 1 μm. The fluorescence radiation was detected with the use SDD detector. The S, Cl, K, Ca, Fe, Cu, Zn were present in all fibers of muscles analyzed. The preliminary data analysis showed differences between the elemental composition of fibres affected by pathogenic changes. However, it should be considered that not all the fibres which constitute the tissue in a relevant sample are in the same phase of pathogenic changes. Some can present advanced changes, other initial ones. The discovered changes are supposed to be bigger after careful selection of the analysed fibres, which is a goal of the further analyses. The spatial inhomogeneity of fibre construction may also have a strong influence here.

STUDIES ON NEW METHOD FOR ACCELERATOR PRODUCTION OF ^{99}MO

Małgorzata Żółtowska, Izabela Cieszykowska, Tomasz Janiak, Tadeusz Barcikowski, Józef Leon Parus, Renata Mikołajczak

Radioisotope Centre POLATOM, National Centre for Nuclear Research, Poland

Abstract:
Technetium-99m is the most widely used isotope for medical imaging. Usually, it is produced by eluting from the ^{99}Mo/^{99m}Tc generators delivered to hospitals. Due to systematic worldwide decrease in the number of research reactors, in which the production of this radionuclide is possible, alternative methods of ^{99}Mo production or direct production of ^{99m}Tc are investigated. Relatively new method is the photonuclear reaction ^{100}Mo(γ,n)^{99}Mo under influence of bremsstrahlung of powerful electron accelerator. As this method produces low specific activity (LSA) ^{99}Mo, the efficient separation of ^{99m}Tc from the excess of molybdenum is required. This can be achieved by utilizing new adsorbents, which are either selective for ^{99m}Tc or show a large capacity for Mo.

This work presents results of the investigation of following stages related to obtaining of ^{99m}Tc using linear accelerator: preparation of robust ^{100}Mo target allowing high yield of ^{99m}Tc, rapid, simple and efficient methods for target dissolution and isolation of ^{99m}Tc from LSA ^{99}Mo.

It has been assumed that the optimal molybdenum target geometry for irradiation in the linear accelerator is the package of several thin molybdenum discs, 20 mm in diameter, mounted in an appropriate disc holder while maintaining gaps between the discs. The pressing of molybdenum powder into disc with the diameter of 20 mm and the thickness of 1.2 mm followed by its sintering in hydrogen atmosphere was employed for Mo target preparation and the process was optimized by adjusting the mass of the molybdenum powder to the given diameter and thickness and sintering process time and temperature.
Dissolution of molybdenum was carried out by oxidizing sintered molybdenum discs with 30% hot H_2O_2 and then alkalizing the solution in 5M NaOH. Depending on the number of Mo discs, the dissolution time was 10-20 minutes.
The separation of ^{99m}Tc from excess of molybdate ions was performed in the so-called reverse generator system using TK 202 resin (Triskem Int.) selective for ^{99m}Tc and allow molybdenum to pass through the column. ^{99m}Tc separation was most efficient in 5M NaOH. Depending on the molybdenum content in the starting solution, ^{99m}Tc recovery from the column containing TK 202 resin reached 90%-96.9%.
Acknowledgements: This project was supported with the funds awarded by the Ministry of Science and Higher Education in Poland within the agreement No. 3969/IAEA/2018/0, IAEA Research Contract No. 22652 and CERAD project, financed under Smart Growth Operational Programme 2014-2021, Priority IV, Measure 4.2.

VALIDATION OF THE CHEMICAL PROTOCOL FOR THE DETERMINATION OF LANTHANIDES ELEMENTAL IMPURITIES IN URANIUM OXIDES

Andreea Elena Serban, Florin Adrian Albota, Erhan Ionuz, Catalin Tuta, Viorel Fugaru, Marian Virgolici

Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Romania

Abstract:
A nuclear material can be characterized in terms of its physical and chemical characteristics such as: dimension, particle size, isotopic concentration, trace element impurities etc. Though these analyses can be performed through routine scientific methods (XRF, SEM, Gamma-spectrometry, ICP-MS etc.), origin assessment of a nuclear material is a difficult task that requires a joint approach. Nuclear forensics practitioners adopted a geological approach in characterizing the U ore in terms of elemental impurities concentrations. It was shown that the Rare-Earth Element (REE) pattern, along with the ratios of Pb, Sr and Nd isotopes, are specific to the extraction place of the primary U material. Nevertheless, these techniques were debated in international intercomparison exercises, and the scientific community supports new studies focused on their applicability in chronometry and provenance determination. An efficient procedure of sample preparation and data analysis is mandatory for an accurate measurement of U materials. The following study is therefore focused on the validation of the ICP-MS procedure for the determination of lanthanide elemental content and fingerprint in a Uranium Reference Material, without the use of chemical separation. The data analysis is focused on the validation of the following parameters: accuracy, precission (repeatability), and the determination of the limits of quantitation. In this study were collected 4 subsamples of UO2 produced by Merck, Germany. The proposed method for sample preparation and analysis of "UO2 Merck" samples has been validated and is proposed for routine lsaboratory testing. ICP-MS instrumental analysis, data interpretation and evaluation will be performed in the same manner as in the present validation study. The method described in this study represents an intermediate step towards fingerprinting uranium materials.

SOFTWARE FOR DQE CALCULATION IN DIGITAL MAMMOGRAPHY

Magdalena Dobrzyńska[a], Anna Wysocka-Rabin[a], Ewa Fabiszewska[b], Katarzyna Pasicz[b], Witold Skrzyński[b]

[a]National Centre for Nuclear Research, Poland
[b]Maria Sklodowska-Curie National Research Institute of Oncology, Poland

Abstract:
Detective Quantum Efficiency (DQE) is an objective parameter which describes performance of the detector in a mammography unit. DQE calculation is based on quantitative image analysis that is independent of the observer. In this work we present new software for DQE calculation that is fully compliant with the standards of the International Electrotechnical Commission (IEC 62220-1-2:2007).
This software was implemented in Python 3.7 language with a user-friendly graphic interface. Its step-by-step structure guides the user through the process of calculation of DQE components: Signal Transfer Property (STP), Noise Power Spectrum (NPS) and Modulation Transfer Function (MTF). If raw DICOM files are input using IEC recommended steps, the calculation procedure requires minimum action from user. Results are immediately displayed in diagram form and complete output data are exported to a .csv file, which allows the user to choose different displays or perform further analysis.
To illustrate the software performance, we present results obtain for a Siemens Mammomat Inspiration unit at the Maria Sklodowska-Curie National Research Institute of Oncology (MSCNRIO) in Warsaw. Measurements were made for different anode/filter combinations and tube voltage values (26 ÷ 34 kV) without an anti-scatter grid. An edge test device for MTF determination was constructed at the National Centre for Nuclear Research.

MONTE CARLO EVALUATION OF ARCCHECK® DETECTOR ACCURACY TO REPRODUCE DOSE DISTRIBUTION FROM IR-192 BRACHYTHERAPY SOURCES.

