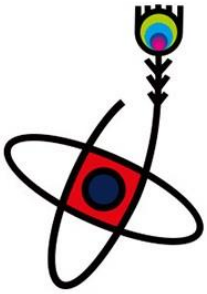


NUTECH–2017

International Conference on

Developments and Applications of Nuclear Technologies

Book of Abstracts

10-13 September 2017

AGH Kraków

AGH University of Science and Technology
Faculty of Science and Applied Computer Science
Kraków 2017

ISBN 978-83-925779-5-9

Organizers & Sponsors

AGH University of Science and Technology
Faculty of Physics and Applied Computer Science

Faculty of Physics and Applied Computer Science

Faulty of Energy and Fuels

Institute of Nuclear Chemistry and Technology

Co-operation

International Atomic Energy Agency

International Irradiation Association

Conference program

Cultural Heritage and Environmental Protection

FULL FIELD PIXE WITH AN X-RAY CAMERA PRESENTING HIGH-ENERGY AND HIGH-LATERAL RESOLUTION

Francesco Paolo Romano[1,2,*], Claudia Caliri[2], Lighea Pappalardo[1,2], Francesca Rizzo[2], Hellen Cristine Santos[2]

[1]CNR, Istituto per i Beni Archeologici e Monumentali, Via Biblioteca 4, 95124 Catania, Italy
[2]INFN, Laboratori Nazionali del Sud, Via Santa Sofia 62, 95123, Catania, Italy

ABSTRACT

Analytical applications often require the noninvasive and simultaneous elemental mapping of samples with spatial resolution and chemical sensitivity. Particle Induced X-ray Emission (PIXE) is a well-established technique that can be used for mapping the lateral distribution of chemical elements. Generally, elemental images are obtained in dedicated beam lines by scanning the samples with a primary beam (i.e., low energy protons) focused down to a dimension of few tens of microns or less. In recent times, a Full Field PIXE method has been developed as a novel alternative to the scanning approach. A broad beam irradiates the sample at once; X-ray fluorescence induced by the primary radiation is detected through a polycapillary installed in front of a position- and energy-sensitive detector allowing the fast elemental imaging. This work discusses the possibility of performing the FF-PIXE with a commercial and low cost CCD detector coupled to a 1:1 straight shaped polycapillary. This system, named Full Field X-ray Camera (FF-XRC), has been recently developed at the LANDIS laboratory of INFN-LNS and IBAM-CNR in Catania (Italy). The use of a special photon counting technique allowed the use of the device for the energy and laterally resolved X-ray fluorescence spectroscopy. The FFXRC is operated with an in-house programmed software programmed in Matlab. It controls the device and allows performing on the fly the elemental imaging of samples with a region of interest (ROI) method. At the end of a measurement, it creates the spectra of each pixel allowing analyzing collected datasets with a least square fitting imaging procedure available in external software (for instance in PyMCA). The low cost of the system, compact dimensions and the easy-to-use electronics (only a USB cable and an office PC is necessary to control the instrument) make this device a valid tool for Full Field imaging applications. The FF-XRC camera has been installed in a FF-PIXE end station at the 80° beam-line of the INFN-LNS operated with a low energy proton beam of wide dimensions extracted in the air. The beamline is served by a 13 MV TANDEM accelerator that provides, among others ions, proton beams up to 25 MeV energies. Proton energy can be tuned down to about 5 MeV and a maximum current of 1 mA can be delivered to users for experiments. A sample holder equipped with a 4 axis travel system is positioned at about 14 cm from the Kapton window. This air path allows to degrade proton energy down to a value of about 3 MeV, better suited for performing PIXE measurements on samples. The beam dimension is about 30 mm diameter that fully cover the field of view of the detector. Results of the use of the novel FF-PIXE end station in applications of interest in Cultural Heritage and Geochemistry are presented and discussed.

INVESTIGATION OF LONG LASTING LUMINESCENCE IN HALITE FROM KLODAWA SALT MINE

Magdalena Biernacka*, Renata Majgier, Arkadiusz Mandowski

Institute of Physics, Jan Dlugosz University
ul. Armii Krajowej 13/15, 42-202 Częstochowa, Poland

Keywords: optically stimulated luminescence (OSL), variable delay optically stimulated luminescence (VD-OSL), regeneration effect (RE), halite.

ABSTRACT

Halite (rock salt) is a mineral, which is one of the most common occurring on the Earth. Halite has the ability to store information on the absorbed dose of ionizing radiation in its crystal structure. The recovery of the dose is possible using modern luminescent methods, such as optically stimulated luminescence (OSL).

Due to high sensitivity to radiation and strong luminescence signal, halite seems to be promising for retrospective reconstruction of absorbed dose. However, the prospective effectiveness of these methods depends on the knowledge about luminescence kinetics in the material. Dosimetric properties of halite are determined by complex processes leading to luminescence emission. One of the phenomena hindering interpretation of OSL signal is regeneration effect (RE). This effect relates to self-renewal of the OSL signal between subsequent continuous wave OSL (CW-OSL) readouts [1,2,3]. Theoretical explanation of this phenomenon is still not clear. However, possibly it relates to simultaneous localized and delocalized transitions of trapped charge carriers [2].

This work presents studies on long lasting luminescence in halite. The method of variable delay OSL (VD-OSL), designed specifically to study RE [2], was used to determine the time scale of regeneration in halite depending on various factors, e.g. dose, measurement temperature and storage after irradiation. The samples were collected from the salt mine in Kłodawa (Poland). Irradiation was made using laboratory $^{90}Sr/^{90}Y$ β source. The equipment used for VD-OSL measurements was custom-made OSL reader HELIOS-1 [4], as well as commercially available Risø TL/OSL reader [5].

[1] Biernacka, M., Mandowski, A. (2013). Radiation Measurements, 56, 31-35.
[2] Mandowski, A., Biernacka, M. (2014). Radiation Measurements, 71, 265-269.
[3] Biernacka, M., Majgier, R., Maternicki, K., Liang, M., Mandowski, A. (2016). Radiation Measurements, 90, 247-251.
[4] Mandowski, A., Mandowska, E., Kokot, L., Bilski, P., Olko, P., Marczewska, B. (2010). Elektronika: konstrukcje, technologie, zastosowania, 51(2), 136-138.
[5] Bøtter-Jensen, L., Bulur, E., Duller, G. A. T., Murray, A. S. (2000). Radiation Measurements, 32(5), 523-528.

Acknowledgements: This work was partly supported by research project no 2014/15/N/ST10/05148 from the Polish National Science Centre.

* corresponding author: m.biernacka@ajd.czest.pl

THE ANALYSIS OF SELECTED ELEMENTS ACCUMULATION IN ARABIDOPSIS THALIANA BY MEANS OF RADIOTRACER METHOD

J. Dudała, M. Kud, R. Szymańska, P. Sekuła, B. Ostachowicz

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Mickiewicza Av. 30, 30-059 Krakow, Poland

Keywords: radiotracer method, Arabidopsis thaliana, model organism

ABSTRACT

The aim of the presented study was to determine the influence of ionizing radiation on the development of *Arabidopsis thaliana* as well as the degree of accumulation of selected elements using the radiotracer method. *Arabidopsis thaliana* is a small annual flowering plant in the mustard family (Brassicaceae). Its rapid life cycle and ability to growth in the laboratory make it a model organism for the study of plant physiology, biochemistry and development

In order to perform the experiment 98 plants were used. They were divided into seven groups treated with different ways between 20^{th} and 40^{th} day of their life cycle. Among them there were three groups treated with radioactive solutions of sulphur S-35, iron Fe-59 and the mixture of radioactive sulphur and iron (S-35 plus Fe-59). The next three groups were treated with nonradioactive solutions of sulphur, iron and the mixture of sulphur and iron. There was also one control group which was treated with distilled water.

Forty days after planting the plants were gently pulled out of the ground and washed with distilled water. Then they were morphologically tested (the plant size, stem length, leaf number, rosette quality etc.). The next step was the determination of the content of chlorophyll A and B as well as the content of carotenoids. The radiometric methods were used to analyse the radionuclide content in analysed samples.

The results of the investigations allowed to determine the influence of physical and chemical factors such as the radiation influence and concentration of selected elements on the growth plant process.

Acknowledgements

This work was supported by the Polish Ministry of Science and Higher Education and its grants for Scientific Research.

X-RAY DUAL SOURCE COMPUTED TOMOGRAPHY AS A MODERN TOOL IN THE INVESTIGATIONS OF WOODEN SCULPTURES

Anna Mikołajska[*1] , Małgorzata Urbańczyk Zawadzka[2], Robert Paweł Banyś[2], Agnieszka Kosakowska[3]

[1]Academy of Fine Arts in Cracow, Poland – Faculty of Conservation and Restoration of Works of Art, Laboratory of Conservation Chemistry and Physics
[2] Radiology and Diagnostic Imaging Department, John Paul II Hospital
[3] Consiste – Conservation and Restoration Company

Keywords: wooden sculptures, technical structure, non-destructive investigation, Computed Tomography

ABSTRACT

For over a century, X-ray radiation plays an important role in the cultural heritage area. X-ray techniques belong to the fundamental methods used in the investigation and conservation of works of art. They have been developed over the last decade thanks to the recent use of new and advanced analytical techniques.
Computed tomography (CT) is one of the most powerful non-destructive techniques and therefore it is used for the full volume inspection of an object. It provides morphological and physical information on the inner structure of investigated objects. The only disadvantage of this technique is its cost and therefore it is rarely used as a standard tool in the investigations of cultural heritage objects.
Few years ago the collaboration between Radiology and Diagnostic Imaging Department (John Paul II Hospital) and Laboratory of Conservation Chemistry and Physics (Academy of Fine Arts in Cracow, Poland – Faculty of Conservation and Restoration of Works of Art) started.
For the last two years we have examined many sculptures and wooden panel painting, inter alia, the Crucifix from the oldest church in Kraków, Church of St. Adalbert or the globes from the Museum of Collegium Maius. Using this technique we are able to look inside the object and localize every single change in the wood, joins of different elements or any other elements added through the ages. The other main advantage of this technique is also the possibility of creating 3D scans.
For this presentation we have chosen two sculptures made of different kinds of wood.
The first one is the gothic sculpture, Saint Mary's sculpture of the crucifixion group from the church in Gryfów Śląski. The other one is also gothic, it's also Saint Mary's sculpture of the crucifixion group but from the church in Gorysławice.
The DSCT investigation has provided important information on the condition of two sculptures and the spatial distribution of layers with different attenuation of X-ray radiation (ground layers, fillings, paint layers).

* corresponding author: amikolajska@asp.krakow.pl

NUCLEAR MICROPROBE IN ANALYSIS OF ENVIRONMENTAL SAMPLES

W.J. Przybyłowicz[*1,2] and J. Mesjasz-Przybyłowicz

[1] Materials Research Department, iThemba LABS, South Africa
[2] AGH University of Science and Technology, Faculty of Physics & Applied Computer Science, Poland

Keywords: PIXE, RBS, PIGE, STIM, elemental mapping

ABSTRACT

Using focused ion beams of MeV energy provides set of complementary methods, referred to as a nuclear microprobe, for microanalysis and micro-mapping of major, minor and trace elements in environmental samples. Particle Induced X-ray Emission (PIXE) is typically complemented by ion backscattering spectrometry (BS) or scanning transmission ion microscopy (STIM), particularly useful in the evaluation of the specimen matrix of biological materials. PIXE is able to simultaneously detect almost all elements present in environmental materials, at sensitivities down to parts per million. Nuclear reactions induced by the ion beam also enable analysis of light elements, not accessible by PIXE (e.g. F, B, Li, Be,…).

In this presentation we will show selected examples from a broad range of environmental studies realized using the nuclear microprobe at iThemba LABS (South Africa), from analysis and mapping of uranium distribution in coal ores, through projects related to ecophysiology, such as changes in elemental distribution related to mycorrhiza and plant-insect herbivore interactions, to nutrient biofortification of a staple food and phosphorus toxicity affecting farming of protea plants.

[*] corresponding author: przybylowicz@tlabs.ac.za

SOURCE IDENTIFICATION AND APPORTIONMENT OF PM2.5 FRACTION IN SIXTEEN EUROPEAN CITIES - OUTCOME OF THE IAEA REGIONAL TC PROJECT

L. Samek[1], N. Civici[2], F. Mutallimov[3], R. Radic[4], B. Veleva[5], K. Sega[6], I. Beslic[6], K. Eleftheriadis[7], E. Diapouli[7], S. Vratolis[7], Z. Kertesz[8], D. V. Turchenko[9], M. Bernatonis[10], L. Nikolovska[11], G. Djukanovic[12], D. Jancic[13], V. Balan[14], L. Furman[1], Z. Stegowski[1], S. M. Lopes Almeida[15], M. Radenkovic[16], N. Banu Oztas[17], E.Hristova[5], L. Vukic[20], J. Knezevic[21], M. Manousakas[7], A. Stefanovska[22], E. Cantay[17], A. M. Rodriguez Y Baena[18], A. Markowicz[19], R. Padilla Alvarez[19], A. Karydas[19]

[1]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, ul. Mickiewicza 30, 30-059 KRAKOW, POLAND
[2]Centre of Applied Nuclear Physics, Qesarake Street, P.O. Box 85, TIRANA, ALBANIA
[3]Ministry of Ecology and Natural resources of the Republic of Azerbaijan ,National Environmental Monitoring Department, 50 Haydar Aliyev Ave., BAKU, AZERBAIJAN
[4]Republic Hydrometeorological Institute, Put Banjaluckog Odreda bb., P.O. Box 147, 78000 BANJA LUKA, BOSNIA AND HERZEGOVINA
[5]National Institute of Meteorology and Hydrology Bulgarian Academy of Sciences, 66 Tzarigradko Chaussee, 1784 SOFIA, BULGARIA
[6]Environmental Hygiene Unit, Institute for Medical Research and Occupational Health (IMI), Ksaverska cesta 2, P.O. Box 291, 10001 ZAGREB, CROATIA
[7]National Center of Scientific Research "Demokritos",P.O. Box 60228, Patriarhou Grigoriou and Neapoles, Agia Paraskevi, 15310 ATHENS, GREECE
[8]Institute for Nuclear Research, Hungarian Academy of Science, Bemter 18C, 4026 DEBRECEN, HUNGARY
[9]National Nuclear Center of the Republic of Kazakhstan, Institute of Radiation Safety and Ecology, Krasnoarmeyskaya 2, 071100 KURCHATOV, KAZAKHSTAN
[10]Environmental Protection Agency, A. Juozapavičiaus 9, LT-09311 VILNIUS, LITHUANIA
[11]Institute of Public Health, SKOPJE, REPUBLIC OF MACEDONIA
[12]Environmental Protection Agency, IV Proleterske, 81000 PODGORICA,MONTENEGRO
[13]Center for Ecotoxicological Research of Montenegro (CETI), Put Radomira Ivanovica 2, PO Box 371, 81000 PODGORICA, MONTENEGRO
[14]State Hydrometeorological ServiceGrenoble Str 134, MD-2072 CHISINAU, REPUBLIC OF MOLDOVA
[15]InstitutoSuperior Tecnico, Universidade de Lisboa, Estrada Nacional 10, BOBADELA-LRS, PORTUGAL
[16]Vinca Institute of Nuclear Sciences, P.O. Box 522, 11001 BELGRADE, SERBIA
[17]Saraykoy Nuclear Research and Training Center, Turkish Atomic Energy Authority (TAEK), Atom Caddesi No. 27, 06983 ANKARA, TURKEY
[18]International Atomic Energy Agency, Department of Technical Cooperation, Division for Europe, Europe Section 1, B1086, Vienna International Centre, Wagramer strasse 5,P.O. Box 100, 1400 VIENNA, AUSTRIA
[19]International Atomic Energy Agency, Department of Nuclear Sciences and Applications,
Division of Physical and Chemical Sciences, Physics Section, Nuclear Spectrometry and Applications, Laboratory SEIB, Vienna International Centre, Wagramer strasse 5, P.O. Box 100, 1400 VIENNA, AUSTRIA
[20]University of Banja Luka, Faculty of Technology, BANJA LUKA, BOSNIA AND HERZEGOVINA
[21] Serbian Environmental Protection Agency, Ruze Jovanovic 27a, 11 160 BELGRADE, SERBIA
[22] Ministry of Environment and Physical Planning, SKOPJE, REPUBLIC OF MACEDONIA

ABSTRACT

The study was performed in 16 countries in the frame of the International Atomic Energy Agency (IAEA) Regional Technical Co-operation (TC) project entitled "Supporting Air Quality Management (Phase II)". The aim of the project was to increase the knowledge about the status of atmospheric pollution in the TC Europe Region by broadening access to nuclear (or related) analytical techniques together with source apportionment and long-range transport tools. The major objective of the project was to establish a monitoring network for the purpose of: (1) verifying the compliance to European regulation on admissible values for mass concentration of air particulate matter (APM) and regulated metals (Pb, Cd, Ni, As), (2) source apportionment studies and long-range transport of pollutants at regional and global scale. Samples of PM2.5 fraction of air particulate matter were collected in each country at urban background (13 cities located in Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Kazakhstan, Lithuania, Republic of Macedonia,

Montenegro, Republic of Moldova, Poland, Portugal*)*, suburban (1 city located in Turkey) and background (2 sites located in Azerbaijan, Serbia) locations from January 2014 to January 2015 every 3rd day (24 hour sampling). Some countries extended sampling to December 2015. In total 2067 samples were collected and analyzed in all countries mentioned above. Annual average mass concentration of PM2.5 fraction was in the range of 9.8(±4.1) $\mu g/m^3$ for Kazakhstan - 55(±43) $\mu g/m^3$ for Turkey. During winter they were in the range 11.8(±7.9) $\mu g/m^3$ for Greece to 69(±36) $\mu g/m^3$ for Republic of Macedonia while during summer the values were from 4.1(±1.4) $\mu g/m^3$ for Lithuania to 31.8(±8.2) $\mu g/m^3$ for Republic of Macedonia. Elemental composition of PM2.5 was determined by XRF or PIXE as well as ICP-MS. Source identification and apportionment by positive matrix factorization model (PMF) was performed for concentration data from 14 countries. Twelve different sources of PM2.5 were identified as follow: secondary aerosol, biomass burning, traffic, oil combustion/refinery, steel, smelting, Ca-enriched, winter sanding, mineral dust, marine aerosol, incineration and cement production.