Adam Cichoński[a], Anna Wysocka-Rabin[a], Adam Kowalczyk[b]

[a]National Centre for Nuclear Research, Poland
[b]Maria Sklodowska-Curie National Research Institute of Oncology, Poland

Abstract:
An ArcCHECK® detector is a device designed to perform dosimetric measurements in external beam accelerator radiotherapy. It is a 3D detector array that contains 1386 semiconducting diodes, arranged in spiral pattern around a cylindrical cavity. However, the construction of the detector should also allow it to be used in brachytherapy to verify dose distribution from internal sources configuration. In this study, experimental irradiation of a specially designed phantom BrachyPlug placed inside the ArcCHECK® detector was performed. The BrachyPlug is a cylindrical-shaped, homogeneous PMMA phantom, with 3 systems of canals designed to reproduction of typical source configurations in brachytherapy treatment. The experimental irradiation plan included 120 source positions located in 6 canals of BrachyPlug phantom. The radiation source used in experiment was Ir-192 microSelectron-v3, one of the most common used in HDR brachytherapy. The final result of ArcCHECK® measurement is a 2D map of dose distribution on the detector's surface. In this study, the raw measurement results, output values from detector diodes, were compared with a reference dataset obtained from Monte Carlo simulation of the experimental setup. The simulation was performed in EGSnrc code. The simulation script, over 20 thousand lines, included 1386 detector diodes of ArcCHECK®, a BrachyPlug phantom with all 20 canals arranged in 3 systems, 120 source positions, 41 energy lines of Ir-192, material data and list of required parameters. Experimental raw data from the ArcCHECK® detectors were given in number of counts, whereas the calculation results were obtained in specific EGSnrc unit, the dose normalized per number of particles per number of sources. To avoid unit inconsistency, both experimental and simulation results were normalized to maximum value in each set, and were compared directly. The general accordance between simulation and measurement in presented study was considered satisfactory, with an average difference of diode output values 1.069% and SD 3.95%. In addition, a 2D map of obtained differences of output values was created to show where the differences were the highest. Most of the differences occurred close to areas where small unexpected source dislocations took place during the experiment. These differences in ArcCHECK® measurements from small source dislocations are further confirmation of the objective of this study, i.e. to illustrate the potential usefulness of the ArcCHECK® detector to verify a brachytherapy plan.

BEAM DYNAMIC CALCULATIONS FOR MODIFIED ACCELERATOR SYSTEMS IN THE EARLY NEUTRON SOURCE PROJECT

Wojciech Grabowski, Marcin Staszczak, Anna Wysocka-Rabin

National Centre for Nuclear Research, Poland

Abstract:
The Early Neutron Source project is part of the IFMIF (International Fusion Material Irradiation Facility) project under a Bilateral Agreement between EU and Japan.
The DONES (DEMO Oriented Neutron Source), which is a deuteron-lithium source of high energy neutrons, has been designed to test materials for the proposed fusion reactor. DONES will produce a 125 mA deuteron beam, which will be accelerated to 40 MeV energy and will hit a liquid lithium curtain, causing intensive neutron production. These neutrons will interact with experimental probes of materials in a test cell located behind the lithium target.
The DONES Accelerator System includes an injector, a low energy beam transport section, a Radio Frequency Quadrupole (RFQ) accelerator, a Medium Energy Beam Transport (MEBT), a Superconducting Radio Frequency Linear Accelerator (SRF-L) and a High Energy beam transport Line (HEBT).
The general aim of our research was SRF-L optimization following modification of the accelerating system. The specific aim of our calculations was to find phase values for each accelerating cavities separately, and to achieve a deuteron beam that matched each of two criteria simultaneously: (a) the energy of the beam had to reach at least 40 MeV at the end of SRF-L; (b) energy losses of the beam has to be less than 1 W/m.
Our initial calculations were performed for a 4-cryomodules design, which was later modified to a 5-criomodules SRF-L, which we optimised. For the best variant, beam energy was over 40.2 MeV and there were no losses. In the results presented here, the space between MEBT and SRF-L and the spaces between cryomodules were extended to allow for the possibility of adding more beam diagnostic devices.
Calculation results of beam energy losses, statistical parameters of the beam and beam density in analysed phase spaces were obtained using TraceWin code. TraceWin code was developed by CEA Saclay for linear and non-linear, 2D or 3D, charged particle beam dynamics calculations and optimization of beam parameters.
To determine the best solution, we checked 22 main variants of the extended 5-cryomodules accelerator. This variants differ with phase value for each accelerating cavity. For each main variant we calculated several sub-variants. Sub-variants have the same cavity phases, but differ in respect to optimization of other elements, such us solenoids.
The highest-ranked solution we found, achieved 40.18 MeV beam energy with no energy losses.

Session: POSTER SESSION II

RADIATION SYNTHESIS OF POLY(ACRYLIC ACID) NANOGELS FOR DRUG DELIVERY APPLICATIONS – POST-SYNTHESIS PRODUCT STABILITY

Beata P. Rurarz, Małgorzata Bukowczyk, Natalia Gibka, Sławomir Kadłubowski, Piotr Ulański

Institute of Applied Radiation Chemistry, Lodz University of Technology, Poland

Abstract:
Biomaterial engineering can exploit ionizing radiation in many ways. Among others, synthesis of polymer nanomaterials is considered as a very promising application. High-dose-rate radiation processing of dilute aqueous solutions of polymers, such as poly(acrylic acid) - PAA, can yield nanogel particles - internally cross-linked macromolecules, called also "frozen coils". These structures, in contrary to native untreated polymers, are able to retain their conformation despite changing environment (pH, ionic strength, temperature, concentration, etc.). That is why they are potentially applicable as nanocarriers in drug delivery applications. Reactive species generated by water radiolysis, particularly $^{\bullet}OH$ radicals responsible for reactions occurring in the system, allow carrying out the cross-linking process without adding harmful initiators, catalysts or crosslinking agents, rendering obtained nanoparticles perfectly suitable for biomedical applications.
One of the biggest problems with the use of nanoparticles however is their physical, chemical and biological instability, when aqueous suspensions are stored for prolonged periods. Therefore, development of the best protocols for the particular nanoparticles' storage is of essence. In our research we have already experienced some of the issues related to the product aggregation, and so far, we were resolving it by trial and error. Therefore, we have performed preliminary study in which we have systematically assessed the influence of various processing and storage scenarios we used to employ, on the stability of the radiation-synthesized PAA nanogel particles in suspension, in order to choose the optimal way of handling the product after its synthesis.
We have confirmed that none of the strategies we used to employ in our lab, and hence we have hereby tested, are substantially detrimental to our product. Filtration with 0.2 μm filters was proven sufficient for sample purification and prolonged storage in aqueous suspension did not exert negative effect on the stability of particles in suspension. We have also demonstrated that lyoprotectant-free lyophilization was suitable for our polymer nanoparticles, despite some earlier doubts. All samples were easily redispersible and reconstituted nanogels did not show any pronounced deviations in stability throughout the experiment. This is very important fact for further applications of particles as nanocarriers – if any stability problems will demonstrate following nanogels conjugation with targeting ligands or therapeutic moieties, we will know that those issues are not based on inherent properties of our polymer nanocarrier.