SILVER DENARII OF THE EARLY PIASTS ANALYZED BY PIXE AND XRF

Janusz Lekki[*1], Czesława Paluszkiewicz[1], Ewa Pięta[1], Tomasz Pieprzyca[1], Zbigniew Szklarz[1], Marta Matosz[2], Julio M. del Hoyo Meléndez[2]

[1]Institute of Nuclear Physics, Polish Academy of Sciences, PL31422 Cracow, Poland
[2]Laboratory of Analysis and Non-Destructive Investigation of Heritage Objects, The National Museum in Krakow, PL31109 Cracow, Poland

Keywords: micro–PIXE, micro–XRF, Silver denarii, medieval Poland

ABSTRACT

The late X century in Poland is the time of development of a Polish medieval state, together with introduction of denarii, being an attribute of independency and authority of the first Polish rulers. The scarcity of denarii from this time period is remarkable as there are only about two hundred and fifty items currently above ground. The biggest fraction of this set is housed in a National Museum in Cracow and this collection was the object of the current study, which aim is to determine the denarii surface elemental composition. The major elements detected for these denarii are Ag and Cu, while minor elements such as Pb, Fe, Au, Bi, and Zn may also be present. In a previous study [1], this collection was examined using micro-X-ray fluorescence (XRF) spectrometry and multiple conclusions have been drawn, mostly based on the quantitative determination of major elements. In the current study particle induced X-ray emission (PIXE) spectroscopy was employed with the aim of cross–comparing the results obtained with both techniques and performing a better quantification of the denarii elemental composition, especially for trace elements. An evaluation of the results generally shows a slightly higher Ag content determined by PIXE relative to XRF, in the 90-97% Ag range. This assessment of the data suggests that the majority of the denarii analyzed are characterized by Ag surface enrichment, which is a common process observed in archaeological silver-copper alloys. This observation is possible when one considers the lower penetration depth of the protons used in the PIXE analysis relative to that of the primary X-rays generated by the Rh tube used in the XRF examination. Although the data obtained from both techniques offer information about the composition of the base alloy, it is important to consider that deposition of corrosion products at the surface of the denarii may be also accountable for the variations observed due to the use of different micro-sampling locations with each of the two instruments. The two techniques evaluated offer a promising tool for numismatic studies since they provide a way of conducting nondestructive quantitative analysis of silver-copper alloys used in historical denarage.

[1] J.M. del Hoyo-Melendez, P. Świt, M. Matosz, M. Woźniak, A. Klisińska-Kopacz, Ł. Bratasz, *Nucl. Instrum. Meth. In Phys. Res.* **B 349** (2015) 6.

[*] corresponding author: Janusz.Lekki@ifj.edu.pl

AIR QUALITY IN KRAKOW: APPLICATION OF CARBON ISOTOPE COMPOSITION TO QUANTIFY FOSSIL FUEL CONTRIBUTION TO TOTAL SUSPENDED PARTICULATE MATTER

M. Zimnoch, F. Morawski, J. Bartyzel, K. Rozanski

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, al. Mickiewicza 30, 30-059 Krakow, Poland

ABSTRACT

According to the latest urban air quality database, a majority of cities with more than 100 000 inhabitants do not meet WHO air quality guidelines [1]. Social initiatives as well as a city authorities activities aiming at implementation of the mitigation strategies cause interest increase in research towards better understanding of parameters and mechanisms influencing on air quality in urban environment (sources of particulate matter and gaseous contaminants, spatial and temporal variability of air quality, impact of atmospheric dynamics on the air quality, and several others).

Krakow belongs to four largest cities in Poland and simultaneously ranks among the most polluted cities in Europe. With nearly one million inhabitants, rapidly growing car traffic and significant industrial activities, Krakow agglomeration represents a typical urban environment in the eastern Europe. Characteristic features of the local climate are generally weak winds (annual average around 2.7 m s^{-1}) and frequent temperature inversions, extending sometimes over several days, particularly during winter seasons. These factors favor accumulation of pollutants originating from surface emissions in the city atmosphere. There is an ongoing discussion on the role of different emission sources of total suspended particulate matter (TSPM) in the city's atmosphere, such as traffic, low- and high-level emissions related to burning of coal for heating purposes, resuspension of street dust, and some others.

The presented work was aimed at exploring possibilities of using carbon isotope composition of total particulate matter collected in Krakow atmosphere, for better characterization of TSPM sources in the city, with the focus on seasonal changes of the character and intensity of those sources. Archived samples of TSPM deposited on filters (sampling interval between 5 and 20 days) and spanning the period 2005 - 2010 [2] were used for this purpose. For each year one pair of filters representing summer and winter conditions was selected.

The measurements of ^{13}C and ^{14}C content in the total elemental carbon collected on filters revealed large seasonal variability of these two parameters. The mean fossil-fuel carbon fraction (pFF) derived from AMS radiocarbon analyses was 66.2 and 38.1%, for winter and summer samples, respectively. There was a strong positive correlation of pFF with $\delta^{13}C$, suggesting intensified burning of coal as the main source of fossil fuel derived carbon during winter in the city. Intensified burning of fossil fuels during winter was also reflected in larger percentage of fossil carbon in gaseous CO_2 present in the city atmosphere ($ffCO_2$) during winter. The linear relationship observed between pFF and $ffCO_2$, when extrapolated to $ffCO_2 = 0$ suggest that during summer ca. 30% of fossil carbon in TSPM originates from sources not related to burning processes (most likely wearing of car tires and asphalt).

References:

[1] WHO's Urban Ambient Air Pollution database - Update 2016 (www.who.int/phe).

[2] M. Zimnoch, P. Wach, L. Chmura, Z. Gorczyca, K. Rozanski, J. Godlowska, J. Mazur, K. Kozak, A. Jeričević. Factors controlling temporal variability of near-ground atmospheric ^{222}Rn concentration over central Europe.Atmospheric Chemistry and Physics, **14** (2014) 9567-9581.

THE FULL-FILED XRF IMAGING SYSTEM FOR NON-INVASIVE INVESTIGATION OF ARTWORKS

A. Mendys[*1], T. Fiutowski[2], P. Frączek[2], S. Koperny[2], M. Lankosz[2], B. Łach[2], B. Mindur[2], K. Świentek[2], P. Wiącek[2], P. Wróbel[2], W. Dąbrowski[2]

[1] The National Museum in Krakow, Al. 3 Maja 1, 30-062 Krakow, Poland
[2] AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Al. Mickiewicza 30, 30-059 Krakow, Poland

Keywords: X-ray fluorescence imaging, cultural heritage

ABSTRACT

In this work we present a new full-field X-ray fluorescence imaging system for non-invasive investigations of cultural heritage objects. Recently the XRF imaging has been demonstrated to be a very effective tool for mapping of elemental distribution which offers possibility to study spatial distributions of inorganic pigments in artworks. The technique is useful to investigate provenance of the object as well as to study the artist technique and becomes very popular in the art conservation research. Compared to popular scanning macro-XRF systems, the full-field XRF technique allows one simultaneous imaging of large area of samples. Due to lack of the measurement head that moves very fast and very close to the investigated object this approach ensures greater safety for the investigated object. Moreover, the infinite depth of field of the pinhole camera allows one to investigate non-flat surfaces.

Our system is equipped with two Varian VF-50J low power air-cooled X-ray tubes and employs 10x10 cm^2 Gas Electron Multiplier (GEM) detector, custom developed Application Specific Integrated Circuits, and custom developed readout and data acquisition system [1,2]. An XRF image of the irradiated area is projected on the surface of the detector by a pinhole camera. The in-house developed prototype of the instrument enables adjusting the geometry of the measurement in order to optimize the excitation conditions for chosen projection parameters. Moderate energy resolution of GEM detectors limits elemental selectivity of the system, however, in many applications, especially for initial fast screening of large area objects, the GEM based systems can be very useful. By optimization of the front-end electronics and detector readout system significant improvement of the energy resolution has been achieved compared to typically reported values of 20-25% for 5.9 keV line.

In this work first XRF images obtained with the new system are presented. The measurements were performed on several phantoms painted with different pigment compositions and with overlapping paint layers. Obtained result shows great potential of the described technique in the area of art work analysis. Methods of data analysis and prospects for further applications of the developed system will be discussed.

The authors would like to acknowledge The National Centre for Research and Development for financial support within Applied Research Programme (project no. PBS3/A9/29/2015).

[1] W. Dąbrowski, T. Fiutowski, P. Frączek, S. Koperny, M. Lankosz, A. Mendys, B. Mindur, K. Świentek, P. Wiącek, P.M. Wróbel, Journal of Instrumentation 11, 2016, C12025.
[2] B. Mindur, W. Dąbrowski, T. Fiutowski, P. Wiacek, A. Zielińska, Journal of Instrumentation 8, 2013, T01005.

Medical Applications and Dosimetry

IS IONIZING RADIATION GOOD OR BAD?

Michael P.R. Waligórski*

Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN)
Radzikowskiego 152, 31-342 Kraków, Poland
and
Maria Skłodowska-Curie Memorial Institute of Oncology (COOK), Poland
Garncarska 11, 31-115 Kraków, Poland

Keywords: nuclear tests, nuclear energy, medical exposure, radiation protection

ABSTRACT

X-rays, discovered by Roentgen in 1895, and gamma-rays, two years later - by the Skłodowska – Curie couple, were quickly applied in medicine. By now, this "good" ionizing radiation has saved an uncountable number of human lives through advances in radio-diagnostic, nuclear medicine and radiotherapy procedures. The same ionizing radiation turned "bad" some 50 years later when, from unprecedented progress in nuclear physics research, nuclear bombs destroyed Hiroshima and Nagasaki. In the aftermath of the Second World War, peaceful and controlled nuclear fission was promised to supply nuclear energy "too cheap to measure". While that expectation was not to be borne out, nuclear power industry became an important element of world economy and politics. The "Ban-the-Bomb" movement of last century's 60's which opposed weapons of mass destruction was later also to turn against nuclear energy - for the "bad" radiation it produced. The benefits to human health of the same "good" radiation, appear to be totally ignored by any such movement. The 1986 Chernobyl and 2011 Fukushima nuclear power plant accidents were further taken to prove the apparently great hazards of "bad radiation" from nuclear energy. However, the actual long-term individual doses received or radiation effects of these accidents were not perceptible against naturally occurring doses, cancers or genetic effects, as by now clearly stated by ICRP or UNSCEAR. The reasons for the "radiophobic" social perception of radiation risk are therefore worth discussing, as is the role played in this context by the LNT (Linear-no-Threshold) principle. LNT, recommended by the ICRP, which is applied world-wide by national regulatory bodies for radiation protection. Based on these recommendations, over 300,000 people around the Chernobyl NPP and over 16,000 people around the Fukushima NPP were relocated, which destroyed the local social structures, and caused actual human death, due to stress, grieving, insomnia, depression, anger or alcoholism, and not to radiation-induced cancer. The human loss due to relocations from the Chernobyl area is unknown, but some 1600 deaths are attributed to the Fukushima relocations. Current research on health effects of low doses of radiation also suggests the possibility that a dose threshold may exist below which either no radiation effects occur or adaptive response or hormesis (i.e. beneficial effects due to the human immune system) arise, similar to the beneficial effects in immunization or low level physical exercise. This calls for a discussion of a possible revision of the LNT principle in radiation protection.

* corresponding author: z5waligo@cyfronet.pl

ION BEAM MICROANALYSIS OF SELECTED ELEMENTS IN HUMAN BRAIN TUMOUR TISSUES

A. Wandzilak[1,2], E. Radwańska[3], D. Adamek[3], L. Jeromel[4], P. Vavpetič[4], P. Pelicon[4] and M. Lankosz[*2]

[1] Max Planck Institute for Chemical Energy Conversion, Stiftstrasse 34-36, D- 45470, Mülheim an der Ruhr, Germany (current affiliation)
[2] AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, al Mickiewicza 30, 30-059 Krakow, Poland
[3] Jagiellonian University, Medical Faculty, Chair of Pathomorphology, ul. Grzegorzecka 16, Krakow
[4] Jožef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia

ABSTRACT

Brain tumours are still one of the least understood types of cancer. In order to successfully combat the disease it is very important to learn about the mechanism of its formation. It is believed that trace elements play an important role in neoplastic processes. For this reason, information on the differences in their levels and spatial distribution in healthy and cancerous tissues may contribute to the knowledge concerning biochemical reactions involved in oncogenesis.

The samples were collected intraoperatively during the resection of a brain tumour. Among the samples analyzed, there were tumours with different grades of malignancy, according to the latest World Health Organisation (WHO) classification, and non-cancerous control samples. The samples were studied with Particle Induced X-ray Emission which enabled obtaining high resolution maps of selected elements contained in the tissue. The studies were carried out in the Microanalytical Center of the Jozef Stefan Institute in Ljubljana. The analysis revealed that elements such as Na, Mg, P, S, Cl, K, Ca, Fe, Cu and Zn were present in all tissues analysed. Preliminary analysis showed that the average concentration of iron decreases in cancerous tissues with high malignancy grades as compared to the control samples. Also, an increase in the concentrations of zinc and phosphorus was noted in highly malignant samples (III and IV malignancy grade according to WHO). These results may contribute to the understanding of biochemical processes involved in oncogenesis.

[*] corresponding author Marek Lankosz Marek.Lankosz@fis.agh.edu.pl

NEW DEUTERIUM-DEUTERIUM (D-D) NEUTRON GENERATOR DEVELOPED FOR MEDICAL, INDUSTRY AND HOME LAND SECURITY APPLICATION

K. Bergaoui[*1], N. Reguigui [1]

[1] National Center of Nuclear Sciences and Technologies. Technopole Sidi Thabet, BP 72-CP 2020, Tunisia.

Keywords D-D neutron generator, MCNP, BNCT, Explosive Detection System, Neutron radiography

ABSTRACT

A new deuterium-deuterium (D-D) neutron generator has been developed for wide range of applications. These applications include medical (i.e., Boron Neutron Capture Therapy, BNCT), homeland security (i.e., Prompt Gamma Activation Analysis, PGAA and Fast Neutron Activation Analysis, FNAA) and industry (PGAA and Neutron Radiography). The plausibility of BNCT treatment of the cancer using neutrons from a DD-110 is assessed by calculating the distribution of photon equivalent dose on a breast phantom using Monte-Carlo (MCNP6) simulations. Beam Shaping Assemblies (BSA) is investigated and an optimized configuration is proposed. The radiography facility used in the measurements and simulations employs a fully high-voltage-shielded, D-D neutron generator. Both fast and thermal neutron images were acquired with the generator and a Charge Coupled Devices camera. To shorten the imaging time and decrease the noise from gamma radiation, various collimator designs were proposed and simulated using MCNP6. Design considerations included the choice of material, thickness, position and aperture for the collimator. Optimization of a D-D neutron generator based Explosive Detection System (EDS) was performed using Monte-Carlo simulation. The shape and the thickness of the moderators and shields are optimised to produce the highest thermal neutron flux at explosive position and the minimum total dose at the outer surfaces of the explosive detection system walls. In addition simulation of the response functions of NaI, BGO, and $LaBr_3$-based γ-ray detectors to pure chemical elements is described.

[*] corresponding author: bergaoui.kaouther@gmail.com

DOES TRANSCRANIAL DIRECT CURRENT STIMULATION HAVE ANY EFFECT ON THE ELEMENTAL AND MOLECULAR COMPOSITION IN THE BRAINS OF OBESE RATS?

Agata Ziomber[1], Artur Dawid Surówka[2], Mateusz Czyżycki[2,3], Alessandro Migliori[3] and Magdalena Szczerbowska-Boruchowska[2]

[1]Chair of Pathophysiology, Faculty of Medicine, Jagiellonian University Medical College, Czysta 18, 31-121 Krakow, Poland
[2]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, al. A. Mickiewicza 30, 30-059 Krakow, Poland, corresponding author email: asurowka@agh.edu.pl
[3]International Atomic Energy Agency (IAEA), Vienna, Austria and ELETTRA Sincrotrone Trieste, Basovizza TS, Italy

Keywords: Brain stimulation, obesity, Fourier transform infrared spectroscopy, synchrotron X-ray fluorescence,

ABSTRACT

A high-caloric diet is considered as one of the most significant risk factors for developing cardiovascular and neurological alterations. Recent evidence highlights that overnutrition may alter the electric activity in the brain areas triggering appetite and craving, gradually leading to food addiction, which may result in major obesity [1]. In order to understand the impact of a high-caloric diet on brain electric activity, the interplay between changes in molecular components (lipid, protein) and metal ions (Na^+, K^+, Cl^-) must be studied in the brain, which may shed some new light on the neurochemical patomechanisms underlying obesity [2]. In our study, we aimed at showing, whether or not, impacting the brain electric activity by transcranial direct current brain stimulation (tDCS) has any behavioral and biochemical effects on lipid, protein secondary structure and levels of metal ions in obese rats [3]. For doing so, thin brain tissue sections were taken from electrically- and sham-stimulated rats on a high-caloric diet. The samples were raster-scanned with modern elemental and molecular micro-imaging techniques: synchrotron X-ray fluorescence (SRXRF) and Fourier transform infrared (FTIR) spectroscopies. The contribution will aim at outlining the details of our unique brain stimulation procedure, and comparing the most striking elemental and molecular changes invoked in the appetite-triggering brain areas in obese (stimulated/unstimulated) rats. It will be demonstrated that the clinical efficacy of the anodal-type tDCS has a stronger impact on the brains. Perturbation in the levels of elemental components will be shown to stay in line with the molecular changes in terms of lipid peroxidation, and those involving protein secondary structure components. The study demonstrates that by stimulating the brains of rats addicted to a high-caloric diet, the feeding behavior can be significantly changed resulting in decreased appetite and craving. Therefore, our brain stimulation protocol paves the way for novel treatments for challenging metabolic syndromes causing major obesity.

Acknowledgments
This work was supported by the National Science Centre Poland, grant number DEC-2013/09/B/NZ4/02539. We would also thank ELETTRA Sincrotrone Trieste (Italy) for beamtime provision.