SYNTHESIS AND EB-INDUCED MODIFICATION OF POLY(HYDROXYETHYL METHACRYLATE)-BASED HYDROGELS

Katsiaryna Dziarabina[a], Sławomir Kadłubowski[a], Piotr Ulański[a], Uliana Pinaeva[b], Xavier Coqueret[b]

[a]Institute of Applied Radiation Chemistry, Faculty of Chemistry, Lodz University of Technology, Poland
[b]Institut de Chimie Moléculaire de Reims, Université de Reims Champagne-Ardenne, France

Abstract:
4D-printing is currently emerging as a new area of additive manufacturing. We are currently exploring the potentialities of high-energy radiation processing to impart additional functionalities to 3D-patterned polymeric objects produced by stereolithography and fuse deposition modeling.
Controlled exposure of polymer-based 3D-patterns to high-energy radiation can result in changes of molecular weight or in cross-link-density depending on the response of the given macromolecules in terms of scission and covalent interchain linkages. Radiation treatment can also be applied to more complex polymeric systems swollen by solutions of reactive components as metal salts or monomers, allowing for their functionalization by in situ radiolytic synthesis of metal NPs or for graft polymerization, respectively. This approach requires the advanced control of chemical modifications at the various stages of the elaboration process.
This communication reports on the synthesis and properties of hydrophilic networks based on blends of hydroxyethyl methacrylate (HEMA) and ethyleneglycoldimethacrylate (EGDMA) as a cross-linker, before and after exposure to EB radiation. The samples were prepared as disk-shaped xerogels by photopolymerization using 365 nm sources. The progress and completion of polymerization for various monomer blend compositions was monitored by near-infrared spectroscopy. The kinetic profiles of monomer conversion exhibit the typical sigmoidal shape associated with the auto-acceleration phenomenon that takes place during the free radical polymerization of monomers in the bulk state. Isothermal swelling kinetics of the xerogels in pure water was shown to follow a Fickian behavior with diffusion characteristics that were dependent on the EGDMA content (0 – 6 wt-%) but not much affected by the exposure duration.
EB-irradiation (10 – 100 kGy) of poly(HEMA) networks with various initial cross-link densities was shown to have a moderate impact on the swelling characteristics and thermomechanical properties of the materials treated in the dry or swollen state. However, gravimetric measurements revealed that irradiation induces the formation of extractables with a non-trivial dependence on dose.
Similar gels have been synthesized by UV irradiation at 254 nm, using concentrated (50 – 80%) aqueous solutions of HEMA and EGDMA, with H_2O_2 (6 – 15%) as a photoinitiator. On this basis, further tests have been performed, aimed at obtaining stimuli-sensitive gels, by adding cationic and anionic monomers as well as N-isopropylacrylamide as a precursor of thermosensitive products.
Preliminary experiments performed on the disk-shaped hydrogels and on 2D-patterned structures prepared on surface-treated glass plates using photomasks show that high-energy radiation post-treatment allows to produce grafted hydrogels and nanocomposites including gold nanoparticles.

RADIATION STABILITY OF HIGH TEST PEROXIDE (HTP)

Wojciech Głuszewski[a], **Natalia Okroj**[b]

[a]*Institute of Nuclear Chemistry and Technology, Poland*
[b]*JAKUSZ - SpaceTech Sp. z o.o., Poland*

Abstract:
Concentrated Hydrogen Peroxide (HTP) when used as an oxidant or as a mono-propellant is nearly non-toxic, while being environmentally friendly. For these reasons, it can be used in various rocket propulsion systems or for propulsion of gas turbines as the so-called "green" rocket propellant/oxidizer. Additionally, tests with the use of ionization radiation are of standard evaluation procedures for any propellant to be used in space. The effect of gamma radiation on the phenomenon of 90% and 98% hydrogen peroxide (four types of HP with different stabilizers) decomposition is described. The parameter used to express the amount of decomposition of HP is active oxygen loss (AOL), expressed as percent active oxygen loss (%AOL). Percent AOL is determined experimentally by measuring changes in mass (weight) and concentration. As an alternative method, the use of gas chromatography has been proposed. With the use of GC radiation doses can be examined two orders lower. In the gravimetric method, the doses were changed in the range from 500 to 5,000 Gy. In the chromatographic method, the doses varied from 20 Gy to 5,000 Gy. Dependencies of the amount of postradiation oxygen released as a function of dose size are presented. In experimental studies with the use of GC, it was found that all HTP samples in contact with glass slightly spontaneously decompose at room temperature. In order to assess this effect, tests were carried out on oxygen release efficiency without irradiation for 30 min, 60 min and 90 min from the moment the sample was poured into the bottle until the sample was injected onto the column. As a result, the average volume of oxygen released without irradiation of the samples was determined. Corrections were calculated as the starting point, taking the time from the moment the sample was poured into the bottle until the sample was injected onto the column. It is the sum of irradiation time and waiting time for analysis. It was quantified how the irradiation time (radiolytically generated water) affects the peroxide decomposition efficiency. Gas chromatography using a packed column (Al_2O_3) and a thermal conductivity detector is a convenient method for testing the stability of HTP-based rocket fuel.

Głuszewski, W., 2019. The use of gas chromatography for the determination of radiolytic molecular hydrogen, the detachment of which initiates secondary phenomena in the radiation modification of polymers, Polimery, 64, 10, 44-49.

IMPACT OF ELECTRON BEAM TREATMENT ON COPOLYMERS OF POLYLACTIDE AND POLY(TRIMETHYLENE CARBONATE) IN AN AIR ATMOSPHERE

Magdalena Rzepna[a], Grażyna Przybytniak[a], Jarosław Sadło[a] , Anna Iuliano[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Warsaw University of Technology, Poalnd

Abstract:
Polylactide (PLA) is currently widely used as medical implants in the form of anchors, screws, plates, etc. as well as decomposable packaging material (caps, bags). PLA is biodegradable and biocompatible polymer, but brittle. The addition of poly(trimethylene carbonate) (PTMC) increases flexibility, which makes PLA-PTMC copolymers an interesting materials for emerging applications. The growing interest in this types of polyesters and copolyestrs is associated with their interesting physical and chemical properties that largely meet the requirements of the medical and packaging industries. Exposure to high-energy radiation can also be a convenient way to modify or sterilize PLA-based products intended for medical applications.
The effect of exposure of polylactide (PLA) and poly(trimethylene carbonate) (PTMC) statistical copolymers to ionizing radiation was studied by means of EPR spectroscopy. In addition, the influence of radiation-induced processes on thermal properties, miscibility of the components, average molecular weight (Mw) and average molecular number (Mn) were investigated for doses in the range of 0-200 kGy. In copolymers containing PLA and PTMC components in a ratio of 30:70 and 70:30 dominated PLA radicals identified in the homopolymer under cryogenic conditions. This showed that PTMC radical centers either recombine or are transferred to PLA along the macromolecules. The results obtained for the nonirradiated and irradiated samples showed that the glass transition values measured by differential scanning calorimetry (DSC) and calculated using the Fox equation were similar and indicated the compatibility between the constituents of the tested copolymers and their miscibility. Mw and Mn changes measured by gel permeation chromatography were used to determine the radiation yield of scission G(S) and cross-linking G(X). In the case of PLA and PLA-rich copolymers, the difference between G(S) and G(X) with increasing dose increased, thus the chain scission predominated over cross-linking. For PTMC rich copolymer, the effect was the opposite - at higher doses the G(S)–G(X) difference decreased, indicating higher competitiveness of cross-linking under these conditions.