References
[1] N. Hariri, L., Thibault, Nutr. Res. Rev. 23 (2010) 270–299
[2] S.J. Brooks, et al., PLoS One. 8 (2013) e60393
[3] D. Liebetanz, et al. Epilepsia. 47 (2006) 1216–1224

X-RAY FLUORESCENCE ANALYSIS OF CHANGES OF CHEMICAL COMPOSITION OF THE OVARIAN CANCER TISSUES

P. M. Wróbel[*1] Ł. Chmura[2], M. M. Grzelak[1], Z. Stęgowski[1], M. Lankosz[1], B. Steńczyk[1], D. Adamek[2], R. Jach[3], M. Czyżycki[1,4], A. Migliori[4], A. Karydas[4,5]

[1]AGH-University of Science and Technology, Faculty of Physics and Applied Computer Science, al. A. Mickiewicza 30, 30-059, Krakow,Poland
[2]Department of Pathomorphology, Faculty of Medicine, Jagiellonian University Medical College, ul. Grzegorzecka 16, 31-531 Krakow, Poland
[3]Department of Gynecology and Obstetrics, Faculty of Medicine, Jagiellonian University Medical College, ul. Kopernika 23, 31-501 Krakow, Poland
[4]Physics Section, Nuclear Science and Instrumentation Laboratory (NSIL), IAEA Laboratories, A-2444 Seibersdorf, Austria
[5]Institute of Nuclear and Particle Physics, NCSR "Demokritos", 15310 Aghia Paraskevi, Athens, Greece

Keywords: X-ray fluorescence imaging, ovarian cancers, elemental analysis, human tissue samples

ABSTRACT

Ovarian cancer is the seventh most common cancer among women worldwide, and mortality rates from this cancer are higher than for the other gynecological cancers. The knowledge about elemental distribution in various areas of the ovarian tissues affected by the cancer can help us to understand the cancerogenesis process. The purpose of our studies was to investigate if the spatial distribution of selected minor and trace elements changes in different types of ovarian cancer tissues.

In our study 18 human ovarian samples were used. For each sample two subsequent slices were cut with use of cryo-microtome: one for the histopathological analysis (on microscopic slide) and the second one for the elemental imaging (on ultralene foil). The slice thickness of 20 μm was chosen.

The preliminary experiment was conducted with use of laboratory microbeam X-Ray Fluorescence setup [1]. The setup is equipped with the low power Mo X-ray tube with a polycapillary lens and SDD detector. The X-ray tube was operated at full power (50 kV / 1 mA). The acquisition time was 60 s per pixel and the average scan area was about 12 mm^2 (the measurement step was 100x100μm^2). Experiments were performed in air. The main experiment was conducted at the International Atomic Energy Agency end-station at X-ray Fluorescence beamline of Elettra Sincrotrone Trieste facility. The beam was monochromatized with the RuB_4C multilayer monochromator – the energy of 10 keV was used. The beam spot size and step size was 250x120 μm2. The fluorescence radiation was detected with a SDD detector. The experiment was performed in vacuum ($2 \cdot 10^{-7}$ mbar). The time of the measurements was 5 s per pixel and the average scan area was 30 mm^2.

In both experiments the difference of elemental composition of the neoplastic area and the stromal area of the ovarian tissues were revealed. K-means clustering and positive matrix factorization were applied for data analysis. The results of elemental analysis were confronted with the results of the histopathological examination.

[1] P. Wróbel et. al., Talanta 93 (2012) 186-192

[*] corresponding author: pwrobel@agh.edu.pl

INFLUENCE OF DIFFERENT GAMMA RADIATION DOSES ON PVA/GELATIN BASED SCAFFOLDS

Justine P. R de Oliveira*[1], Maria J. A. de Oliveira[1], Isabela C. da Silva[1], Gustavo H. C. Varca[1], Ademar B. Lugão[1]

[1]Nuclear and Energy Research Institute – IPEN-CNEN/SP, Brazil.

Key words: scaffold, polymers, pore size, gamma radiation, platelet rich plasma.

ABSTRACT

The present work aimed to study the influence of different radiation doses on a polymer blend at cryogenic and room temperature by means of crosslinking formation, pore size, morphology, topography and mechanical properties. The scaffold was prepared based on two formulations, one composed by gelatin (7%, w/w) and PVA (5%, w/w), and the second by gelatin (10%, w/w) and PVA (5%, w/w). The formulations were separately solubilized in distilled water and heated up to 80 ºC under constant stirring for 1 hour. Posteriorly, both blends were disposed in circular glass moulds. Half of samples was frozen for at least 24 h and then irradiated at 15, 25 and 50 kGy. The other half was cooled at 4 ºC for at least 24 h and then irradiated using the same doses. After irradiation both sample groups were frozen and freeze dried. The scaffold was characterized in terms of structure and morphology by mechanical assays, differential scanning calorimetry, scanning electron microscopy, optical coherence tomography and infrared spectroscopy. In addition, platelet adhesion and release, and cytotoxic assays were also performed. Samples irradiated at 15 kGy presented pore size diameter of around 1.4 μm and porosity of 54%, while samples irradiated at 25 kGy, presented pore size diameter of around 1.1 μm and porosity of 49%. Optical coherence tomography showed that gelatin control samples presented more superficial degradation as irradiation dose increased, while PVA control sample presented higher integrity, indicating that this polymer is less sensitive to gamma radiation. The system presented suitable mechanical properties and the platelet adhesion and release assays showed that the scaffold presented adequate pore size range to host and release the platelets, and non-cytotoxic to platelets, featuring adequate properties to be applied as dressing for wound treatments.

* corresponding author: justinepaula@gmail.com

STUDY THE BEHAVIOR OF SOME EPR DOSIMETERS UNDER DIFFERENT ENERGIES RANGE

M. A. H. Rushdi*

Sudan Atomic Energy Commission

Keywords: effective atomic number, Z_{eff}, EPR Dosimetry, low energy, photon interaction

ABSTRACT

An investigation has been done to study the response of various EPR dosimeters (Alanine, Ammonium tartrate, Lithium oxalate, Sodium carbonate, potassium methionate, Strontium sulfate, Barium dithionate) focusing in low and intermediate photon energy. Different gamma sources of energy ranging from 0.021 to 1.25 MeV (^{103}Pd, ^{170}Tm, ^{99}Tc, ^{192}Ir, ^{137}Cs, ^{65}Zn and ^{60}Co) which they are commonly applied in radiation technology, were used. The significant variation appeared in Z_{eff} value due to the variations in the dominance of photo interaction process at different energy regions. Compton scattering is a dominant mode of photon interaction, the Z_{eff} can be represented by a mean effective atomic number. Auto-Z_{eff} software and single value XMuDat program used to compute the Z_{eff} and then the obtained values were compared.

* corresponding author: Mohamed Rushdi: mohdrushdi000@gmail.com

DETECTION OF IRRADIATED SPICES BY THERMOLUMINESCENCE – AN INTERCOMPARISON STUDY

Ivana Sandeva*, Hristina Spasevska, Margarita Ginovska, Lihnida Stojanovska-Georgievska

Faculty of Electrical Engineering and Information Technologies, Ss. Cyril and Methodius University in Skopje, Rugjer Boshkovik bb, PO Box 574, 1000 Skopje, Republic of Macedonia

Keywords: thermoluminescence, food, irradiation

ABSTRACT

The following study represents the results of the thermoluminescence (TL) analysis done on different spices in two laboratories.

Food is irradiated in order to reduce the number of harmful microorganisms and toxins, thus prolonging its shelf life, delaying ripening and preventing sprouting. European and national legislation specifies the special requirements for irradiated food, including its proper detection. TL is one of the most used physical methods for detection of irradiated food. When minerals found in food are exposed to ionizing radiation during the irradiation process, they accumulate radiation energy by which some electrons jump to higher energy states. On their way back to ground state, they may remain trapped in some imperfections of the crystal lattice. When these minerals are exposed to heat trapped electrons are released, they recombine with holes and a TL signal is obtained. Because of the variety of food samples, a control sample cannot be used, so analysis is done twice for each sample. The first measurement is done after the isolation of minerals and detection of the TL signal, whereas the second measurement is done after exposing the sample to a certain dose of ionizing radiation and detecting the TL signal for the second time. By these measurements two TL glow curves are obtained, which represent the dependence of the TL intensity on temperature. TL glow ratio gives the ratio of the maximum TL intensity from the first and the second measurement. The magnitude of the TL glow ratio, as well as the shape of TL glow curves can identify the sample as irradiated or unirradiated.

Measurements are done on three samples, including unirradiated paprika standard, irradiated paprika standard and unirradiated black pepper. Minerals are isolated according to the standard EN 1788 Foodstuffs - Thermoluminescence detection of irradiated food from which silicate minerals can be isolated. All samples are correctly identified as irradiated or unirradiated in both laboratories. Obtained results from the two laboratories are in accordance with each other.

Acknowledgement

The authors wish to thank the Department of Health and Social Affairs, Office of Consumer Protection and Food Control in Aarau, Switzerland for their help and support in performing the measurements.

* corresponding author: ivana@feit.ukim.edu.mk

Development of Nuclear Methods

RECENT DEVELOPMENT IN NUCLEAR METHODS FOR PROCESS MONITORING

Tor Bjørnstad [*1,2]

[1] Institute of Energy Technology (IFE), Kjeller, NORWAY
[2] Nuclear Chemistry, University of Oslo, Blindern, Oslo, NORWAY

Keywords: process monitoring, short-lived radionuclides, radiotracer generators, neutron generators

ABSTRACT

In many fields of *process monitoring*, nuclear methods constitute a technically indispensable tool. However, the use of open or encapsulated radioactive sources is increasingly under public scrutiny, often because of misunderstandings or lack of knowledge. In order to sufficiently mitigate these perceived shortcomings and make the use of nuclear monitoring methods acceptable by process owners and the public, one has to substantiate reduction of any unnecessary human or environmental risks associated with such technologies.

For open radioactive sources, i.e. mainly in the form of radiotracers (aqueous, organic or particulate), focus are now on increased application of *short-lived radionuclides* whenever these can be used. Short-lived radionuclides are commonly produced by neutron irradiations in nuclear reactors or by charged particle reactions at particle accelerators. Hence, due to transportation time and logistics, there is an upper practical limit to the distance of their use from the radionuclide production facilities. Typical industrial examples are off-shore petroleum production in remote areas or onshore process industry in countries which do not host such production facilities. Therefore, there is an increasing focus on developing industrial brands of *radiotracer generators*, which are based on a secular equilibrium between the long-lived mother and the short-lived daughter radionuclides. This presentation will give some examples of such generators and define the status of their development.

Additionally, many long-lived encapsulated radioactive sources used in fixed mountings today (two examples are ^{60}Co and ^{137}Cs) may, in principle, be substituted by the use of small *neutron generators* which can be turned on and off on demand. The recent years' development and availability of such transportable neutron generators give, in fact, several new technical possibilities, some of which are summarily mentioned here: 1. on site production of short-lived radionuclides for injection into processes, 2. on-line mounting onto transportation pipelines for in-situ and on-line generation of short-lived tracers directly in the process stream, 3. application of prompt gamma-ray spectra from neutron-induced nuclear reactions generated in the process stream (PGNA) for monitoring of specific mass movement, 4. the use of neutron transmission (thermal and fast neutrons) or reflection (thermal neutrons) monitoring of specific mass movement, 5. generation of prompt gammas in external fixed target for gamma transmission experiments (mass density measurements), and more. This presentation will also describe some of these emerging possibilities in some detail.

The use of equipment and methods described here leads to reduced radiation exposure and virtually no left-over activity or radio-contamination after the monitoring process is completed.

[*] corresponding author: tor.bjornstad@ife.no

MANAGEMENT OF RADIOACTIVE WASTE IN ISOTOPE LABORATORY WITH UNSEALED RADIOACTIVE SOURCES

O. Fałowska, J. Dudała

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Mickiewicza Av. 30, 30-059 Krakow, Poland

Keywords: radioactivity, radioactive waste,

ABSTRACT

The Faculty of Physics and Applied Computer Science at the AGH University of Science and Technology has a long and rich history of nuclear methods usage, including radiometric methods. At the Faculty, there are several laboratories in which the nuclear methods are used. Particular attention should be paid to the unique radiochemical laboratory with unsealed radioactive sources. Due to the specifics of working in the laboratory, there are both liquid and solid radioactive waste produced. They generate radiological hazard, therefore the proper management of such waste is essential for environmental protection. Particular attention should be paid for personal safety and radiological protection.

The laboratory has both scientific and didactic profile. For better estimation of effective radiation dose for stuff and students, it is desirable to perform the detailed analysis of the radioactive waste produced during the teaching process.

Under typical conditions the following radionuclides are used: Fe-59, Co-60, U-238, S-35, I-131, Br-80, Br-82 and Mn-56.Different nuclides are not mixed in one container, they are stored in separate containers. The dose rate at the container surface is measured by radiometer. The activity and the concentration of radioactivity are the basis for the classification of radioactive waste. Up to now such parameters were estimated roughly on the base of the initial conditions, but quantitative analysis was not done before.

The presented study is aimed at detailed quantitative analysis of radioactive waste generated in the laboratory with unsealed sources during the teaching process.

Acknowledgements

This work was supported by the Polish Ministry of Science and Higher Education and its grants for Scientific Research.

TIME-SCALE DISCRIMINATION AND CHARACTERIZATION OF NEUTRON AND GAMMA SIGNALS USING NONNEGATIVE MATRIX FACTORIZATION OF STILBENE ORGANIC SCINTILLATOR`S OUTPUTS

Hanane Arahmane[*1], El-Mehdi Hamzaoui[2] and Rajaa Cherkaoui El Moursli[1]

[1] LPNR Laboratory, Mohammed V University, Faculty of Sciences, Rabat, Morocco
[2] National Centre for Nuclear Energy, Sciences and Techniques (CNESTEN), Rabat, Morocco.

Keywords: Continuous wavelet transform (CWT), Mexican Hat, Neutron-gamma discrimination, Nonnegative Matrix Factorization, Regularized Lee-Seung.

ABSTRACT

In this research work, we tackled the neutron-gamma discrimination at the output of Stilbene organic scintillation detector as a blind source separation problem. Thus, the output signals of the used detector have been considered as mixtures of several unknown sources which we tried to recover using Nonnegative Matrix Factorization algorithms. Thus, the blind source separation now raises great interest. In fact, it plays an important role in many diverse application areas: telecommunications, biomedical engineering... Recently, they have been used to solve the pileup problem at the output of HPGe detector used in gamma spectrometry. This encouraged us to apply them to analyze the output of Fission Chamber in order to achieve online neutron flux monitoring inside a research reactor.
The computation of performance index of separability of each tested algorithm has allowed us to select the Regularized Lee-Seung method as the most efficient nonnegative matrix factorization algorithm which permits to achieve the best neutron-gamma discrimination. The recovered independent components issued from the application of this algorithm are then characterized using their time-scale representations. For that reason, we used the continuous wavelet transform, based on the Mexican Hat function. The visual reading of the obtained scalograms allowed us to define a qualitative criterion for neutron-gamma discrimination task.

[*] corresponding author: hanane ar1@hotmail.com

TECHNETIUM-99M AND BARIUM-137M SIGNALS SEPARATION AND RETRIEVAL IN INDUSTRIAL RADIOTRACER APPLICATION LABORATORY

H. Kasban and H. Arafa

Engineering Department, Nuclear Research Center, Atomic Energy Authority, Egypt
E-mails: Hany_kasban@yahoo.com, horeyaarafa@hotmail.com

Keywords: Radiotracer, Tc^{99m}, Ba^{137m}, Signal Separation, Principle Component Analysis

ABSTRACT

Radioisotopes are used in several applications in industry, where the radioisotope injected into the system and the radiation detectors are used for obtaining the output signals. The output signals are analyzed to provide information about the system behavior or to determine the system problems. In some cases, the system is multi-phase system, in such cases; more than radioisotope is used, resulting a mixture of radioisotopes signals. The main problem is in such cases is the separation of these signals from each other. This paper presents an efficient method based on advanced signal processing techniques for separating mixed two radioisotopes signals from each other. Two different radioisotopes (Technetium-99m (Tc^{99m}) and Barium-137m (Ba^{137m})) were injected into a physical model for simulation of chemical reactor (PMSCR-MK2) to obtain the radiotracer signals using data acquisition system connected to radiation detectors. Some signals enhancement steps are performed such as; background correction, radioactive decay corrections, and signal denoising filtering, then applying the signal separation methods. The separation methods that used are; time domain separation method, independent component analysis separation method, and principal components analysis separation method. The results show that the signal enhancement steps improve the separation process. Also the results show the superiority of the principal components analysis separation method to the other separation methods.

PREPARATION OF EPOXY RESIN BASED- GAMMA RAY SOURCE FROM ^{152}EU AND THEIR CHARACTERIZATION USING EFFICIENCY TRANSFER FUNCTIONS IMPLEMENTED IN ANGLE 4 AND MEFFTRAN

Haluk Yücel*[1], Senem Zümrüt[1], R. Bora Narttürk[1], Gizem Gedik[1]

[1]Ankara University, Institute of Nuclear Sciences, Tandoğan, 06100, Ankara, Turkey

Keywords: Radioactive source, epoxy, efficiency transfer function, gamma-ray spectrometry

ABSTRACT

Todays, gamma spectrometric method is commonly used in routine radioactivity measurements. In this context, the accurate and precise measurement of low level activity in the samples is always an important issue in a nuclear analytical laboratory. The most reliable way is that a direct calibration n can be performed using standard radioactive sources of the same geometrical dimensions, density, and chemical composition, compared with the samples of interest. However, for all radionuclides of interest, standard sources are not often available for all foodstuff, environmental, industrial raw materials and geological minerals.

In recent years, the close-counting geometry is commonly used in HPGe detectors to obtain more accurate results from the samples with low activities,especially re-entrant beakers (e.g.,Marinelli etc). In this study, in-house gamma-ray calibration sources were prepared with use of a novel epoxy resin (□=1.14 g□cm-3) as a base matrix mixed with radioactive 152Eu standard solution. To validation, 152 Eu isotope is quite suitable for detector calibration in a wide energy range from 121.78 keV to 1408.01 keV. The homogeneity of the produced in-house gamma-ray sources was tested in a 5ml glass ampoule and 6ml vials in the well of a p-type HPGe detector with a 44.8% relative efficient. The homogeneity is found to be better than 99.5%. For the characterization of the produced sources, the efficiency transfer functions were derived from ANGLE 4 and MEFFTRAN softwares, respectively.