Acknowledgments
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871 and the Polish Ministry of Science and Higher Education, project 3697/H2020/2017/2.

EPR STUDY OF GAMMA IRRADIATED MEMBRANES DEDICATED FOR GAS SEPARATION APPLICATIONS

Marta Walo, Jarosław Sadło, Urszula Gryczka

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Radiation-induced grafting has been a powerful method to provide unique value-added materials from easily available polymers. This technique offers many advantages such as: simplicity in controlling parameters of grafting, uniform grafting of vinyl monomers or good reproducibility of treatment. Therefore, polymers grafting initiated by gamma or electron beam (EB) radiation is, in some fields a well-established technique that enables to prepare materials of tailored properties (e.g. metal ion adsorbents, battery separators, thermosensitive cell culture surfaces, antibacterial masks, etc.) [1].
For several years membrane processes are of great interest due to the possibility of applying these technologies for the removal of pollutants from both the liquid and gas phases. The increase in the use of membrane technologies is associated with their continuous development, increased ecological awareness and the fact that they remain efficient in the light of increasingly restrictive environmental regulations. However, new membranes with improved properties are still needed to be used more widely in the existing applications and in new one as well. Radiation grafting is one of the method used for modification of membranes properties.
Membrane processes can be used for biogas purification and enrichment. Enrichment of biogas to have of higher calorific value can be achieved by removal of carbon dioxide. Thus obtained biomethane may be applied as fuel for heat and electricity co-generation or after compression as a fuel for automobiles [2].
In the present work, the radicals created during the gamma irradiation of membranes dedicated for gas separation applications were studied. Analysis of radical centres in commercial polyimide film known as Kapton and Matrimid 5218 was performed in order to estimate the susceptibility of the polymers to the formation of radicals, and indirectly, ability to form covalent bonds with the monomer molecule grafted onto these surfaces.
Samples were gamma irradiated in air and in vacuum at room and liquid nitrogen temperatures. Interpretation of the experimental signals was proposed and the mechanism of radicals decays in irradiated polymers was suggested.

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Acknowledgements

The work is performed in the frame of IAEA Coordinated Research Project "F22072": "Development of Radiation-Grafted Membranes for Cleaner and Sustainable Energy (Contract No: 23589).

THE EFFECT OF NANOCELLULOSE ADDITION AND RADIATION TREATMENT ON THE PROPERTIES OF STARCH-PVA FILMS

Krystyna Cieśla[a], Anna Abramowska[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Advanced Pharmaceutical Concepts (APS) Institute, Poland

Abstract:
The studies are directed to search of new materials for biodegradable packaging, in particular for food foreseen for radiation decontamination, as well as the new "green" technologies supported by ionizing radiation that might be applied for manufacturing of new materials based on renewable resources. .
Nanocellulose (NC) became attractive last decade as a good compatibilizer in polymer blends according to its unique structure and high reactivity. The present studies concerns the effect of addition of nanocellulose to the composition of the films based on starch:PVA system, supported by ionizing radiation
Our previous results have already shown that appropriate selection of starch:PVA ratio and irradiation conditions enables to produce good quality films [1, 2]. It was also found that NC reveal considerably higher sensitivity to irradiation as compared to micro-metric celluloses [3], Currently, the effect of ionizing radiation on the properties of the films prepared with addition of nanocrystalline cellulose, nanofibrinal cellulose or nanobiocellulose at the level till 10 % was studied.
The films were prepared by solution casting. Irradiations were carried out in Gamma Chamber or in e-beam using doses in the range 5 -70 kGy. Examination of mechanical properties, contact angle to water, swelling in water, gel content and SEM observations were done for evaluation the films' properties.
The effect of irradiation depend on the sample composition and on the irradiation condition. It was found that addition of NC decreases participation of degradation and increases participation of crosslinking processes.
Selected compositions containing nanocellulose have revealed better mechanical properties as compared to the films prepared without the NC addition, and appeared resistant to irradiation, or show improvement of particular properties after irradiation. The radiation effect can be related to the modified microstructure of the films and to the surface oxidation processes, and show the formation of the crosslinked network of starch:PVA matrix with NC under ionizing radiation.
The materials seems to be appropriate for packaging of food foreseen for radiation decontamination. It can be concluded that addition of NC and radiation treatment is an useful procedure in manufacturing the better starch:PVA films.

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INFLUENCE OF THE NUMBER OF DOUBLE BONDS IN FATTY ACIDS CROSSLINKED ON COPPER ON ITS CORROSION INHIBITION IN ATMOSPHERIC CONDITIONS

Katarina Marusic, Nives Matijaković, Damir Kralj, Branka Mihaljević

Ruđer Bošković Institute, Croatia

Abstract:
Copper is a malleable and ductile metal which is a very good conductor of both heat and electricity. Copper has low chemical reactivity. In moist air it slowly forms a greenish surface film called patina which protects the metal from further attack. Because of its advantages copper has a wide range of applications. To prolong the lifetime of copper made objects its surface is treated by different coatings, which are often not safe for the environment. Due to this reason new protective coatings are being developed for application on copper.
Fatty acids are long chain molecules and non-toxic compounds with an affinity for self-assembling on metals. Once self-assembled on its surface the metal becomes hydrophobic. Thus, by blocking access for water to the surface the dissolution of the metal is disabled. If the fatty acid is unsaturated the film can be crosslinked by the use of gamma irradiation. Crosslinking makes the film more durable and stable. The protective efficiency of coatings developed this way depends on the type of fatty acid used, preparation conditions and environment the metal is exposed to.
In this work the protective efficiency of coatings prepared from two different unsaturated fatty acids is compared: elaidic and linoelaidic acid. Both compounds are unsaturated trans fatty acids with 18 carbon atoms, where elaidic has one, while linoelaidic acid has two double bonds.
The developed coatings were characterized by FTIR and goniometry. Their protective properties were investigated by electrochemical methods (potentiodynamic polarization and electrochemical impedance spectroscopy) in a solution simulating urban atmospheres. The optimal conditions for crosslinking were determined and the properties of the obtained coatings, as well as the properties of the non-crosslinked coatings were compared. The results have shown that both coatings offer good protective properties to copper in atmospheric conditions. For successful crosslinking a larger irradiation dose is needed in the case of linolelaidic acid.