The characterization of in-house source prepared in a Marinelli beaker was then performed by using an n-type 78.5% relative efficient HPGe detector. For the case of a close counting geometry, some coincident gamma-rays from 152Eu radionuclide was chosen to determine the necessary corrections for TCS effects by using GESPECOR software. Self-absorption effects in matrix composition were also applied to measure the accurate activity contained in beaker. For the efficiency calibration curves, experimental data were checked by using efficiency transfer functions. As a result of the work, the source preparation procedure was validated for in-house gamma-ray sources within the accuracy of □4-5% for the source activities. The chosen epoxy resin has high stability and durability and gives a well homogeneity. It has also some advantages such as its low effective atomic number and low density, and other physical properties to produce a radioactive source.

Acknowledgement: This work was supported by TÜBİTAK Project coded as 116F308.

* corresponding author: haluk.yucel@ankara.edu.tr

Radiation Chemistry and Industrial Applications

RADIOISOTOPES IN INDUSTRIAL AND ENVIRONMENTAL STUDIES

Andrzej G. Chmielewski

Institute of Nuclear Chemistry and Technology*, Warsaw, Poland

ABSTRACT

A broad field of applications is based on ionizing radiation penetration properties, and its precise detection is linked to open and sealed radiation sources' utilization. Optimization of industrial processes is essential not only for efficient, safe and sustainable industrial operation, but also to save materials, energy, protect the environment and reduce plant shutdown time, thus leading to high economic benefits – hence leading to socio-economic development of humanity. Complex industrial processes (particularly multi-phase systems) including environmentally related processes (such as harbors and dams, oil fields and ore/coal mines), are manifested in many industrial and environmental systems. It is therefore essential to have suitable means to investigate such systems for process optimization and trouble-shooting – preferably without shutting down the plant/process. Radiotracers and sealed source techniques are best-suited methods to address these problems faced by industry. Nuclear techniques (radiotracers and sealed sources), in most of the cases, provide on-line investigations without shutting down the plant/process. New emerging and advanced technologies based on radiotracers and sealed source applications (like gamma Computed Tomography (CT)/Single Photon Emission Computer Tomography (SPECT), Computer Aided Radioactive Particle Tracking (CARPT), Radiotracer Residence Time Distribution (RTD, remote sensing and in-situ radionuclide analysis (Route-monitoring gamma-ray mapping are being invented and introduced for routine use. Automation and improvements in instrumentation and hardware, such as tracer injection systems, detectors and data acquisition systems are developed for safer and reliable application. Utilization of radionuclide generators for on-site production of radiotracers for industrial applications is important to overcome non-availability of radiotracers especially for those Member States that do not have nuclear reactors and radiotracer production facilities. All these end-user addressed applications are based on science developed in the universities and research centres, which demonstrate and transfer new applications to industry to be used in a safe and proper manner. It is a joint input of scientists and professionals working in the field to the main UN Millennium Goals of achieving a resource-efficient and climate-change-resilient economy and society, protecting and sustainably managing natural resources and ecosystems, and ensuring a sustainable supply and use of raw materials and other environmental resources, in order to meet the needs of a growing global population within the sustainable limits of the planet's natural resources and eco-systems. This universal humanistic role of science and technology was articulated by Madame Curie, a lady who was born exactly 150 years ago in Warsaw as Maria Skłodowska. She developed a new innovative and effective tool – ionizing radiation, which broke new ground in physics and chemistry and also opened the door for advances in engineering, biology and medicine.

Acknowledgements
The study is being performed in the frame of IAEA CRP F22065 "Radiometric Methods Applied in Hydrometallurgical Processes Development and Optimization" and Polish Ministry of Science and Higher Education co-financing grant "Rozwój radiometrycznych i radioznacznikowych technik dla procesu hydrometalurgicznego odzysku metali deficytowych".

*IAEA Collaborating Centre
corresponding author: A.Chmielewski@ichtj.waw.pl

IONIZING RADIATION FOR FOOD PRESERVATION PROCESSING: LESS OR IN EXCESS?

Amilcar L. Antonio[*1], Isabel C.F.R. Ferreira[1], Pedro M. P. Santos[2], Sandra Cabo Verde[2]

[1] CIMO, ESA, Instituto Politécnico de Bragança, Portugal.
[2] C2TN, IST, Universidade de Lisboa, Portugal.

Keywords: Food preservation; ionizing irradiations; physical; chemical; bioactives

ABSTRACT

The industrial use of ionizing radiations, such as gamma and electron beam (e-beam) radiation, is regulated and authorized by international organizations (EU, EFSA, IAEA, FAO, WHO) for several purposes: medical devices sterilization, materials modification, heritage preservation and food decontamination. However, there is mistrust among the general public regarding food irradiation due to the wrong association with an induced radioactivity on the product. Therefore, several obstacles have to be overcome in order to promote food irradiation as a safe and useful application of ionizing radiations. The increasing demand for safe and healthy food is another issue that could help to promote the use of these technologies. In Europe, the preservation of food by irradiation is strongly regulated but is still not very popular, in spite of several food safety issues, such as pathogens contamination or insects' infestation that could be easily solved by an environment friendly technology, without the use of chemical fumigants. We will present briefly the recent state-of-art of food irradiation research in Portugal, selecting the main results of three collaborative projects funded by national and international agencies, regarding the effects of gamma radiation on physical and chemical parameters of selected materials: fruits, vegetables and mushrooms, toward the objective to keep the focus on this valuable tool for food processing.

Acknowledgments

To the Projects/Agencies that supported this research: Portuguese Government and E.U. funds: PRODER/FEADER/EU (AROMAP Project); Foundation for Science and Technology (FCT, Portugal) for financial support to CIMO (PEst-OE/AGR/UI0690/2014), and C2TN (RECI/AAG-TEC/0400/2012 and UID/Multi/04349/2013 projects); International Atomic Energy Agency (IAEA) Coordinated Research Project CRP-D6-RC-1163.2 and IAEA Research contract 19220.

[*] corresponding author: amilcar@ipb.pt

CONVERSION OF NATURAL POLYMERS TO MONOCYCLIC COMPOUNDS

Ponomarev A.V.*, Kholodkova E.M., Pavlov Yu. S., Skiba S.A.

Frumkin Institute of Physical Chemistry and Electrochemistry, Russian Academy of Sciences, Moscow, Russia

Keywords: radiolytic conversion, biopolymers, furans, pyridines, phenols

ABSTRACT

Natural polysaccharides (cellulose and chitin) and polyphenols (lignin), being the most widespread renewable materials, represent rather tempting feedstocks to obtain valuable chemicals. In the course of conversion the moderate fragmentation resulting in monocyclic products such as furans, phenols, benzenediols and pyridines would be rather desirable. However conventional processing technologies give few such products or are multistage and thereby expensive.

High-temperature radiolysis could serve as more proper way to form monocyclic organic products. Irradiation of natural polymers results in formation of high-molecular cation-radicals and macroradicals which possess low thermal stability. The moderate fragmentation of radical intermediates occurs at temperatures below a threshold of pyrolysis initiation. As a rule, primary cleavage of chemical bonds takes place between macromolecule base units. As a result of removal of a monocyclic fragment the residual macromolecule remains in the form of a radical that provides possibility of its further fragmentation via the chain mechanism.

Main products of pyrolysis are lightest fragments (CO, CO_2, H_2O, CH_4) together with the heavy charred residue. In turn, radiolysis provides higher yield of monomeric derivatives such as furans (from cellulose), vanilloids, monoatomic and dihydric phenols (from lignin), and pyridines (from chitin). Accordingly, high-temperature radiolysis of lignin possesses the important advantages over pyrolysis.

The report describes a technique of biopolymers conversion to monocyclic compounds and the mechanism of the radiation-thermal transformations.

* corresponding author: Ponomarev@ipc.rssi.ru

ACCIDENT TOLERANT MATERIALS IDEAS AND PERRSPECTIVES

Sartowska Bożena*, Starosta Wojciech

Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland

Keywords: Accident Tolerant Materials (ATM), fuel elements claddings, zirconium alloys

ABSTRACT

Severe nuclear accidents have been shown that under extreme conditions the high temperature reaction between zirconium alloys and water leads to intense generation of hydrogen and possible hydrogen-oxide mixture explosion. From the nuclear reactor safety point of view the strong improvements are required in the areas of: nuclear fuel composition, cladding integrity and the fuel - cladding interaction.

Zirconium based alloys have very good water corrosion and radiation resistance at normal working conditions of nuclear reactors. Due to these properties it is commonly used as cladding material for fuel elements. However, in the case of Loss of Coolant Accident – LOCA - conditions, the extremely fast oxidation of zirconium at steam atmosphere or and air/steam mixture occurs.

The concept of Accident Tolerant Fuels (ATF) and Accident Tolerant Materials (ATM) has been developed recently for this purpose. Advanced cladding technologies for the increasing of claddings' corrosion resistance are investigated in order to two ideas:

(i) developing of new materials for claddings production - as for example: SiC composites, FeCrAl alloys, ferritic martensitic alloys,

(ii) protective coatings on Zr alloys - as for example: on the base of silicon, ceramics MAX, FeCrAl alloys, SiC, $MoSi_2$

Scientific works are carried out in different institutes and laboratories in the world. The state of art and perspectives of ATM materials will be presented.

Acknowledgements

The work has been partially supported under IAEA Research Contract No. 19026/R0 and by Polish Ministry of Science and Higher Education under decision 3689/IAEA/2017/0.

* corresponding author: b.sartowska@icjtj.waw.pl

DETERMINATION OF OPTIMUM PARAMETERS FOR ^{241}Am ALPHA SOURCE PREPARATION BY ELECTRODEPOSITION METHOD

H. Yücel[1], G.Ö. Çakal[*1], R. Güven[1], S. Limon[1]

[1]Ankara University Institute of Nuclear Sciences, 06100 Tandoğan, Ankara, Turkey

Keywords: electrodeposition, alpha spectrometry, ^{241}Am source preparation, chemical recovery, homogeneity

ABSTRACT

Electrodeposition is most commonly used method for alpha source preparation, thus resulting in the quality of analysis of actinides in the samples. The source for alpha spectrometric measurements should be prepared as a uniform and stable source. The aim of this study is to obtain the optimum parameters for ^{241}Am alpha source prepared from standard solution by using in-house electrodeposition unit. Then, the effect of pH, electrodeposition time, current, the distance between electrodes and cathode disc type on the chemical yield and homogeneity of the electrodeposited sources are investigated. In the preparation of ^{241}Am source on a disc, ammonium sulfate solution is mainly used as the electrolyte and a spiral shaped Pt is used as anode in the deposition cell. ^{241}Am deposited discs were measured by alpha spectrometry with use of 450 mm^2 and 600 mm^2 PIPS detectors for about 4 days. The homogeneity of the electrodeposited sources is examined by using SEM images. To obtain the auto radiographic images, a CR cassette having a phosphor layer, is used because it is sensitive to ionizing radiation. The homogeneity of the discs and the radial activity distribution were evaluated by using Image J program.

As a result, it is found that the chemical recovery of at least 70% is obtained for the ^{241}Am electrodeposition at the optimum parameters which are pH=3.5, current= 0.1 A, deposition time= 3h, distance between electrodes=1 cm and disc type = nickel plated stainless steel. The reasonably good energy resolution for the present PIPS detectors is obtained when compared to a multinuclide calibration source (Analytics) containing ^{241}Am.

[*] corresponding author: gcakal@ankara.edu.tr

THE EFFECT OF IONISING RADIATION ON THE STARCH-PVA-NANOCELLULOSE FILMS FORESEEN FOR PACKAGING APPLICATION. ACTIVE FOOD PACKAGING

Krystyna Cieśla*, Anna Abramowska, Joanna Drewnik, Wojciech Głuszewski, Marcela Grabowska

Institute of Nuclear Chemistry and Technology, Dorodna 16 str., 03-195 Warsaw, Poland

Keywords: starch - poly(vinyl alcohol) - nanocellulose, food packaging, ionising radiation, antioxidant properties, migration phenomena

ABSTRACT

The studies are connected to the increasing interest in substitution of traditional packaging by the materials prepared basing the natural and biodegradable polymers. Due to perspective of radiation technologies for polymers modification and due to potential application of the materials for packaging of the products predicted for radiation decontamination/sterilization, the necessity appeared for studying the radiation effects in such materials.

Our previous studies have shown that it is possible to improve the properties of the starch based films by applying ionising radiation [1-3]. The present studies deal with search of new biodegradable materials based on starch-PVA and starch-PVA-nanocellulose systems. These studies concerns the effects of using different starch and PVA substrates, addition of several differently structured nano- and micro-sized celluloses, changing of the starch:PVA ratio and nanocellulose content in the composite materials. The effects of gamma and electron irradiation (performed with doses in the range from 1 kGy till 75 kGy), on the films with modified composition to was investigated in purpose to search for the conditions that enables to improve the films properties as well as in purpose to determine the sensitivity of the potential packaging materials to ionising radiation. The trials for additional functionalization of the materials were also conducted on the way of a supplementary chemical treatment. The focus was on addition the selected natural substances (that are known to reveal antioxidant or antimicrobial activity), or selected monomers (that are expected to improve the films properties), on the various steps of the films preparation.

Mechanical and hydrophilic/hydrophobic properties of the non-irradiated and the irradiated films, and migration phenomena taking place in liquid food simulants depend on the sample composition and on the conditions applied during syntheses and irradiation [4-6]. Irradiation with low doses enables to obtain the films with selected compositions characterized by improved functional properties. It has also appeared possible to obtain the films showing antioxidant activity and to modify this activity as well as a characteristic release the active component from the films by modification of the chemical composition and irradiation condition. The results were related to the chemical processes involved in films and to their modified microstructure and showed the potential of using the selected compositions for packing some groups of food, including the products predicted for radiation decontamintion.

Acknowledgements:
The work was sponsored by Polish Ministry of the Science and the Higher Education (co-funded project) and in the frame of the International Atomic Energy Agency Coordinated Research Project F2206, research contract No: 17493

References

[1] K.A.Cieśla, A.Nowicki, M.J. Buczkowski, Radiation modification of the functional properties of the edible films prepared using starch and starch – lipid system. Nukleonika, 55(2) (2010), 233-242.

[2] K.Cieśla, N.Watzeels, H.Rahier, Effect of gamma irradiation on thermophysical properties of plasticized starch and starch surfactant films. Radiat. Phys. Chem, 99 (2014**),** 18-22.

[3] K Cieśla., B.Sartowska, Modification of the microstructure of the films formed by gamma irradiated starch examined by SEM, Radiat. Phys Chem 118 (2016), 87-95.

[4] A. Abramowska, K.A. Cieśla, M. J. Buczkowski, A. Nowicki, W.J. Głuszewski: The influence of ionizing radiation on the properties of starch-PVA films. Nukleonika 60 (3) (2015) 669-677.

[5] K.A. Cieśla, J. Drewnik, A. Abramowska, M.J. Buczkowski, W.J.Głuszewski, A.Nowicki, J. Boguski, G. Strzelczak, B. Sartowska. Based on starch - PVA system and cellulose reinforced packaging materials. The effects of ionising radiation. *in* Report of the 3rd RCM of the CRP on Application of Radiation Technology in the Development of Advanced Packaging Materials for Food Products, 11-15 July 2016, Vienna, Austria. 11-15 July 2016, Ed. A. Safrany, IAEA, Vienna, Austria (2016) pp 232 – 247.

[6] K. Cieśla, A. Abramowska, J. Boguski, J. Drewnik. The effect of PVA type and radiation treatment on the properties of starch-PVA films. Radiat. Phys. Chem., submitted.

* corresponding author: k.ciesla @ichtj.waw.pl

PROTEIN CROSSLINKING ONTO GOLD NANOPARTICLES BY GAMMA RADIATION

Gustavo H.C. Varca[*1], Janaína A.G. Barros[1], Jorge G.S. Batista[1], Rafaela Sasounian[2], Gustavo T.M. Silva[2], Vitor M. Zamarion[2], Kattesh V. Katti[3], Ademar B. Lugão[1]

[1]Instituto de Pesquisas Energéticas e Nucleares (IPEN-CNEN/SP), Av. Lineu Prestes 2242, 05508-000, São Paulo, Brazil.
[2]Instituto de Química, Universidade de São Paulo, Avenida Lineu Prestes 748, 05508-000, São Paulo, Brazil.
[3]University of Missoury, 223 Physics Bldg., 65211-7010, Columbia, United States.

Keywords: Gold nanoparticles, Protein Crosslinking, Ionizing Radiation, Bovine Serum Albumin.

ABSTRACT

The use of gold nanoparticles for diagnosis and treatment of cancer has received great attention over the last decade. Particularly, the possibility to use them for theranostics has increased the interest in the medical and scientific community. Weak technological aspects are related to the low biological affinity and non-specific toxicity. The use of albumin is of highlighted interest as albumin has been associated to inorganic particles to overcome biopharmaceutical challenges, including site-specific delivery and other biopharmaceutical advantages. The current work addresses the use of radiation and its effects over the crosslinking of bovine serum albumin onto gold nanoparticles. The idea of crosslinking the albumin onto gold surface aims to improve the stability of the protein layer onto gold nanoparticles in biological systems. Gold nanoparticles were synthesized by green technology using resveratrol and albumin capping was performed by physiosorption followed by irradiation at doses of 2.5, 5, 7.5, 10 and 15 kGy using ^{60}Co as a radioactive source. Nanoparticle properties were assessed by dynamic light scattering, UV/Vis spectrophotometry and transmission electron microscopy. Protein crosslinking was monitored by fluorescence studies and stability of the nanoparticles was evaluated by zeta potential and titration with sodium chloride. The results evidenced the formation of a protein layer onto gold nanoparticles and revealed a protein crosslinking by means of bityrosine as a function of irradiation dose. Stability was considerably improved by the presence of the protein layer and the crosslinked protein layer.

[*] corresponding author: varca@usp.br

DESTRUCTION OF AMPHETAMINE IN AQUEOUS SOLUTION USING GAMMA IRRADIATION

Turki S. Alkhuraiji[1], Abdul-Wali Ajlouni[2]

[1]King Abdulaziz City for Science and Technology–KACST, Nuclear Science Research Institute, National Center for
Irradiation Technology, P. O. BOX 6086–Riyadh 11442, Saudi Arabia
[2]Naif Arab University for Security Sciences-Department of Forensic Chemistry, Riyadh, Saudi Arabia

Keywords: Amphetamine; Mineralization; Gamma irradiation; Advanced oxidation process; degradation.

ABSTRACT

Amphetamine-type stimulants are among the most prevalent and widespread commonly abused drugs. Amphetamine and its derivatives were detected in aquatic environment. This study aimed to demonstrate experimentally the ability of γ-irradiation combined with persulfate anions ($S_2O_8^{2-}$) to degrade and mineralize the amphetamine in aqueous solution. An initial amphetamine concentration of 125 μM in distilled water was completely degraded by a γ-ray dose of 2.8 kGy. Generation of the sulfate radical ($SO_4^{\bullet-}$) from the fast reaction of added $S_2O_8^{2-}$ with hydrated electrons (e_{aq}^-; $k_{e^-_{aq}/S_2O_8^{2-}} = 1.1 \times 10^{10}$ $M^{-1}.s^{-1}$) improved the efficiency of amphetamine degradation and mineralization. A γ-ray dose of 0.667 and 0.350 kGy in the absence and presence of $S_2O_8^{2-}$ anions degraded 90% of the amphetamine, respectively. For γ-ray/free O_2 and γ-ray/$S_2O_8^{2-}$ systems, 11.5 and 7 kGy was required for 50% amphetamine mineralization, respectively. Addition of HCO_3^- anions lowered the amphetamine degradation yield, whereas N_2 gas, SO_4^{2-}, and Cl^- anions had a negligible effect.

Nuclear Energy

COMPARISON OF STATISTICAL EVALUATION OF CRITICALITY CALCULATIONS FOR DIFFERENT REACTOR TYPES

J. Janczyszyn, G. Domańska*, J. Cetnar

AGH-University of Science and Technology, Faculty of Energy and Fuels, Kraków, Poland

Keywords: nuclear reactor, criticality calculation, uncertainty

ABSTRACT

Limitations of correct evaluation of k_{eff} in Monte Carlo calculations, claimed in literature, need to be addressed more thoroughly. Respective doubts concern: the proper number of discarded initial cycles, the sufficient number of neutrons in a cycle and the recognition and dealing with the k_{eff} bias. Calculations were performed to provide information on these points with the use of the MCB code for several types of reactor cores: critical and subcritical, thermal and fast. Presented are results of testing the calculation results for: stability of variance, relation between standard deviation reported by MCNP and this from the dispersion of multiple independent k_{eff} values, the second order standard deviations obtained from different numbers of grouped results. All obtained results for numbers of discarded initial cycles from 0 to 5500 were analyzed leading for interesting conclusions. Exemplary results are presented in the figure below.

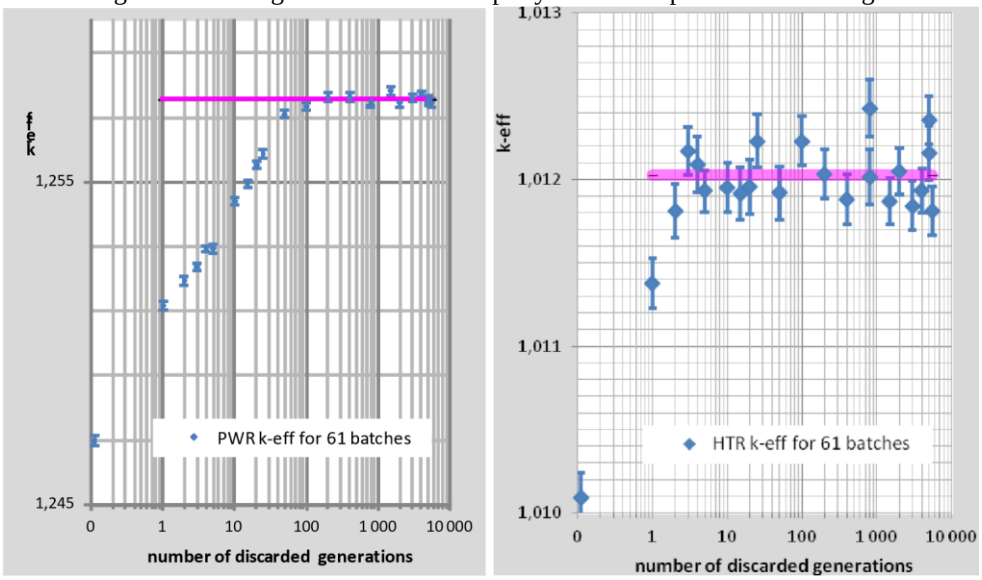


Fig. Results of the dependence of average k_{eff} on the number of discarded initial cycles for PWR and HTR cores (average values from 60 independent calculation results).

* corresponding author: grazyna.domanska@fis.agh.edu.pl

THE STUDIES ON ZIRCONIUM ALLOYS SURFACE LAYER PROPERTIES MODIFICATIONS FOR THE ENHANCEMENT OF THEIR HIGH TEMPERATURE OXIDATION RESISTANCE

Wojciech Starosta[*1], Marek Barlak[2], Agnieszka Kochmańska[3], Piotr Kołodziejczak[4], Magdalena Miłkowska[1], Michał Rydzewski[5], Bożena Sartowska[1], Jerzy Smolik[5], Piotr Tomassi[6], Lech Waliś[1]

[1] Institute of Nuclear Chemistry and Technology, 03-195 Dorodna 16, Warszawa, Poland
[2] National Centre for Nuclear Studies, Andrzeja Sołtana 7, 05-400 Otwock, Świerk, Poland
[3] West Pomeranian University of Technology, 19 Piastów Avenue, 70-310 Szczecin, Poland
[4] Warsaw University of Technology, Narbutta 85, 02-524 Warszawa, Poland
[5] Institute for Sustainable Technologies, K. Pułaskiego 6/10, 26-600 Radom, Poland
[6] Institute for Precision Mechanics, Duchnicka 3, 01-796 Warszawa, Poland

ABSTRACT

Zirconium alloys are extensively used in nuclear technologies. Long, thin wall cylindrical zirconium alloy tubes serves in nuclear reactors as claddings for nuclear fuel. They enable hermetic confinement of the nuclear fuel pellets loaded inside and prevent the nuclear fission fragments from escaping the fuel into the coolant and contaminating it. The zirconium alloys have been selected for the operation in nuclear reactor due to low cross section for zirconium thermal neutrons absorption, sufficiently good corrosion resistance in water environment at working condition of reactor and sufficiently good stability of their mechanical properties under the influence of neutron irradiation. At normal operating conditions of light water reactor (360°C, 195 bar) the zirconium claddings slowly oxidise as the result of the chemical interaction with cooling water and are replaced when oxidation reaches level of 16 % .

Unfortunately, completely unsatisfactory is resistance of zirconium claddings to high temperature oxidation in the water steam and water steam containing hydrogen. Such conditions are expected in the case of severe accidents related to the loss of active cooling (LOCA nuclear accident). Due to the exothermic character of zirconium oxidation reaction, oxidation processes accelerate rapidly at higher temperatures (exceeding 800°C) leading to the catastrophically fast oxidation of claddings and to the generation of large volume of hydrogen liberated in the course of oxidation reactions. The accumulation of hydrogen is dangerous due to the possibility of chemical explosion of oxygen-hydrogen mixture. Such events, although rare, negatively influence the public opinion acceptance for the development of nuclear energy. Moreover, the costs of removing of damaged reactor core and restoration of accompanying damages to the environment are enormously large.

After nuclear accident in Japan (Fukushima 2014) the safety of nuclear installation became a hot topic. The concept of Accident Tolerant Fuels (ATF) that are much more resistant to oxidation in the accident event have been elaborated. The most revolutionary proposition consists in replacing zirconium alloys claddings with those made of silicon carbide. Others, possible for implementation in short time perspective, consist on deposition of external coating over conventional zirconium alloys claddings. Such coatings should be made of material able to develop protective scale in high temperature water vapor environment. Possible candidates include MAX ceramic, zirconium silicide or zirconium silicate coatings.

The studies on the zirconium oxidation processes and countermeasure actions have been started in Institute of Nuclear Chemistry and Technology five years ago in the framework of strategic program "Technologies supporting of safe nuclear power engineering" . Following these initial studies the more detailed research program has been elaborated involving participation of partners from other institutes. The main goal of this program consist in the developing the methods of modification of surface layer of zirconium claddings by different physical and chemical methods. Among the physical modifications methods the following techniques have been applied: - high-intensity pulsed ion-plasma beams treatment of the samples enabling melting of the surface layer and doping of electrodes material into the melted surface layer,
- coatings deposition by magnetron sputtering of zirconium silicide or chromium targets,
- melting of the aluminium or silicon particles deposited on the surface of zirconium alloy using TIG technique. Two chemical methods applied include plasma electrolytic oxidation and slurry diffusion method for slurries containing aluminium or silicon compounds.

The results of the experimental works concerning synthesis method, characterization of the coatings, as well as autoclave and furnace tests will be reported.

Acknowledgment: the financial support from IAEA Research Contract No. 19026/R0, Polish Ministry of Science and Higher Education under decision 3689/IAEA/2017/0 and Polish Ministry of Science and Higher Education under decision 3578/ZIBJ Dubna/2016/0 is gratefully acknowledged.

[*] corresponding author: w.starosta@ichtj.waw.pl

NATIONAL CENTRE FOR NUCLEAR RESEARCH - FIRST 6 YEARS

K. Kurek

National Centre for Nuclear Research, Andrzeja Sołtana 7, 05-400 Otwock-Świerk

ABSTRACT

The National Centre for Nuclear Research commenced operations on September 1, 2011. The Polish Govermment's decision to merge POLATOM Institute for Atomic Energy (IEA) and the Sołtan Institute for Nuclear Studies (IPJ) has ended an almost 30-year-long period , during which the Swierk Research Center remained fragmented. The former Institute for Nuclear Research has been brought back to life under a new name and with a new set of tasks to acomplish. NCBJ conducts pure and applied research in widely understood nuclear physics, elementary particle physics, astroparticle, plasma physics. The Institute specializes in akcelerator physics and technology, material research with nuclear techniques, the developmnet of spectrometric techniques, nuclear electronics. The Institute operates the multifunctional nuclear research reactor MARIA. Radioizotope Centre POLATOM is located in the structure of NCBJ. POLATOM develops techniques for practical application of radioizotopes in various sectors, among them majority of products and services is used in health care.
I will present the current scientific activity of NCBJ, plans and vision for the future development.

NEUTRON SPECTRUM UNFOLDING PROCESS USING BAYESIAN INFERENCE

Orliński M.*[1], Cetnar J.[1]

[1]AGH University of Science and Technology, al. Adama Mickiewicza 30, 30-059 Kraków

Keywords: Neutron spectrum unfolding, Bayesian inference, reaction rates, activation foils

ABSTRACT

The estimation of accurate neutron flux spectrum is particularly important for research and development of nuclear systems to their usage. The nuclear material properties varies over irradiation time and particles spectrum. However it is impossible to directly measure the neutron radiation, what encourages for developing indirect methods of energy distribution assessment. The method proposed in this article bases on the Monte Carlo sampling from multivariate normal distribution with Bayesian inference for unfolding neutron spectrum [1,3].

It is essential to perform a reliable characterization of the neutron spectral distribution in particular new research or prototype nuclear installation, e.g. ITER (International Thermonuclear Experimental Reactor) [4]. The information of particle fields including the estimation of covariance matrix can provide a full range knowledge about predicted neutron spectrum inside an investigated material. The method has been developed at the AGH University [1,2] and has been implemented in our team. The proposed algorithm uses the Monte Carlo method to generate random samples from a multivariate normal distribution (MVN) using *a priori* neutron spectrum. Subsequently, a weight, which is in fact the likelihood of MVN probability density function, is assigned for each randomized spectrum using the Bayesian inference approach. The weighted distribution is used to obtain a new multivariate normal distribution with covariance matrix, which gives a better estimate of neutron spectrum. The iterative execution of proposed algorithm allows to get satisfactory results of neutron spectrum unfolding.

This new approach of unfolding process is practically insensitive to first guest of *a priori* neutron spectrum in contrary to other currently existing methods. Moreover in our novel methodology we directly obtain full information about the uncertainties of every energy group by computing the covariance matrix of MVN distribution. The preliminary results reveal a promising potential of Bayesian approach to the neutron spectrum unfolding process.

[1] J.Cetnar, I.Królikowski, L.Ottaviani, A.Lyoussi, Characteristics of SiC neutron sensor spectrum unfolding process based on Bayesian inference, ANIMMA 2015: the fourth international conference on Advancements in Nuclear Instrumentation Measurement Methods and their Applications: Lisboa, 20–24 April 2015.

[2] J.Cetnar, I.Królikowski, Report on treatment and analysis of the outcome signal of a combined detector system, I_SMART (Innovative Sensor for Material Ageing and Radiation Testing), Work Package 4: Tools for signal recognition, InnoEnergy Innovation Project Proposal for the topic "Nuclear Energy", 1 Dec 2014.

[3] M.Nakazawa, N.Ueda, T.Taniguchi, A.Sekiguchi, A new adjustment code based on the Bayes' theory combined with the Monte-Carlo technique, J. P. Genthon and H. R6ttger (eds.), Reactor Dosimetry, 649-656, ECSC, EEC, EAEC, Brussels and Luxembourg, 1985.

[4] https://www.iter.org/sci/BeyondITER (access 28-04-2017)

* corresponding author: morlinsk@agh.edu.pl

APPLICATION OF THE HYBRID NUMERICAL METHOD TO THE CHARACTERISTICS OF OXIDIZING ENVIRONMENT IN THE PWR PRIMARY CIRCUIT

Lukasz Kazmierczak[*1], Dorota Swiatla-Wojcik[1]

[1] Institute of Applied Radiation Chemistry, Faculty of Chemistry, Lodz University of Technology, Zeromskiego 116, 90-924 Lodz, Poland

Keywords: water radiolysis, LWR, PWR, kinetic simulation, coolant chemistry

ABSTRACT

In the pressurized water reactor (PWR), water is used as a coolant and neutron moderator. In the primary circuit the coolant is exposed to a mixed flux of fast neutrons and gamma rays. Irradiation of liquid water results in the formation of strong oxidants: short-living radicals (OH, HO_2) and stable molecular products (H_2O_2, O_2). These corrosive agents pose severe problems with intergranular stress corrosion cracking (IGSCC) leading to material degradation. The harmful corrosive effect is additionally strengthened by low pH, ca. 5.8 at the operating temperatures ~300 °C. In order to control the oxidizing environment, chemicals like hydrogen, hydrazine, ammonia, and LiOH are usually added to the coolant.

To assess the electrochemical corrosion potential knowledge of chemical reactions occurring in the primary circuit under operating conditions is needed but difficult to gain because of high temperature (275-315 °C), pressure (~155 bar), and intense radiation field. Hence, computer simulation and modeling are necessary to predict time profiles and steady-state concentrations of oxidizing species under varying operational modes. Recently proposed hybrid method [1] provides a comprehensive numerical approach, combining diffusion-kinetic modelling of the radiation track chemistry and kinetic simulation of secondary reactions in the bulk coolant. In this work the hybrid method has been used to characterize concentration of harmful oxidants in different parts of the PWR primary circuit. We report the effect of temperature, radiation composition, and dose rates. Our aim is to single out principal reactions contributing to the formation of H_2O_2, $HO_2^{\bullet}$, $^{\bullet}OH$ and O_2. The effectiveness of hydrogen and LiOH addition in suppressing the formation of O_2 and H_2O_2 is simulated and discussed.

[1] D. Swiatla-Wojcik, *Radiat. Phys. Chem.*, 127 (2016) 236-242.

[*] corresponding author: lukaszkazmierczak7@o2.pl

IMPLEMENTATION OF THE POLISH NUCELAR POWER PROGRAMME – A STUDY OF SOCIOECONOMIC EFFECTS

Miśkiewicz*[1], G. Zakrzewska-Kołtuniewicz[1], M. Antoszewski[2], M. Plich[3], K.Iwińska[4]

[1]Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland
[2]SGH Warsaw School of Economics, al. Niepodległości 162, 02-554 Warsaw, Poland
[3]Institute of Econometrics, University of Lodz, Rewolucji 1905r. 41, 91-214 Lodz, Poland
[4]Collegium Civitas, 1 Defilad Square, Warsaw 00-901, Poland

Keywords: nuclear power, macroecomic modelling, CGE and IO models, social aspects

ABSTRACT

The aim of the studies was an assessment of social and socio-economic impacts of nuclear programme in Poland. These issues are very important for Poland - the country that is just beginning to develop nuclear power. In order to analyze the socio-economic impacts of nuclear programme at the national level, two types of economic models: EMPOWER model and Computable General Equilibrium (CGE) model were reviewed and applied.

EMPOWER is a generic extended Input-Output (I-O) model for impact assessment of nuclear power plants (NPP) proposed by IAEA. It allows for calculating not only direct and indirect but also induced effects, labor market response and feedback from financing of investments. Based on preliminary calculations it was seen that as a result of the start of construction of a NPP in Poland, the GDP as well as other macroeconomic variables increase slightly. It also turns out that in the situation, when the investment for the construction of a nuclear power plant reaches its maximum, macroeconomic variablesreact much more strongly.

The purpose of the simulations using CGE model was to examine under what external conditions (parameters) a power generation using nuclear technology in a given year is cost-effective. Three different scenarios were considered: (i) analysis of the impact of the expected climate and energy policy on the profitability of nuclear power, (ii) analysis of the impact of changes in the capital cost for the price of electricity production, and thus on the economic viability of the nuclear project and (iii) analysis of the impact of the mechanism of a fixed price for the production of energy from nuclear power on the profitability of the nuclear power in Poland.

In parallel, to study the economic effects, the efforts have been made towards the development of methods for analyzing social impacts of implementation of Polish Nuclear Energy Programme (PNEP). Chosen methodological approach combines information from both qualitative and quantitative data in order to obtain results which are spectrum of knowledge from existing data (public opinion polls) and the qualitative sociological research. Internet monitoring of the nuclear discourse is being conducted as well as the analysis of public perception and expert assessment of nuclear Energy. The study uses **Q**-methodology to investigate the subjective perspectives of people and identifiy 4 main points of view on implementing PNEP.

Acknowledgement
The studies were supported by financial resources for science in the years 2016-2017 granted for the implementation of the international co-financed project No 3672/IAEA/2017/0 and IAEA Research Contract 18541.