RHEOLOGICAL, MICROSTRUCTURAL AND THERMAL PROPERTIES OF MAGNETIC POLY(ETHYLENE OXIDE)/IRON OXIDE NANOCOMPOSITE HYDROGELS SYNTHESIZED USING ONE-STEP GAMMA-IRRADIATION METHOD

Ivan Marić[a], Nataša Šijaković Vujičić[b], Anđela Pustak[a], Marijan Gotić[c], Goran Štefanić[c], Goran Dražić[d], Jean-Marc Grenèche[e], Tanja Jurkin[a]

[a]Ruđer Bošković Institute, Radiation Chemistry and Dosimetry Laboratory, Croatia,
[b]Ruđer Bošković Institute, Laboratory for Supramolecular Chemistry, Croatia,
[c]Ruđer Bošković Institute, Molecular Physics and Synthesis of New Materials, Croatia,
[d]National Institute of Chemistry, Department of Materials Chemistry, Slovenia,
[e]Institut des Molécules et Matériaux du Mans CNRS UMR-6283, Le Mans Université, France

Abstract:
Magnetic polymer gels are a new promising class of nanocomposite gels with numerous potential application as effective absorbents of toxic ions in water, in soft actuators such as artificial muscles, in tissue engineering, drug delivery, hyperthermia applications etc. The aim of this work was to explore the ability of γ-irradiation technique for a one-step synthesis of magnetic hydrogels. Magnetic PEO/iron oxide nanocomposite hydrogels were successfully synthesized using one-step γ-irradiation method starting from poly(ethylene oxide) (PEO) and iron(III) suspensions followed by simultaneous crosslinking of PEO chains and reduction of Fe(III) precursor. γ-irradiation dose and concentrations of Fe^{3+}, 2-propanol and PEO in the initial suspensions were varied and optimized. With 2-propanol and at high doses magnetic hydrogels with embedded magnetite nanoparticles were obtained, as confirmed by XRD, SEM and Mössbauer spectroscopy. The quantitative determination of γ-irradiation generated Fe^{2+} was performed using the 1,10-phenanthroline method. DSC and rheological measurements confirmed the formation of well-structured network. The thermal and rheological properties of the gels depended on the dose, PEO concentration and amount of nanoparticles synthesized inside gels (initial Fe^{3+} content). Both enthalpies and temperatures of melting and crystallization of gels decrease with the dose and the amount of formed magnetic NPs. More amorphous and stronger gels were formed at higher dose and higher nanoparticle content. The properties of the synthesized gels were determined by the presence of magnetic iron oxide nanoparticles, which acted as reinforcing agents and additional crosslinkers of the PEO chains thus facilitating one-step gel formation.

This work was financially supported by the Croatian Science Foundation under the project UIP-2017-05-7337 “The impact of polymers on the radiolytic synthesis of magnetic nanoparticles” (POLRADNANOP).

A CONTROLLABLE METHOD FOR THE SYNTHESIS OF MAGNETIC IRON OXIDE AND IRON OXIDE/AU NANOSTRUCTURES USING γ-IRRADIATION

Ivan Marić[a], Anđela Pustak[a], Marijan Gotić[a], Goran Dražić[b], Goran Štefanić[a], Krešo Zadro[c], Tanja Jurkin[a]

[a]Ruđer Bošković Institute, Croatia
[b]National Institute of Chemistry, Slovenia
[c]University of Zagreb

Abstract:
Magnetic iron oxide nanoparticles (MNPs) due to their unique magnetic and electrical properties have applications as sensor, contrast agents, in drug delivery and for hyperthermia cancer treatments. In this work we have used γ-irradiation as an attractive and ecologically friendly technique for the synthesis of magnetic nanoparticles at room temperature. γ-irradiation has an advantage of inducing electrons and other reducing species homogeneously through the sample. We have systematically studied the influence of γ-irradiation dose on the synthesis of iron oxide nanoparticles. The iron(III) chloride alkaline aqueous solutions were purged with nitrogen and g-irradiated with addition of 2-propanol. DEAE-dextran was used as growth and stabilizing agent of MNPs in suspensions. The phase composition, stoichiometry and morphology of MNPs were controlled by adjusting γ-irradiation dose and dose rate. Irradiation with doses 10 - 36 kGy resulted in the formation of very small 4 nm spherical substoichiometric magnetite NPs, whereas at higher dose (50 kGy or more) the major phase was magnetic δ-FeOOH (feroxyhyte) in the form of nanodiscs. The magnetic measurements showed superparamagnetic behaviour of magnetite NPs and exceptional intrinsic room-temperature magnetic properties of δ-FeOOH nanostructures with the Curie temperature above 300 K. The reduction of ferric (Fe^{3+}) to ferrous (Fe^{2+}) ions was quantitatively determined using the 1,10-phenanthroline spectrophotometric method. The reduction proceeds fast in the beginning stages of irradiation (up to 30 kGy, ~65% Fe^{3+} reduced), slows down after this initial period, and reaches 100% reduction at ~75 kGy. However, ferrous ions (Fe^{2+}) that formed upon γ-irradiation of iron(III) precursor in the form of intermediate $Fe(OH)_2$ were highly susceptible to oxidation and in the contact with air oxidized to Green Rust (formula) and further upon isolation to δ-FeOOH nanodiscs. Furthermore, the possibility to use γ-irradiation to form iron oxide/Au nanostructures was explored.

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Acknowledgments:
This work has been supported by the Croatian Science Foundation under the project UIP-2017-05-7337 (POLRADNANOP).

THE USE OF GC AND DRS TO STUDY POSTRADIATION PHENOMENA OF POLYPROPYLENE OXIDATION

Wojciech Głuszewski

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
The main problems hindering recycling are different product quality compared to their original counterpart. In practice, large quantities of recycled plastics with strictly controlled specifications and a competitive price are also needed. In this context, it is interesting to what extent the radiation treatment of polypropylene (PP) affects the properties of the recyclate. To date, radiation-resistant PP varieties have been sought in the context of medical devices. Currently, however, in connection with the search for ecological solutions in the field of polymers, a greater propensity of radiation-modified PP to biodegradation may be its advantage.
Observation of dynamics of oxidation processes in polymers is convenient by gas chromatographic method. One record secures determination of abstracted H_2, and CO. The present work shows also advantages of oxygen determination, in particular the loss of oxygen, consumed in oxidation of polymer. Therefore the determination of the rate of oxidation is easily measured, as well as the formation of one of the oxidation products.
Particularly interesting is the case of polypropylene, in which ionizing radiation initiates the chain oxidation process. The oxygen connection is accompanied by regeneration of the macro radical at a different point in the chain. Samples of polypropylene were irradiated at room temperature and liquid nitrogen temperature. For radiation treatment, electron beams (linac "Elektronika 10/10", dose rate of 14,000 kGy/h) and gamma radiation (radiation sources: GC 5000 and Issledovatel, dose rates of 3.5 and 0.35 kGy/h) were used. Oxygen was absorbed until its complete depletion in bottles (after about 250 hours at 22°C and 400 hours for -192°C) with average yields of 3.5 μmol/J and 1.4 μmol/J per hour.
Primary (deprived of standard photostabilizers and antioxidants) polypropylene produced in Basell Orlen Polyolefins was used in the research. The phenomena of postradiation oxidation of non-transparent powders were studied using DRS (Diffuse Reflection Spectroscopy). Postradiation oxidation of irradiated and non-irradiated polypropylene was compared.
Styrene was used in studies of the protective effect of aromatic compounds in PP radiolysis. As a recycled material, radiation-treated PP can be used, for example, to obtain PP/wood pulp composites.