* corresponding author: a.miskiewicz@ichtj.waw.pl

APPROACH TO MONTE CARLO BURNUP OPTIMIZATION

Grzegorz Kępisty*[1], Jerzy Cetnar[1]

[1]AGH University, Faculty of Energy and Fuels, Department of Nuclear Energy, Krakow, Poland

Keywords: Monte Carlo, optimization, gradient method, burnup, SERPENT, time mesh;

ABSTRACT

In this work we present a concept of optimization for steady state reactor burnup simulations. Presented approach is based on the gradient method [1]. Suggested aim function bases on results comparison with a reference simulation (discrepancies of nuclide field, few-groups cross sections or k_{eff}). For the purpose of numerical study we use continuous energy Monte Carlo burnup code SERPENT [2] and the assembly geometry from Pressurized Water Reactor [3]. State-of-art methodology and good practices of Monte Carlo burnup simulations are applied. The input parameters under optimization are the number of active neutron cycles and the time steps grid. Total execution time is constrained for considered simulations performed on one node of cluster computer. We manage to predict the simulation time length with accuracy of few %. Our results show that, depending on aim function, the optimal simulation results are observed for substantially different time mesh / neutron precision. For example better depletion results at end-of-cycle are observed when tens of steps are set, while more accurate cross-sections are predicted when several time steps are in use. Our methodology is applicable for Monte Carlo and deterministic codes and it gives some new clues for code users.

[1] M.C. Fu, Optimization for Simulation: Theory vs. Practice, INFORMS Journal on Computing, 14:3 (2002) 192–215;

[2] J. Leppänen, Serpent – a Continuous-energy Monte Carlo Reactor Physics Burnup Calculation Code, User's Manual, 2015, http://montecarlo.vtt.fi/download/Serpent_manual.pdf;

[3] G. Kępisty, J. Cetnar, P. Stanisz, Parametric studies of the PWR fuel assembly modeling with Monte-Carlo method, Annals of Nuclear Energy 94 (2016) 189–207;

* corresponding author: gkepisty@agh.edu.pl

THE IN-VESSEL MELT RETENTION STRATEGY FOR EXISTING AND FUTURE NUCLEAR POWER PLANTS – COMPUTATIONAL FLUID DYNAMICS SIMULATIONS WITHIN AND BESIDES THE HORIZON2020 PROJECT

Maciej Skrzypek[*1,2], Eleonora Skrzypek[1,2]

1 National Center for Nuclear Research, ul.Andrzeja Sołtana 7, 05-400 Otwock-Świerk, Poland
2 Warsaw University of Technology, ul. Plac Politechniki 1, 00-661 Warsaw, Poland

Keywords: Severe Accidents, IVMR, CFD, Management Strategy, corium pools

ABSTRACT

The topic of the paper is the assessment of the In-Vessel Retention (IVR) strategy in context of the thermalhydraulics computations with the use of the CFD software. This strategy is considered and investigated under the European H2020 IVMR project for the existing and future water cooled power plants, although some of the project results can be extrapolated to the other more innovative reactor types. The issues investigated in the project are multiple involving the mechanical, thermal and strictly computational ones, while the calculations presented in this paper are covering the specific phenomenon study – the focusing effect, which is the main risk to the Reactor Pressure Vessel wall under severe accident conditions. The focusing effect is present in the thin metallic layer formed on the top of the molten corium pool after its stratification. In the paper the used CFD tool and its capabilities – the use of the turbulence models, are discussed in relation to the experimental data from the scaled water tests, which is one of the steps in the project activities. The computations are giving the indicators for the efficient mesh and model set ups for the chosen CFD code. In this step the assessment of the code is done to check it in frame of its suitability for use to the safety analysis for the water reactors. The discussion of the results is leading to the second phase, where the prototypical computations are performed for the full scale reactor case under severe accident conditions in the high power PWR.

* corresponding author: maciej.skrzypek@ncbj.gov.pl

THE MEASUREMENTS OF THE HIGH ENERGY EVAPORATED NEUTRONS BY MEANS OF ^{89}Y THRESHOLD REACTION ACTIVATION METHOD

M. Bielewicz[*1,2], E. Strugalska-Gola[1], S. Kilim[1], M. Szuta[1], S. Tyutyunnikov[2]

[1]National Centre for Nuclear Research, Otwock-Świerk 05-400, Poland
[2]Joint Institute for Nuclear Research, 141980 Dubna, Russia

Keywords: ADS, Ittrium, threshold, neutron measurements

ABSTRACT

This work is carried out within the project radioactive waste utilization problems by means of QUINTA assembly simulating ADS (Accelerate Driving Systems). The deeply subcritical Quinta assembly has about 500 kg of natural uranium and the lead shielding. The assembly was irradiated by proton and deuteron beams with energy from 0.66 to 8 GeV retrieved from the accelerators located in the JINR laboratories, Dubna. The (n, xn) threshold reaction method based on yttrium activation detectors let us to evaluate average neutron flux spectrum of energy hire than that of fission neutrons and near the maximum evaporation energy (about 40 MeV). The neutron flux density measured in the three different neutron energy ranges: 11.5 – 20.8 MeV, 20.8 - 32.7MeV and 32.7 – 100 MeV will be presented as well as theirs comparison.

* corresponding author: marcin.bielewicz@ncbj.gov.pl

REVERSED ENGINEERED 3D FUEL BUNDLE FOR CFD UNCERTAINTY STUDY

Piotr A. Prusiński[*1], Tomasz Kwiatkowski[1], Piotr Warzybok[1]

[1] National Centre for Nuclear Research, Andrzeja Soltana 7 str., 05-400 Otwock-Swierk, Poland

Keywords: reversed engineering, 3D scanned geometry, CFD analysis, nuclear fuel bundle, uncertainty analysis

ABSTRACT

The Computational Fluid Dynamics (CFD) methodology was invented to bring answers related to mass and energy transport phenomena in a greater resolution than any measuring technique can provide the data without disruption the flow. The benefits of its implementation are observable in various aspects of life, including hydraulic systems (like sanitations or HVAC), transportation, medicine, sport etc., however the results of CFD analyses for nuclear applications are doubtful to some extent. The reason is its inherent uncertainty that is hard to assess and hard to accept without extra explanations and margins implementations due to safety issues. A multi-parametric nature and no simple recipe for a single case, i.e. choice of domain discretization, physics applied or simplifications due to computational hardware limitations - to outline at least few of them - makes it impossible to be accepted in a conservative society of nuclear engineers.

This particular paper is not to solve any of the above. It is to bring to attention of the wider audience and briefly discuss another topic that needs further investigation which is geometric precision of CFD-grade experiments. It is because the main stream of current CFD specialists world-wide discussion concerns the insufficient resolution of the input data (limited to capabilities of the particular measuring hardware) given by the experimentalists and their impact on the final CFD results. There is however another unknown that seem to be systematically overlooked, meaning a precision of the manufacturing.

CFD analyses are generally based on blueprints that are not necessarily 1:1 to the manufactured object. However, this should be of a particular importance when nuclear safety plays the first role. This paper is to present the difference in CFD results between the analysis based on blueprint design and on real geometry extracted thanks to 3D scanning and industrial computer tomography system combination available at the National Centre for Nuclear Research. The object of interest will be a unique rod-type fuel assembly designed for testing in matrix of the MARIA Research Reactor.

[*] corresponding author: piotr.prusinski@ncbj.gov.pl | +48 22 273 11 26

Accelerators and their Applications (ARIES related session)

NEW TRENDS IN RADIATION PROCESSING

Andrzej G. Chmielewski

Institute of Nuclear Chemistry and Technology*,Warsaw, Poland

ABSTRACT

Ionizing radiations in the form of gamma rays, energetic electrons and X-rays (Bremsstrahlung) are being used for many practical applications. Successful irradiation processes provide significant advantages in comparison to typical thermal and chemical processes, such as higher throughput rates, reduced energy consumption, less environmental pollution, more precise control over the process, and the production of products with superior qualities. In some applications, radiation processing can produce unique effects that cannot be duplicated by other means. High-energy, high-power gamma X-rays or electron beams can modify the physical, chemical and biological properties of materials and commercial products on an industrial scale. Many gamma sources and electron accelerators with a variety of specifications were built and installed for these purposes. These technologies have been evolving for more than fifty years, and this field is still expanding. The biggest industrial use of ionizing radiation is the modification of the properties of polymers, including rubber. Ionizing radiation finds use in a variety of industrial applications such as wire and cable insulation, tire manufacturing, production of polymeric foams, heat-shrinkable films and tubing, curing of coatings, adhesives and composites, printing, and other technological development. Cross-linked PE pipes (PEX) for house application are processed with application of electron accelerators. Other applications of ionizing radiation include synthesis of hydrogels, radiation curing of polymeric composites, production of Teflon additives, radiation-cured flexography, coatings, adhesives, paints and printing inks. The ability to fabricate structures with nanometric precision is of fundamental importance to any exploitation of nanotechnology including graphene. Beside lithography, ionizing radiation became a perfect tool for formation and synthesis of nanoparticles and nanocomposites. The other major use of this technology is the sterilization of medical devices. Approximately 50% of the single use medical devices in the UK and 40–50% of all disposable medical products manufactured in North America are sterilized by ionizing radiation. There are other important fields from the social point of view: environmental protection and cultural heritage preservation. Municipal and industrial activities of mankind lead to environmental degradation. Radiation technology may contribute to environmental protection to a great extent. Efficient technologies for gas, liquid and solid wastes treatment were developed. Ionizing radiation is the most effective one regarding biohazards' control even in sealed containers. The preservation of world cultural heritage is a key issue for maintaining national identity, and understanding the exchanges among civilizations throughout history. Cultural heritage (CH) artefacts that are based on paper, textiles or wood are prone to biological attack under improper conservation conditions. Application of ionizing radiation for the disinfection of CH artefacts has been successfully demonstrated in recent years with participation of museums and libraries.

Acknowledgements.

The work is financed by H2020 ARIES project and Ministry of Higher Education and Science (Poland).

*IAEA Collaborating Centre
Corresponding author: A.Chmielewski@ichtj.waw.pl

ECONOMICAL EVALUATION OF RADIATION PROCESSING WITH HIGH INTENSITY X-RAYS

Z. Zimek*

Centre of Radiation Research and Technology, Institute of Nuclear Chemistry and Technology, Warsaw, Poland

Keywords: X-rays, economical evaluation, radiation processing

ABSTRACT

X-rays application for radiation processing was introduced to industrial practice and in some circumstances is found to be more economically competitive and offer more flexibility than gamma sources. Recent progress in high power accelerators development gives opportunity to construct and apply reliable high power electron beam to X-rays converters for industrial application. The efficiency of the conversion process depends mainly on electron energy and atomic number of the target material, as it was determined in theoretical predictions and confirmed experimentally. On the other hand lower price of low energy direct accelerators and theirs higher electrical efficiency may have certain influence on economic results as well. There are number of other parameters which can effectively change process economic results like average beam power level, spare part cost, optimal shape of electron beam and electron beam utilization efficiency. All these parameters and related to them expenses may affect unit cost of radiation facility operation and have significant influence on X-ray process economy. The optimization of X-rays converter construction is also important, but it does not depends on type of accelerator. The paper discusses the economics of radiation processing with high intensity of X-rays stream emitted by conversion of electron beams with different energy (2, 5 and 7 MeV). The evaluating and comparing costs of alternative technical solutions were included to predict unit cost of Xrays facility operation.

* corresponding author:kz.zimek@ichtj.waw.pl

INDUSTRIAL RF ELECTRON ACCELERATORS ILU TYPE

A.Bryazgin*, V.Bezuglov, A.Vlasov, L.Voronin, M.Korobeynikov, A.Lukin, S.Maksimov, V.Nekhaev, A.Panfilov, V.Radchenko, A.Sidorov, V.Tkachenko, B.Faktorovich, E.Shtarklev.

Budker Institute Of Nuclear Physics, Novosibirsk, Russia

Keywords: Electron accelerator, Radiation technologies

ABSTRACT

The radio frequency pulse accelerators type ILU cover the energy range 0.8-10 MeV, their power is up to 100 kW. BINP produces ILU types of RF accelerators for E-beam and X-ray processes. These accelerators have wide energy and power diapasons of electron beam. It allows use them for different applications in radiation chemistry, medical device sterilization and food irradiation. Talk includes description of accelerators and the examples of real radiation complexes in industry. Accelerators use for design new perspective radiation technologies in scientific institutes also.

* corresponding author: A.A.Bryazgin@inp.nsk.su

INDUSTRIAL WASTEWATER TREATMENT USING HIGH ENERGY ELECTRON BEAM IRRADIATION: REMOVAL OF CHROMIUM (VI) HEAVY METAL

Fathi Djouider* and Mohammed S. Aljohani

Nuclear Engineering Department, Faculty of Engineering, King Abdulaziz University
Po Box 80204, Jeddah, 21589, Saudi Arabia

Keywords: Electron beam irradiation, water radiolysis, chromium (VI) degradation, superoxide radical, formate effect.

ABSTRACT

Background of the study
Chromium(VI) heavy metal is a major water contaminant in most industrial effluents, due to its carcinogenicity and its impact on ecosystems, while Chromium (III) is non-toxic and is an important element for human metabolism. Large quantities of Cr(VI)-contaminated wastewater are produced by chemical-intensive industries and discharged into aquatic environments. The objective of this study is to evaluate the radiation induced reduction of Cr(VI) to Cr(III) by $O_2^{-\bullet}$ free radical radiolytically produced in aerated solution at neutral pH in the presence of formate.

Methodology
The degradation of Cr(VI) was investigated by continuous and pulsed electron beam irradiation by a 2.5 MeV van de Graaff in aerated solution at neutral pH, which is close to natural conditions in most wastewaters. Pulse durations of 0.6, 1.2 and 2 μs were used. The dose obtained was between 7 and 500 Gy per pulse. The bleaching of Cr(VI) was observed spectrophotometrically at 370 nm.

Results
The degradation of Cr(VI) increased linearly with the absorbed dose and was significantly enhanced by the added formate. More than 99% of Cr(VI) was removed after a dose of 5 kGy at near neutral pH. To explain the mechanism of this removal, a kinetic model was proposed. Cr(VI) is first reduced by $O_2^{-\bullet}$. This reduction is followed by a disproportionation of Cr(V) into Cr(IV) and a partial recovery of Cr(VI). In a second step Cr(IV), rather than Cr(V), oxidizes $O_2^{-\bullet}$ in a one-electron reaction leading to the formation of the stable and non-toxic Cr(III) product. A partial recovery of Cr(VI) is observed over a period of *ca*. 5 ms following a second order kinetics with a rate constant 8.0×10^6 M^{-1} s^{-1}.

Conclusion
This laboratory study shows that EB irradiation might be effective and economical in the remediation of large volumes of industrial wastewater contaminated with chromium. It is an alternative means to conventional chemical methods of treating effluents.

* Corresponding author. Tel.: +966 558822318. E-mail address: fdjouider@kau.edu.sa

THE REMOVAL OF NO_X AND SO_2 FROM EXHAUST GASES USING A HYBRID ELECTRON BEAM METHOD

E. Zwolińska*[1], Y.Sun[1], A.G. Chmielewski[1], J. Licki[2], A.Pawelec[1], S. Bułka[1], Z., Zimek[1]

[1]Institute of Nuclear Chemistry and Technology, ul. Dorodna 16, 03-195 Waraszawa
[2] National Center for Nuclear Research, ul. Andrzeja Sołtana 7, 05-400 Otwock-Świerk

Keywords: electron beam, NOx, SO_2, hybrid method

ABSTRACT

The main source of air pollutants such as NO_x and SO_2 are exhaust gases generated during the combustion of fuels used in the power and transport sectors. It is estimated that in 2020, pollution from marine sources will exceed the level of pollution from all land-based sources. The concentration of harmful oxides in the off-gas varies with the type of fuel. One of the most commonly used fuels on cargo ships is diesel oil, which contains high concentrations of both NO_x and SO_2. Therefore, it is necessary to use a gas purifying method before releasing them into the atmosphere. The removal of nitrogen oxides is a difficult process, often requiring the use of expensive catalysts (the most commonly used is Selective Catalytic Reduction). However, as international emissions regulations on nitrogen and sulfur oxides tighten, current removal methods are becoming increasingly insufficient. Therefore, it is necessary to look for new cost effective solutions to remove both nitrogen and sulfur oxides with high efficiency simultaneously.

The current study assesses the concept of combining two methods used to clean up the exhaust gases: Electron Beam (EB) and Wet Scrubbing. Electron Beam Flue Gas Treatment (EBFGT) was first demonstrated in the 1970s in Japan. Since then, this method has been investigated and developed by scientists from different countries, among others in USA, Germany, China, Romania and Poland. However, achieving high efficiency when pollutant inlet concentrations are high is very difficult and requires high energy inputs. Absorption methods are commercially used around the world for the SO_2 removal, but the poor NO solubility, which is the main component of NO_x generated during fuel combustion, does not permit the simultaneous removal of both pollutants.

The research is based on the use of hybrid technology to create a synergistic effect and to achieve higher process efficiency. Furthermore, different wet-scrubbing solutions are used in the current study to optimize the removal of pollutants, while also receiving a post-process liquid that could potentially be recycled.

Acknowledgements: This work was partly financed by the Institute of Nuclear Chemistry and Technology, in the frame of Ministerial Statutory Funding Task 4.3 and co-financed by the he Polish Ministry of Science and Higher Education, project 3697/H2020/2017/2.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871

* corresponding author: e.zwolinska@ichtj.waw.pl

APPLICATION OF ACCELERATOR PRODUCED ISOTOPES IN NUCLEAR MEDICINE – INCT RESEARCH ACTIVITY

M. Łyczko*[1], R.Walczak[1], Ł. Dziawer[1], M.Gumiela[1], E.Gniazdowska[1], P. Koźmiński[1], A. Majkowska[1], M. Pruszyński[1], S.Krajewski[2], A.Bilewicz[1]

[1] *Institute of Nuclear Chemistry and Technology, Warsaw, Poland*
[2] *Synektik S.A., Research and Development Center, Warsaw, Poland*

Keywords: scandium-43, scandium-47, astatine-211, technetium-99m

ABSTRACT

In recent years, our scientific activity was focused on production and application of radionuclides for PET technique, ^{43,44}Sc, and for therapeutic use ^{47}Sc and ^{211}At. ^{43}Sc ($t_{1/2}$ = 3.89 h) is an ideal β^+ emitter for PET diagnosis. It can be used as an alternative to ^{68}Ga, because ^{43}Sc has a longer half-life and forms theranostic pair with β^- emitter ^{47}Sc, that is important in planning radionuclide therapy. On the other hand ^{47}Sc- low energy β^- emitter is an attractive candidate for radioimmunotherapy. In our work we propose a new way for cyclotron production of ^{43}Sc in ^{42}Ca(d,n)^{43}Sc nuclear reaction, and ^{47}Sc by proton irradiation of ^{48}Ca target in p,2n reaction. The proposed methods allow to obtain high activity of ^{43}Sc and ^{47}Sc.

Among the others α-emitting radionuclide ^{211}At has attractive properties for use in targeted radionuclide therapy, especially for small tumours and cancer metastasis. ^{211}At is produced via ^{209}Bi(α,2n)^{211}At nuclear reaction and has a 7.2 h half-life - a sufficient time for its production, synthesis, transportation and medical application. However, many astatine compounds that have been synthesized are unstable *in vivo*, providing motivation for seeking other ^{211}At labeling strategies. In our work we propose to utilize formation of strong bond between astatine and Rh^{3+} cation and metallic gold to bind the ^{211}At to biomolecules.

We have shown that gold nanoparticles labelled with ^{211}At functionalized with substance P and trastuzumab presents a prospective solution for the use of the ^{211}At as a therapeutic tool for targeting glioma cells and HER2 positive breast and ovarian cancers.

According to ^{99m}Tc crisis, there is growing interest in the large scale cyclotron production of ^{99m}Tc via the ^{100}Mo(p,2n)^{99m}Tc reaction. In this field we elaborated a simple and fast method for the separation of clinical grade ^{99m}Tc from macroscopic levels of cyclotron irradiated molybdenum targets.

Acknowledgements

This work was a part of the projects of the National Center for Applied Research of Poland Nr PBS3/A9/28/2015, grant Ministry of Science and Higher Education of Poland from funding for science in the years 2016-2019 (cofinanced international program), IAEA Research Contract No:20488 and National Science Center of Poland (Grant 011/01/M/ST406756).

INVESTIGATION OF NEUTRON RADIATION AND INDUCED RADIOACTIVITY FOR THE NEW MEDICAL LINEAR ACCELERATOR - THE VARIAN TRUEBEAM

Adam Konefał[*1], Andrzej Orlef[2]

[1] Department of Nuclear Physics and its Applications, Institute of Physics, University of Silesia, Katowice, Poland
[2] Department of Medical Physics, Center of Oncology, Gliwice Branch, Gliwice, Poland

Keywords: TrueBeam medical linac, neutron production, activation

ABSTRACT

Linear accelerators applied in contemporary radiotherapy generate X-ray and electron beams with energies up to 20 MeV. These high-energy therapeutic beams induce undesirable photonuclear (γ,n) and electronuclear (e,e'n) reactions in which neutrons and radioisotopes are produced. The originated neutrons induce secondary reactions, mainly simple capture reactions (n,γ). In these reactions radioisotopes are also produced. [1-4]

In this work measurements of the non-therapeutic neutrons and the induced gamma radiation were performed for a new medical accelerator - the Varian TrueBeam. This accelerator is a new generation of Varian medical linac making it possible to generate the X-ray beams with a dose rate higher than in the case of the previous models by Varian. This work was carried out for the X-ray beams with nominal potentials of 10 MV (flattening filter free), 15 MV and 20 MV, and for a 22 MeV electron beam. A helium chamber and the induced activity method were used in the neutron measurements. The identification of radioisotopes produced during emission of the therapeutic beams was based on measurements of the energy spectra of gamma-rays emitted in decays of the produced nuclei. The gamma-ray energy spectra were measured by means of the high-purity germanium detector.

The correlation between the neutron fluence and the kind of a beam and nominal potential was observed. The strongest neutron fluence of 3.1×10^6 cm^{-2} Gy^{-1} and 2.0×10^6 cm^{-2} Gy^{-1} for the thermal and resonance energies, respectively, was measured during emission of the 20 MV X-ray beam. The thermal and resonance neutron fluence measured for the 15 MV X-rays was somewhat less, at 1.1×10^6 cm^{-2} Gy^{-1} for thermal neutrons and 6.7×10^5 cm^{-2} Gy^{-1} for resonance ones. The thermal and resonance neutron fluences were smallest for the 10 MV FFF beam and the 22 MeV electron beam and were around two orders of magnitude smaller than those of the 20 MV X-ray beam. This work has indicated that the neutron reactions are dominant because of relatively high cross sections for many elements used in the accelerator construction. The detailed analysis of the measured gamma-ray spectra made it possible to identify 11 radioisotopes induced during TrueBeam delivery. In this work the following radioisotopes were identified: ^{56}Mn, ^{122}Sb, ^{124}Sb, ^{131}Ba, ^{82}Br, ^{57}Ni, ^{57}Co, ^{51}Cr, ^{187}W, ^{24}Na and ^{38}Cl. The obtained results were presented in [5].

References

[1] Konefał, A., Polaczek-Grelik, K., Zipper, W., 2008. Undesirable nuclear reactions and induced radioactivity as a result of the use of the high-energy therapeutic beams generated by medical linacs. Radiation Protection Dosimetry 128, 133-145.

[2] Konefał, A., Orlef, A., Dybek, M., Maniakowski, Z., Polaczek-Grelik, K. Zipper, W., 2008b. Correlation between radioactivity induced inside the treatment room and the undesirable thermal/resonance neutron radiation produced by linac. Physica Medica 24, 212-218.

[3] Konefał, A., Orlef, A., Łaciak, M., Ciba, A., Szewczuk, M., 2012. Thermal and resonance neutrons generated by various electron and x-ray therapeutic beams from medical linacs installed in polish oncological centers. Rep. Pract. Oncol. Radiother. 17, 239–246.

[4] Konefał, A., Łaciak, M., Dawidowska, A., Osewski, W., 2014. Significant change in the construction of a door to a room with slowed down neutron field by means of commonly used inexpensive protective materials. Radiation Protection Dosimetry 162, 197–207.

[5] Konefał, A., Orlef, A., Bieniasiewicz, M., 2016. Measurements of neutron radiation and induced radioactivity for the new medical linear accelerator, the Varian TrueBeam. Radiation Measurements, 86, 8-15.

[*] corresponding author e-mail: akonefal@us.edu.pl

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

W. Grabowski*, K. Kosiński, M. Staszczak, A. Wysocka-Rabin

NCBJ, Andrzeja Sołtana 7, 05-400 Otwock-Świerk, Poland

Keywords: DONES, linear accelerator, beam dynamics

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) system is designed to provide an accelerator-based D-Li neutron source that produces high energy neutrons at sufficient intensity to simulate the first wall neutron spectrum of future nuclear fusion reactors. The DONES plant will produce a 125 mA deuteron beam, which can be accelerated up to 40 MeV, and shaped to have a nominal cross section of 100 mm x 50 mm that impinge on a liquid lithium curtain. The stripping reactions generate a large number of neutrons that interact with material samples 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) section, a Superconducting Radio Frequency Linear Accelerator (SRF-L) and a High Energy Beam Transport Line (HEBT).

The aim of this work was to optimise the SRF-L to meet two requirements at the same time: (a) beam energy of at least 40 MeV at the end of the linac, (b) energy losses of less than 1 W/m in the worst region. To obtain reliable results, we used two calculation codes: TraceWin and GPT (General Particle Tracer) to simulate the accelerator facility from the exit of the RFQ to the entrance of the HEBT. Based on technical data provided by CEA (French Alternative Energies and Atomic Energy Commission), we investigated 66 variants of the accelerating system. Calculation results of beam energy losses, statistical parameters of the beam and beam density in analysed phase spaces were obtained and compared in both codes. At present, the best result obtained is 40.19 MeV beam energy and 8.36 W/m peak energy loss.

On the basis of these results, changes were introduced in the construction of SRF-L.

* corresponding author: Wojciech.grabowski@ncbj.gov.pl

THE ARIES INDUSTRIAL AND SOCIETAL APPLICATIONS NETWORK

R. Edgecock[*1], A. Chmielewski[2], F.H. Roegner[3], A. Faus-Golfe[4], C. Oliver[5], P. Dethier[6]

[1]University of Huddersfield,United Kingdom
[2]Institute of Nuclear Chemistry and Technology, Warsaw,Poland
[3]Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, Dresden, Germany
[4]CNRS Centre National de la Recherche Scientifique, France
[5]CIEMAT Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Spain
[6]IBA Ion Beam Applications SA, Belgium

ABSTRACT

The ARIES H2020 project started on 1st May 2017 and will study many aspects of particle accelerator R&D. It follows on from several earlier projects, the most recent being EuCARD2. One work package, called ISA, will focus on the Industrial and Societal Applications of accelerators, in particular the use of low energy electron beams for many industrial and environmental applications, the use of higher energy electron beams for cancer therapy, nuclear physics studies, etc and the use of ion beams for the production of radioisotopes for imaging and therapy.

This paper will introduce ARIES and the the ISA network. It will describe what we plan to do in the network and show how this follows on from work done in EuCARD2. It should be noted that the ISA network kick-off meeting will follow NUTECH and all participants are welcome to attend.

* Corresponding author: t.r.edgecock@hud.ac.uk

Poster Session I

RELIMINARY STUDY OF THE DOSE DISTRIBUTION IN THE X-RAY BEAM FORMED BY POLICAPILLARY LENS

K. Matusiak, P. Wrobel, A.Jung, J. Dudała

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Mickiewicza Av. 30, 30-059 Krakow, Poland

Keywords: X-ray fluorescence (XRF), confocal-XRF, micro-imaging, TLD dosimetry

ABSTRACT

Polycapillary lenses are the most common choice for the focusing of X-rays into micro-beams. Due to the high gain of X-ray intensity, small focal spot (few tens of microns) and ability to work together with sources of the cone-shaped beams like X-ray tubes this kind of X-ray optics is very popular in laboratory devices for micro-XRF and micro-XRD techniques. Those methodologies are commonly used for non-destructive analyses of biological materials, environmental samples as well as cultural heritage objects. The knowledge of the spatial distribution of radiation emitted by such kind of optics is crucial for analyses of fragile samples and for design of radiation protection shielding.

The aim of this study was to measure the spatial distribution of the dose in the beam formed by polycapillary lens with use of thermoluminescent detectors (TLDs). The X-ray beam was formed by an X-ray tube integrated with a polycapillary lens (X-BEAM, X-ray Optical Systems, USA)with the nominal focal spot of 17 um FWHM (at 17.4 keV) at the working distance of 4.4 mm.

In the study one hundred LiF:Mg,Cu,P TLDs (MCP-N, IFJ PAN, Poland) were applied. Detectors were prepared for the measurements according to the manufacturer recommendation. In particular, preirradiation annealing (240°C, for 10min), irradiation (calibration source Cs-137, dose 1mSv), postirradiation annealing (100°C, for 10min), and readout (three step plateau heating mode: 150°C for 10s, 245°C for 15s, 245°C for 15s) were provided. Individual Response Factors (IRF) as well as calibration curve were calculated and applied.

Measurements were done for several distances, e.g. 18.6cm, 37.4cm and 56.2cm from polycapillary exit. TLDs (dimeter 4.5mm) were distributed in a form of the matrix. One detector was placed close to the focal spot. The times of irradiation were: 5min for all matrix of detectors and 1 min for the detector in the focus beam. The X-ray tube operating point was 50kV, 1mA. The readout process was performed immediately after irradiation.

The obtained results were discussed and compared with the theoretical values. This study confirms a high usefulness of TLD for the spatial dose distribution estimation. Due to high accuracy and convenience of TLDs it will be extended.

APPLICATION OF ^{64}Cu RADIOTRACER FOR INVESTIGATION OF LEACHING COPPER ORE

Tomasz Smoliński*, Marcin Rogowski, Marta Pyszynska, Andrzej G. Chmielewski

Institute of Nuclear Chemistry and Technology, Dorodna 16 Str., 03-195 Warsaw, Poland

Keywords: hydrometallurgy, radiotracer, leaching, copper ore

ABSTRACT

Hydrometallurgical processes are widely used for the recovery of valuable metals including gold, copper, rare earths, uranium etc. The technique of extractive metallurgy involves aqueous chemistry for the recovery of metals from the various raw materials such as ores, concentrates, recycled or residual materials and wastes. The main advantages of hydrometallurgical processes include less energy demand in comparison to pyro-metallurgical processes, are simpler in operation and do not lead to toxic gases emission. Radiotracer techniques are suitable tools for process investigation since most of the elements involved may be activated and their radioactive isotopes easily detected. Various parameters as separation efficiency, process kinetics and flow dynamics of hydrometallurgical systems can therefore be qualitatively and quantitatively evaluated. There is a need for detailed investigations to be carried out to optimize process parameters in order to develop an efficient technology.

Scientific objective of our project is elaboration of efficient method for recovery of copper and critical metals from the various raw materials, even these which contain very low quantity of these elements. Various leaching processes are being considered. Several leaching media such as H_2SO_4, HNO_3, organic acids were applied and multistep leaching processes was investigated. Radiotracer method is a very effective tool for the process investigation. The samples of copper ore were activated into nuclear reactor. The parameters of the neutron activation were calculated. Radioisotope ^{64}Cu was selected as an optimal tracer and it was used for optimization of the leaching process. Optimal leachant and conditions of the process were selected for process up scaling.

Acknowledgements. The study is being performed in the frame of IAEA CRP F22065 “Radiometric Methods Applied in Hydrometallurgical Processes Development and Optimization” and Polish Ministry of Science and Higher Education co-financing grant “Rozwój radiometrycznych i radioznacznikowych technik dla procesu hydrometalurgicznego odzysku metali deficytowych”.

* corresponding author: t.smolinski@ichtj.waw.pl

FORMATION OF POLYMERIZATION RETARDERS VIA HIGH-TEMPERATURE RADIOLYSIS OF LIGNIN

Gorbarev I.N., Kholodkova E.M., Skiba S.A.*, Pavlov Yu. S., Ponomarev A.V.

Frumkin Institute of Physical Chemistry and Electrochemistry, Russian Academy of Sciences, Moscow, Russia

Keywords: electron-beam distillation, lignin, catechols, resorcinols, hydroquinones

ABSTRACT

Lignin, being the basic component of wood, since ancient days was the main source of wood tar. Due to diversity of valuable properties, tar had application as lubricant, protective impregnant for wooden and leather products, insect repellant, odorant, cosmetic and edible ingredient, spice for meat, natural dye for production of paints, chemical reagent, etc. Till now tar is widely used as bio-protection agent.

In the last century tar has been recognized as inexpensive and available polymerization retarder, in particular, as inhibitor of styrene thermopolymerization. Such ability of tar results from presence of various phenols. However inhibiting effect of wood tar is rather small as phenols in tar are diluted with other components which are not possessing inhibiting properties.

Both composition and inhibiting properties of tar improve essentially when tar is forming in the course of an irradiation of lignin or lignocelluloses. Triple increase in productivity of lignin-to-tar conversion takes place via radiation-stimulated distillation of the lignin moreover the obtained tar represents a concentrate of phenols and benzenediols. The inhibiting ability of tar can be increased additionally due to presence of heavy alkanes at feedstock being irradiated.

The report informs of a technique of electron-beam distillation of lignin and of composition distinctivenesses of tar.

* corresponding author Skiba@ipc.rssi.ru

APPLICATION OF RADIOTRACERS FOR COPPER LEACHING FROM FLOTATION TAILINGS

Marcin Rogowski*, Tomasz Smoliński, Marta Pyszynska, Andrzej G. Chmielewski

Institute of Nuclear Chemistry and Technology, Dorodna 16 Str., 03-195 Warsaw, Poland

Keywords: radiotracer, leaching, flotation tailings

ABSTRACT

The copper mining and ore processing is one of the most stable and profitable branch of the Polish economy and one of the fastest growing industry. However, commonly used technologies lead to high losses of valuable and so-called deficit metals in solid wastes streams. The development and implementation of hydrometallurgical technologies is a solution which is feasible for a higher elements recovery efficiency and decreasing hazardous impact of the wastes storage on the environment. Radiotracer methods are the suitable tool for process investigation since most of the elements involved may be activated and their radioactive isotopes can be easily detected. The separation efficiency, process kinetics and flow dynamics of hydrometallurgical systems can be therefore qualitatively and quantitatively evaluated.

As a radiotracer, isotope of copper ^{64}Cu was selected. Samples of flotation tailings and pure copper were irradiated and activated in MARIA Research Reactor (Świerk, Poland). Parameters of neutron activation were: neutron flux $1 \cdot 10^{14}$ $n \cdot cm^{-2} \cdot s^{-1}$ and 15 to 50 minutes of irradiation time. Activated sample (up to 30 MBq) was mixed with an inactive portion of the milled flotation waste. Leaching process is conducted in a glass reactor equipped with pump, filter system and gamma-spectrometer. Spectrum measurement is obtained using the scintillation detector NaI. The dissolution of the material takes place using various acids and a wide range of their concentrations. The level of leached of copper (as well as other metals) is calculated on the basis of the ratio of height the peaks in the spectrum.

Acknowledgements. The study is being performed in the frame of IAEA CRP F22065 “Radiometric Methods Applied in Hydrometallurgical Processes Development and Optimization” and Polish Ministry of Science and Higher Education co-financing grant “Rozwój radiometrycznych i radioznacznikowych technik dla procesu hydrometalurgicznego odzysku metali deficytowych”.

RADIOLUMINESCENCE AND TIME-RESOLVED OPTICALLY STIMULATED LUMINESCENCE OF $LiAlO_2$ and $LiMgPO_4$

B. Marczewska[*1], P. Bilski[1], W. Gieszczyk[1], A. Kilian[1], M. Kłosowski[1], D. Kulig[1], A. Mandowski[2], E. Mandowska[2]

[1] Institute of Nuclear Physics Polish Academy of Sciences, PL-31342 Krakow, Poland [2]
Jan Długosz University, 42-200 Częstochowa, Poland

Keywords: optically stimulated luminescence, radioluminescence, time-resolved readout, luminophores

ABSTRACT

The growing presence of ionizing radiation in all areas of life requires development of various measurement methods to ensure maximum radiation safety. Aside from industrial, scientific and energetic applications, ionizing radiation is increasingly present in medical diagnosis and cancer treatment. Our work is focused on the development of the remote device aimed to control the real dose delivered to the treated tissue volume during radiotherapy session in a real time based on luminophores. Luminophore, in dosimetric applications, is a material which is able to cumulate the information about the absorbed dose during its irradiation and which emits the light during its excitation (by light in the case of optically stimulated luminescence) or which emits the light spontaneously (radioluminescence, RL).