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MODIFICATION OF THE PROPERTIES OF THE FILMS FORMED IN THE STARCH: PVA: NANOCELLULOSE SYSTEM BY ADDITION OF THYMOL AND IONISING RADIATION

Krystyna Cieśla, Joanna Drewnik

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Development of the radiation techniques of polymer modification and of the radiation decontamination and sterilization methods of food and medical equipment induces the need for search the packaging for the products predicted for processing, characterized by at least good resistance to ionizing radiation.
The packaging materials based on natural and biodegradable polymers are at present in focus. Accordingly, methods for optimizing the properties of such materials are being sought, alike modification of their composition and various chemical and physical treatment. Among the other, small molecular products might be introduced into the materials' compositions.
Thymol (Th, 2-izopropylo3-metylo phenol) is a natural phenol terpenoid, occurring in some spice plants. It is sometimes introduced into packaging materials in character of active component.
Our previous studies have shown that modification of the composition supported by irradiation enables to prepare better films in the starch:PVA and starch:PVA:nanocellulose (NC) systems. The present studies concerns the effect of introduction of thymol supported by gamma and electron irradiation on the functional properties of the films prepared basing the above systems.
The films were prepared by solution casting. Irradiations were carried out wth gamma rays or with fast electrons, using the absorbed doses in the range 5 - 25 kGy. Mechanical properties, contact angle to water, swelling in water, gel content, and antioxidant activity were determined for evaluation the films' properties. SEM observations were also done.
Addition of thymol to the films prepared in the starch:PVA and starch:PVA:NC systems contributes to increase in their plasticity and elasticity (with possible decrease in tensile strength). This might be accompanied by increase in hydrophilicity. Irradiation of the films at appropriate conditions lead to further increase in plasticity (with accompanying decrease in hydrophilicity). This result differs from the effect of irradiation detected in the case of the films with similar composition prepared without addition of thymol (decrease in plasticity). The results can be related to the possible participation of thymol molecules in formation of crosslinks between the polymer macromolecules.
In summary: The films prepared basing starch:PVA:NC:Th system with a use of radiation technique have revealed the improved plasticity, as compared to the films prepared basing starch:PVA:NC system. Simultaneously, the film were characterized by acceptable tensile strength and hydrophilic/hydrophobic properties.
The films retain their appropriate functional properties after irradiation with doses in the range up to 25 kGy, which predestines them as potential packaging materials for products subjected to radiation decontamination or sterilization.

RADIATION TREATMENT OF BOOK COVERS MADE FROM LEATHER

Katarina Marusic[a], Helena Pišonić[b], Branka Mihaljević[a]

[a]Ruđer Bošković Institute, Croatia
[b]Faculty of Chemical Engineering and Technology, Croatia

Abstract:
The use of radiation treatment for preservation of cultural heritage has been growing in recent years. Its many advantages compared to classical treatment have attracted attention in many countries. Although the interest in this treatment has grown often conservators and restorers are sceptic towards the effect radiation has on the materials the object is made from. In many cases the object is made of multiple materials and these materials are mostly treated with different coatings or varnishes either to protect the object or to enhance its appearance. The wider use of this technique necessitates a multidisciplinary approach for effectively demonstrating that irradiation does not lead to unacceptable changes in the functional or decorative properties of the artefact as well does not compromise with the authenticity of the artefact.
Leather is a common material used on cultural heritage, like books, furniture or clothing. The process for preparing leather is complex itself, and the restorers make the situation even more complicated when they additionally treat leather with preservatives. All these processes can have an impact when it comes to degradation by irradiation.
In this work the impact irradiation and its conditions have on goatskin used for bookbinding was investigated. Pure goatskin, as well as goatskin treated by two different preservatives commonly used by book restorers was irradiated with different doses and dose rates. The samples were investigated by colorimetry and FTIR and their pH was monitored in the process. The results have shown that the type of preservative used does play a role when it comes to observing changes in irradiated goatskin, but the observable changes were noticed only at doses greater than the doses that are used for treating cultural heritage.

INVESTIGATING CULTURAL HERITAGE MODERN MATERIALS AFTER GAMMA IRRADIATION

Silvana Vasilca[a,b], Daniel Negut[a], Mioara Alexandru[a], Marian Virgolici[a], Valentin Moise[a]

[a]"Horia Hulubei" National Institute of Physics and Nuclear Engineering, Centre of Technological Irradiations IRASM, Romania,
[b]University of Bucharest, Faculty of Chemistry, Department of Analytical Chemistry, Romania

Abstract:
Apart from climatic, chemical, mechanical or thermal factors that induce the degradation of Cultural Heritage artifacts, microorganisms can also play a huge part. It's important to keep the biodegradation level to minimum in order to maintain object's appearance, but also its chemical, physical and mechanical properties. They can lead to stains or discoloration of the surfaces and if the signs of the biodegradation process are not identified in time, objects can be completely destroyed. Cellulose and collagen-based materials, under certain conditions, are largely susceptible to fungal and bacterial damage, due to the action of specific enzymes like cellulases, proteases, glucanases or collagenases and organic acids [1]. Ionization radiation's bactericide and fungicide effect is known for a very long time. Working at DNA level, its efficiency and efficacy advises it for the disinfection of Cultural Heritage artifacts. As for its effect on modern materials, less attention has been paid and very little data can be found in literature.
In the present study, a multi-technique approach was used, based on the combined employment of both in situ non-destructive/ non-invasive techniques (Vibrational Spectroscopy and Colorimetry) and a destructive technique (Simultaneous Thermal Analysis), for the evaluation of ionizing radiation treatment on several modern artifacts, like a colour photograph and colour images printed by laser-jet technique. The present study also proposes an overview of a microbiology assay on the effectiveness of the treatment by ionizing radiation, estimating the microbial load on the surface of different kind of modern objects (cardboard posters and slides), from the archive of The Romanian Peasant Museum. The choice of treatment dose was made for an optimal value between a significant biocidal effect and a minor effect on the physico-chemical properties of the treated objects. In order to establish the effectiveness of gamma radiation treatment, tests for microbial load were performed on the surface of objects, pre- and post-irradiation.
Besides investigating and indicating gamma radiation's effect on these case studies of modern materials by their characterization, this study will highlight once again the fact that it is prerequisite in CH objects' decontamination.

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Acknowledgements:
National Project "Interdisciplinary applications of gamma radiation" (2019-2022)

COMBINATION OF METHODS OF THERMAL AND RADIATION TREATMENT OF SEDIMENTS ASSOCIATED WITH PCBS – THE DELOR TYPE

Marko Fulop[a], Andrea Sagatova[b], Ivan Benkovsky[c], Lubica Foltinova[d], Kamil Conka[e],

[a]ABRS Ltd., Slovakia
[b]Slovak University of Technology in Bratislava, Slovakia
[c]Comenius University in Bratislava, Slovakia
[d]University of Economics in Bratislava, Slovakia
[e]Slovak Medical University in Bratislava, Slovakia

Abstract:
The PCB incineration method is often used to remove the environmental burden by PCBs substances. However, the combustion process produces toxic dioxins and furans (hereinafter also referred to as PCDD / Fs), so this method is increasingly rejected by the inhabitants. Therefore, other, so-called non - combustion methods.
In some non-combustion methods, such as the heat treatment method of sediments, small amounts of PCDD / Fs are produced. If the concentration of PCBs in sediments is high, such as sediments in the Strážský channel, even this non-combustion method can produce PCDD / Fs in concentrations for which it is necessary to remove them. Then, after the heat treatment method, it is preferable to use a radiation processing method that is effective for removing PCDD / Fs. The radiation processing method also removes PCBs from sediments in a second step by degrading congeners until they are converted into biphenyls, which decompose easily in the environment.
The paper presents preliminary results of a simple verification experiment of a combination of the method of heat treatment and the radiation processing method of sediments of the Strážsky channel contaminated with Delor-type PCBs.
By this combination the effectiveness for PCB destruction increased the PCB removal coefficient from 45% to 91%. PCDD / Fs substances formed during previous heat treatment of sediments were destructed by radiation processing, as well.

Announcement:
Irradiation was performed by the linear electron accelerator of UCEA SZU in cooperation with Progresa Final.

IMPROVEMENT OF RADIATION DEGRADATION OF PCBS IN SEDIMENTS

Andrea Sagatova[a], Marko Fulop[b], Ivan Benkovsky[c], Kamil Conka[d], Lubica Darazova[a]

[a]Slovak University of Technology in Bratislava, FEEIT, INPE, Slovakia
[b]ABRS Ltd., Slovakia
[c]Comenius University in Bratislava, Faculty of Pharmacy, Slovakia
[d]Department of Toxic Organic Pollutants,Faculty of Medicine, Slovakia
Slovak Medical University in Bratislava, Slovakia

Abstract:
Polychlorinated biphenyls $C_{12}H_{10-n}Cl_n$ (PCBs) are chemically stable viscous fluids with low flammability. They were used in electric equipment (transformers, capacitors), as additives for lubricants or for hydraulic fluids' and adhesives' production. But due to their toxicity combined with ability to accumulate in fatty tissues of organisms they were realized dangerous and their production was stopped. However, the prevention of their release into the environment was not successful and the PCBs present a serious environmental problem nowadays.

One of important producers of PCBs with commercial names Delor, Hydelor and Deloterm was also Chemko Strazske Ltd. in Eastern Slovakia (1959-1984). The locality near factory with an area of 3000 km^2 and 250,000 inhabitants is considered as one of the most PCB contaminated territories in Europe. The most critical is the sediment in the sewer of chemical factory, where PCBs' contamination exceeds the allowed limits more than 1000-times.

In our research we have aimed to decrease the PCB contamination in the highly contaminated sediments from factory canal by non-thermal, environmental friendly radiation method. The radiolytic dechloration of PCBs was obtained by ionizing radiation in combination with co-solvent in aqueous solution. As the source of ionizing radiation the 5 MeV electron beam was used, applying the dose of 100 and 200 kGy, respectively. The samples were irradiated at linear electron accelerator in Trencin, Slovakia. Two co-solvents were compared to achieve the most effective dechloration. The optimized concentration of co-solvent in sample has improved the radiation degradation by factor of two. The concentration of particular PCB congeners was monitored to evaluate the results. The concentration of PCB congeners in samples was measured at the Department of Toxic Organic Pollutants of the Slovak Medical University in Bratislava. The isotope-dilution method by using of ^{13}C-labeled standard solution with high-resolution mass spectrometry was used.

BALLAST WATER TREATMENT TECHNOLOGY FOR FLOATING "GREEN DOCK"

Tomasz Smoliński[a], Marcin Rogowski[a], Urszula Gryczka[a], Dagmara Chmielewska-Śmietanko[a], Zbigniew Zimek[a], Zbigniew Samczyński[a], Henryk Woźniak[b], Dariusz Wakuluk[b], Artur Kozdra[b], Andrzej G. Chmielewski[a]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Remontowa Shiprepair Yard S.A., Poland

Abstract:
The International Convention for The Control and Management of Ships Ballast Water and Sediments established by International Maritime Organization has introduced requirements to minimize the transfer of harmful aquatic pathogens in ships' ballast water. In the result of these new strict standards ships and shipyards have to use the advanced systems of the ballast water treatment. Currently applied solutions involve hybrid systems combining filtration with UV-irradiation, chemical treatment, electrolysis systems or ozone sterilization. A well-known problem of oxidative water treatment is the formation of disinfection by-products, many of which show genotoxicity, carcinogenicity, or other long-term toxicity. The new proposed approach is application of electron beam irradiation to reduce the level of biological contamination in the water. Before this process water needs filtration pre-treatment. Moreover this is only one of the components of proposed system since shipyard is willing to recycle water for secondary technological use. Solid particulate, ions and other chemical contamination treatment methods are applied along the line. Laboratory tests were carried out for samples of water and sediments left in the ballast tanks taken from several ships arriving to the shipyards from different regions of the world. The samples were taken during dry docking procedure. The doses required to assure microbiological safety (Toxicogenic vibrio cholerae < 1; Escherichia coli < 250; Intestinal enterococci < 100, all - cfu per 100 mL) were evaluated and were less than 3 kGy. Additionally eb irradiation has impact on solid sedimentation properties. On the basis of laboratory experiments a layout of "green dry dock" with electron accelerator installed on board has been developed.

Acknowledgement
The project is founded by POIG project POIR.01.02.00-00-0007/18 implemented under Measure 1.2 Sectoral R&D programs (INNOship) under the Operational Program Intelligent Development 2014-2020, co-financed by the European Regional Development Fund. International collaboration is carried out in the frame of H2020 ARIES (EU) project 'Accelerator Research and Innovation for European Science and Society' and the Ministry of Science and Higher Education (Poland) co-financing project.

INACTIVATION OF INVASIVE MARINE SPECIES AND HARMFUL BACTERIA IN THE PROCESS OF IRRADIATION OF BALLAST WATER WITH ELECTRON BEAM

Dagmara Chmielewska-Śmietanko[a], Urszula Gryczka[a], Henryk Woźniak[b], Artur Kozdra[b], Dariusz Wakuluk[b], Andrzej G. Chmielewski[a]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Remontowa Shiprepair Yard S.A, Poland

Abstract:
The spread of possible harmful invasive aquatic organisms from one region to another caused by the discharge of the ship's ballast water poses a threat to the world's oceans and has gained increasing awareness worldwide.
In 2004 the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments. When the convention enters into force all ships in international traffic must eventually comply with the established discharge limits, D-2 standard which is based on the abundance of different size classes (>10 µm to ≥50 µm) of viable organisms and specified indicator microbes that are harmful to human health (Escherichia coli, Enterococci, Vibrio cholerae). Therefore, to meet the standards various types of equipment, based on different technologies, have been developed for the treatment of ballast water. Most systems for ballast water treatment use UV and electrochemical treatment. The rest uses processes such as ozonation, ultrasound, the addition of biocides, or deoxygenation.
In this work radiation processing technology using electron beam accelerators that offer an innovative solution for rapid damage and destruction of harmful marine organisms, including viruses, bacteria without the addition of chemicals is presented. Samples of water left in the ballast tanks taken from several ships arriving to the shipyards from different regions of the world were used in laboratory experiments. The samples were taken during dry docking procedure. The doses lower than 3 kGy were sufficient to assure microbiological safety, while higher doses (5 kGy) were required for the destruction of harmful marine organisms.

Acknowledgement
The project is founded by POIG project POIR.01.02.00-00-0007/18 implemented under Measure 1.2 Sectoral R&D programs (INNOship) under the Operational Program Intelligent Development 2014-2020, co-financed by the European Regional Development Fund.

EFFECT OF GAMMA IRRADIATION ON MICROBIOLOGICAL AND NUTRITIONAL PROPERTIES OF THE FREEZE-DRIED BERRIES

Slobodan Masic[a], Ivica Vujcic[a], Hristina Spasevska[b]

[a]VINCA Institute of Nuclear Sciences, Serbia
[b]Faculty of Electrical Engineering and Information Technologies, University in Skopje, Macedonia

Abstract:
Lyophilization, also known as freeze-drying or cryodesiccation, is a low-temperature dehydration process that involves freezing the product, lowering pressure, and then removing the ice by sublimation. Freeze-drying is most commonly used to make instant coffee but also works extremely well on fruits such as apples and berries. Freezing does damage living cells, mostly because water expands when freezing, and ice crystals can break the cell walls. Thus, some bacteria will be destroyed by freezing. However, freezing does not remove all bacteria from food. It may decrease the number of bacteria present, but it is not an acceptable way of food conservation, because many harmful bacteria will generally still survive.
Therefore, the method of additional irradiation with gamma rays is applied. It is known that exposure of food to gamma radiation up to 10 kGy destroys microorganisms in food. In this paper, the influence of gamma irradiation on the reduction of microorganisms, molds, and bacteria was examined. For this purpose, five types of berries were tested: blackberries, raspberries, strawberries, blueberries, and sour cherries. It was shown that the radiation dose of 8 kGy is sufficient to eliminate the total number of microorganisms, molds, and bacteria below the permitted limit. Also, it was concluded that gamma irradiation does not affect the nutritional value of the freeze-dried berries.

DETECTION OF RADIATION TREATED VEGETAL EXTRACTS BY THERMOLUMINESCENCE METHOD

Magdalena Miłkowska, Grażyna Liśkiewicz

Institute of Nuclear Chemistry and Technology, Poland

Abstract:
Vegetal extracts the components of dietary supplements and pharmaceutical medicines are distributed in trade in the form of fine powders.
The treatment of foods with the use of ionizing radiation is adapted for reducing of the number of pathogenic microorganisms responsible for food-born diseases and shelf-life extension.
The FAO/WHO Codex Alimentarius adopted dietary supplements containing vegetal extracts, vitamins and microelements as foodstuffs.
In European Union food irradiation is regulated by two EU Directives 1999/2/EC and 1999/3/EC, respectively [1, 2].
In accordance with the Directive 1999/2/EC, any irradiated foodstuff should be properly labeled, even if contains a small admixture of irradiated component only. For the detection of irradiated food standard CEN (European Committee for Standardization) detection methods can be only applied.
Detection method EN-1788-2001[3] is frequently adapted to food from which silicate minerals can be isolated [3].
The aim of the present study is to test the efficacy of this thermoluminescence method for the identification of vegetal extracts exposed to ^{60}Co gamma radiation.
The variety of 10 vegetal extracts adopted in pharmaceutical industry have been tested. The samples of all 10 extracts were irradiated with the doses of 0.5 and 4 kGys, respectively. From the results obtained it was concluded that vegetal extracts available in trade can be reliably detected with the use of thermoluminescence detection method.

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APPLICABILITY OF THERMOLUMINESCENCE FOR DETECTION OF IRRADIATED FOOD TREATED WITH LOW ENERGY ELECTRON BEAM

Grażyna Liśkiewicz[a], Urszula Gryczka[a], Florent Kuntz[b], Dalal Werner[b]

[a]Institute of Nuclear Chemistry and Technology, Poland
[b]Aerial, France

Abstract:
Irradiation is one of a food treatment method aim to increase food safety and thus, reduce food loses. To detect weather food was irradiated or not, number of methods were elaborated and standardised. Techniques detecting irradiation are based on paramagnetic properties of irradiated food (EPR), measurements of energy trapped in minerals (TL, PSL), radiation induced chemical changes (GC/MS) or DNA damage.
Thermoluminescence (TL), is one of the most often used technique which can detect irradiation in food containing minerals like dried herbs, spices, both fresh and dehydrated fruits and vegetables treated with gamma radiation, high energy electron beam or X Rays. However, new approach to radiation processing of food and agricultural products is related to usage of low energy electrons (below 300 keV) limiting their penetration. However, applicability of standardized detection methods needs to be verified for this process.
The scope of presented work was to test spices according to European standard EN 1788:2001 "Foodstuffs - Thermoluminescence detection of irradiated food from which silicate minerals can be isolated" to detect irradiation of food products treated with low energy electron beam. In the experiments, samples of black and green pepper were irradiated with electron beam at different energy levels: 9 MeV, 300 keV, 230 keV and 200 keV and analysed by two laboratories: INCT (Poland) and Aerial (France). Results obtained in both laboratories were 100% consistent. All samples of black pepper were correctly classified. However, green pepper samples irradiated with 200 keV electron beam couldn't be classified.
The results confirmed validity of the method according to European standard EN 1788:2001 to detect irradiation of food with low energy electron beam even though, it is necessary to verify the method for higher number of samples in order to define possible limitations.

The work was support by the IAEA under the CRP D61024 DEXAFI (Poland - Research Contract 19000; France - Research Agreement FRA 19211) and by Polish Ministry of Science and Higher Education project Nr. 3671/FAO/IAEA/2017/0.

Index

R

S

T

U

V

W

Z

ISBN 978-83-946412-4-5

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