Several luminophores, such as Al_2O_3, $LiAlO_2$ and $LiMgPO_4$, produced in a form of crystals grown by micropulling down method (MPD) at the Institute of Nuclear Physics PAN, were investigated in regard to their dosimetric properties. Especially, radioluminescence and time-resolved optically stimulated luminescence (TR-OSL) were studied. For the measurements of RL and TR-OSL a special home-made OSL reader called HELIOS-3 was applied. HELIOS-3, the third device from HELIOS series developed accordingly to the individual research needs, is equipped with two rings of blue and green LEDs for stimulation, PMT with an electromechanical shutter placed in front of the photomultiplier tube for UV light detection, fast electronic controller and a set of optical and interference filters. Besides TR-OSL also RL measurements were performed using the special holder enabling to use x-ray needle source for in-situ irradiation of the investigation sample and its RL readout in a real-time.

The preliminary investigation showed that Al_2O_3, $LiAlO_2$ and $LiMgPO_4$ luminophores are very sensitive to ionizing radiation and are characterized by the good signal repeatability and linear dose response.

Acknowledgments
This work was supported by the National Science Centre, Poland (No. UMO-2016/21/B/ST8/00427).

[*] corresponding author: Barbara.Marczewska@ifj.edu.pl

DETECTION OF IONIZING PARTICLES TRACKS USING RADIOLUMINESCENCE OF LITHIUM FLUORIDE

B. Marczewska*, P. Bilski, W. Gieszczyk, M. Kłosowski, T. Nowak, M. Naruszewicz

Institute of Nuclear Physics Polish Academy of Sciences, PL-31342 Krakow, Poland

Keywords: radioluminescence, track detectors, dosimetry, lithium fluoride

ABSTRACT

Lithium fluoride (LiF) is a material exhibiting several luminescence phenomena, which are applicable for radiation detection and dosimetry. One of them is radiophotoluminescence (RPL), which is fluorescence of color centers created by radiation. Ionizing radiation produces in LiF crystals mostly F centers (anion vacancies trapping electrons), which often aggregate into more complex defects, like F_2 and F_3^+ color centers. F_2 center is composed of two anion vacancies with two bounded electrons, while F_3^+ of three vacancies with two electrons. When these centers are excited with blue light (wavelength near 445 nm), they emit photoluminescence peaked at about 670 nm (related to F_2) and about 525 nm (related to F_3^+).

At the IFJ PAN in Kraków LiF single crystals were grown with the Czochralski method. The cut and polished crystal samples were then exposed to various radiation types: alpha particles, protons, neutrons. The samples were analyzed using Nikon Ni-U wide-field fluorescent microscope equipped with DS-Qi2 CCD camera and 100x objective. The intensity of RPL in the acquired in that way images allowed for visualization of tracks of single alphas and protons, as well as secondary products of neutron interactions. Detection of neutrons seems to be the most perspective application of this methods, as the natural lithium contains ^{6}Li isotopes, which have a very high cross-section for (n,α) reaction. The obtained results are the first successful application for fluorescent detection of particle tracks other material than aluminum oxide and the first successful attempt to use for this purpose a standard wide-field fluorescent microscope.

Acknowledgments
This work was supported by the National Science Centre, Poland (No. 2015/17/B/ST8/02180).

* corresponding author: Barbara.Marczewska@ifj.edu.pl

SOL-GEL SYNTHESIS OF SILICON-BASED COATINGS ON ZIRCONIUM ALLOYS FOR HIGH TEMPERATURE CORROSION RESISTANCE IMPROVING

Miłkowska Magdalena*, Sartowska Bożena, Starosta Wojciech

Institute of Nuclear Chemistry and Technology (INCT), 16 Dorodna Str.,03-195 Warsaw, Poland

Keywords: silica-zirconia coatings, sol-gel method, thin films, zirconium alloys

ABSTRACT

In order to improve the metal surface resistance for oxidation at high temperatures the protective layers are used. Zirconium and zirconium alloys, due to their good water corrosion and radiation resistance at normal working conditions of nuclear reactors, is commonly used as cladding material for fuel elements. But in the case of LOCA conditions their high susceptibility to oxidation at high temperatures leads to the fast degradation of the zirconium claddings.

The work carried out in the ICHTJ Material Research Laboratory concerned the possibility of using zirconiumsilicon coatings for zirconium alloy LWR cladding material to enhance their accident tolerance.

Silica and silica-zirconia films, with different ZrO_2 contents, were prepared by the sol-gel method. The zirconyl nitrate and tetraethoxysilane (TEOS) were used as precursors of zirconia and silica, respectively. The silica or silicazirconia sols were deposited over zirconium alloys by dip-coating method at room temperature, dried and calcined at different temperatures. The obtained films were characterized by optical (OM) and scanning electron (SEM) microscopy, X-ray diffraction (XRD) analysis and energy dispersive spectroscopy (EDS). The prepared samples were investigated with autoclave tests: water, 360°C, 165 bar, 7 days.

The sol gel method seems to be promising for the fabrication corrosion protective coatings on the surface of zirconium alloys.

Acknowledgements
The financial support of IAEA Research Contract No. 19026/R0 and by Polish Ministry of Science and Higher Education under decision 3689/IAEA/2017/0 is kindly acknowledged.

* corresponding author: m.milkowska@ichtj.waw.pl

REMOVAL OF ABSORPTION ARTEFACTS IN THE MACRO-XRF IMAGING OF PAINTINGS

P. M. Wróbel

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Al. Mickiewicza 30, 30-059 Krakow, Poland

Keywords: X-ray fluorescence imaging, X-ray absorption artefacts,

ABSTRACT

The macro-XRF technique allows imaging and identification of hidden paint layers what makes it much more versatile as compared with X-ray radiography. One of the main disadvantages of macro-XRF technique is the fact that characteristic X-rays from deeper paint layers are absorbed in the covering layers. This effect manifest itself in form of artefacts that may impede proper interpretation of acquired images. In previous work a new methodology of correction of those effects that is applicable to the case of polychromatic excitation [1] was introduced. In this approach the problem of empirically chosen correction parameters [2] that introduces a human factor that may distort the result of correction was also overcome.

In this work an upgrade of the methodology of correction of image artefacts from X-ray absorption effects is shown. The K-means clustering was applied for segmentation of the areas of different paint layers structure. This approach allows to improve the calculation of correlation coefficients and opens up an opportunity for further automation of the correction process. Additionally a discussion about possibilities of correction of absorption effects in the system of more than two paint layers is given.

References

[1] P. Wrobel, P. Fraczek, M. Lankosz Anal Chem 88 (2016) 1661 - 1666
[2] M. Alfeld et. al. Appl Phys A 111 (2013) 165-175

EFFECT OF POLYETHYLENE CROSSLINKING FOR PROPERTIES OF FOAMS

Wojciech Głuszewski[1], dr Andrzej Stasiek[2], dr Aneta Raszkowska-Kaczor[2], mgr Daniel Kaczor[2]

[1]Institute of Nuclear Chemistry and Technology, Warsaw
[2]Institute for Engineering of Polymer Materials and Dyes, Toruń

Keywords: polyethylene; foam; radiation crosslinking; postradiation oxidation

ABSTRACT

Crosslinked polyethylene foams are characterized by good thermal insulation properties, low density, low thermal conductivity, high sound absorption and chemical resistance. These properties cause their wide use in construction, automotive, packaging industry and sport. The process for preparing chemically/radiation crosslinked foams consisted of the following steps: preparation of powder mixtures, pellets extrusion, film extrusion, foaming of crosslinking materials. The process of radiation crosslinking of polyethylene with gamma radiation (ɣ) and electron beam (EB) from the point of view of density of foam was tested. Particular attention was paid to postradiation oxidation effect of the polymers. The study used two types of radiation sources of varying the dose rate: gamma radiation (4 kGy/h) and electron beam (14 000 kGy/h). Radiolysis studies of the polymers used were analyzed secreted amount of hydrogen (GH_2, approximately proportional to the number of radicals) and radiation yield of oxygen absorbed by the polymer, GO_2. Film was prepared with different contents of the following ingredients: polyethylene (LDPE) type Malen FGAN 23-D003, Azodicarbonamide type Unicell D1500TSK - foaming agent, zinc oxide, zinc stearate, Tracryl PO 3501, Irganox PS 802 FL. The temperature profile along the barrel was: 100, 110, 125 and 125°C. The polymer film was obtained by the lab equipment consisting of the single screw extruder type Plasti – Corder PLV 151 (Brabender) with the flat die and polishing rolls. The screw parameters were: working length 25D and compression ratio 3:1. The experimental stand was equipped with a device for measuring temperature of heating zone of the plasticizing system and the head. Screw rotation speed was 75 rpm. Foaming process was conducted in silicone oil bath at 225°C for 1.5 min. Gas chromatograph Shimadzu (thermal conductivity detector, molecular sieves 5A) was used from the dose of radiation in the range of 5 to 20kGy. Samples were irradiated in air, in closed vessels with gas phase subjected to gas chromatographic analysis at room temperature. Total apparent density (ρa) was determined from crosslinked and foamed samples. Three samples for each film were studied. The dimension of samples was approximately 50 mm × 50 mm. Overall dimensions of the samples were measured in accordance with European standard. The determination was performed on a test stand equipped with scanning electron microscopy Hitachi SU8010 (Japan, 2011) and Cressington sputter coater module measuring thickness of the sputtered gold layer (Germany, 2011). The microscope is equipped with a cold cathode field emission, SE and BSE detectors and EDX detector for X-ray microanalysis. One of advantages of diffuse reflection spectroscopy (DRS) is the possibility to investigate polymers in any shape. The principle of measurement consists in directing the beam of analyzing light on the surface of the sample. Part of light is reflected back unchanged, but another is bent into the sample and after inside reflections is leaving the sample with spectral information about compounds formed in the result of irradiation and/or compounds present before and destroyed. In our investigations the spectrophotometer JASCO V-670 equipped with reflection device was used.

INVESTIGATION OF THERMAL NEUTRON DETECTION CAPABILITY OF A CdZnTe SEMICONDUCTOR DETECTOR IN A MIXED GAMMA-NEUTRON FIELDS

H.Yücel[1], R.B. Narttürk[*1], S.Zümrüt[1], G.Gedik[1], M.Karadağ[2].

[1]Ankara University, Institute of Nuclear Sciences, Tandoğan, 06100, Ankara, Turkey
[2]Gazi University, Education Faculty, Department of Physics, Teknikokullar, 06100, Ankara, Turkey

ABSTRACT

The aim of this study is to investigate the effect of several moderator materials on the thermal neutron measurement capability of a CdZnTe detector irradiated in a mixed neutron-gamma field. Thermal neutrons produced from water moderated a 37GBq ^{241}Am-Be neutron source is used for the irradiations.

In this study, thermal neutron fluxes were measured at different irradiation positions by foil activation method using dual ^{197}Au(n, ɣ)^{198}Au and ^{55}Mn(n, ɣ)^{56}Mn monitor reactions. The neutron induced gamma ray spectra were measured in the well of a p-type, 44.8% relative efficient HPGe detector (Canberra Inc.). Then, a 5x5x5 mm^3 CdZnTe detector (Spear, eV Products Inc) was irradiated in the irradiation tube of ^{241}Am-Be source unit to determine sensitivity factors of detector in terms of cps per neutron·cm^2.s^{-1}. The CdZnTe detector was covered in 1 mm thick cadminium (Cd) cylindirical box to absorb completely the incoming thermal neutrons to measure epithermal neutron component. To achieve this the cadmium covered CdZnTe detector is placed in a well-thermalized neutron field in the irradiation tube of the ^{241}Am-Be neutron source. The gamma-ray spectra were acquired simultaneously and then the most intense gamma-ray which is 558 keV (0.74ɣ/n) peak area was evaluated to estimate thermal neutron flux. The epithermal component was estimated from the bare detector irradiation because the epithermal neutron cut-off energy is about 0.55 eV at 1mm thick Cd filter. Then the measured count rates from the 558 keV and 651 keV photopeaks of ^{114}Cd calibrated by using the measured neutron fluxes at different irradiation positions. In order to enhance the thermal neutron detection sensitivity of CdZnTe, several moderators such as PTFE, polyethylene, polystyrene were tested. At the same time, to reduce gamma components of mixed field 0.5-1.0 mm Pb box was fitted in annular cylinders covering the detector. The present results indicate that CdZnTe detector with use of some moderator materials covers has a potential to serve a neutron detector in the mixed gamma neutron fields such as reactors, neutron generators, electron linear accelerators (linacs) and cyclotrons or use of isotopic neutron sources. The detailed results will be discussed in this presentation.

*

EFFICIENT APPROACH FOR FEATURES REDUCTION OF BREAST CANCER IMAGES BASED ON TEXTURAL FEATURES

Mohamed S. El_Tokhy*

Engineering Department, NRC, Atomic Energy Authority, P. No. 13759, Inshas, Egypt

Keywords: Signal and Image Processing, mammography, Image Classification

ABSTRACT

This paper presents algorithms for breast cancer classification from mammogram images. Background of breast cancer images are performed as a preprocessing step using Wave Atom (WA) transform. Also, a noise reduction algorithm based on digital filters is introduced. These filters are Median, Wiener and average filters. Comparison between these filters is presented. Furthermore, image enhancement based on generalized histogram equalization method is evaluated. Image segmentation is also implemented. Two different algorithms are evaluated to perform image segmentation. These algorithms are image segmentation using Particle Swarm Optimization (PSO) and image segmentation using hidden Markov random field model and its expectation-maximization (HMRF-EM). The pectoral muscle was extracted from a breast cancer image using Kirsch's templates. Then, the textural features are extracted from the breast cancer images. A simple feature reduction program code is implemented that reduce the extracted features from 22 to 6 only. Accordingly to their effectiveness, better execution time is obtained for image classification.

* corresponding author: engtokhy@gmail.com

THE EFFECT OF GAMMA IRRADIATION ON INTERACTION OF NANOCELLULOSE WITH WATER STUDIED BY DIFFERENTIAL SCANNING CALORIMETRY AND MM-WAVE SPECTROSCOPY

Krystyna Cieśla[*1], Gokarna Pandey[2], Hubert Rahier[3], Johan Stiens[2]

[1]Institute of Nuclear Chemistry and Technology, Dorodna 16 str., 03-195 Warsaw, Poland
[2]Department of Electronics and Informatics, Vrije Universiteit Brussels, Pleinlaan 2, B-1050 Brussels, Belgium
[3]Department of Physical Chemistry and Polymer Science, Vrije Universiteit Brussels, Pleinlaan 2, B-1050 Brussels,Belgium

Keywords: nanocrystalline cellulose, gamma irradiation, water state, interaction with water, differential scanning calorimetry, milimeter wave spectroscopy

ABSTRACT

The studies are connected to practical application of biopolymers, modification of biopolymers and the products manufactured basing biopolymers by applying ionising radiation, and to the radiation sterilization of such products. The interest increases in use of biopolymers for packaging purposes [1-3]. This concerns also packaging of the products predicted for radiation decontamination. Addition of nanocelluloses into polymer and biopolymer materials appears one ability to improve properties of such materials related to packaging application [3]. Recently, the trials are also conducted to modify by radiation techniques the structure and properties of nanoparticles, including nanocelluloses

Interaction of nanocelluloses with water constitute an important issue in relation to dressings or to personal care products based on nanocelluloses, and in relation to packaging materials. We have previously proven that differential scanning calorimetry (DSC) constitutes the appropriate method for studying interaction of biopolymers with liquids. The method enables to distinguish various states of water in cellulosic material [4], as well as to evaluate the crystalline properties of biopolymer systems plasticized by water [5-6]. Similarly, millimeter wave (mm waves) spectroscopy enables to evaluate interaction of water with various materials, including biopolymers and food.

Our present study concerned the influence of gamma irradiation on the interaction of nanocrystalline cellulose (NCN) with water, carried out by differential scanning calorimetry (DSC) and millimeter wave spectroscopy. Powder NCN and gel solutions of NCN were irradiated with gamma rays applying doses of 5 and 25 kGy. The differences were discovered between the non-irradiated samples and these irradiated by means of both methods. A decrease in the content of non-freezable strongly bound water was discovered after irradiation with a dose of 25 kGy. However, the differences were found between the directions of the changes caused by irradiation with a dose of 5 kGy and by irradiation with a dose of 25 kGy. In particular, the increase in participation of the interstitial water or of bulk water content in the fraction of the freezable water can be deduced, depending on the applied irradiation dose. The results can be related to the differences in participation of the degraded and crosslinked products in the materials subjected to irradiation applying both doses.

Acknowledgements

The financial support of the COST FP1205 Action (covering costs of Short Term Scientific Mssion (STSM) of Krystyna Cieśla in VUB) is kindly acknowledged.

References

[1] Report of the 3rd RCM of the CRP on Application of Radiation Technology in the Development of Advanced Packaging Materials for Food Products, 11-15 July 2016, Vienna, Austria. 11-15 July 2016, Ed. A. Safrany, IAEA, Vienna, Austria (2016).

[2] A. Abramowska, K.A. Cieśla, M. J. Buczkowski, A. Nowicki, W.J. Głuszewski: The influence of ionizing radiation on the properties of starch-PVA films. Nukleonika 60 (3) 669-677 (2015).

[3] K.A. Cieśla, J. Drewnik, A. Abramowska, M.J. Buczkowski, W.J.Głuszewski, A.Nowicki, J. Boguski, G. Strzelczak, B. Sartowska: Based on starch - PVA system and cellulose reinforced packaging materials. The effects of ionising radiation. *in* Report of the 3rd RCM of the CRP on Application of Radiation Technology in the Development of Advanced Packaging Materials for Food Products, 11-15 July 2016, Vienna, Austria. 11-15 July 2016, Ed. A. Safrany, IAEA, Vienna, Austria str. 232 – 247 (2016)

[4] K. Cieśla, H. Rahier, G. Zakrzewska-Trznadel, Interaction of water with the regenerated cellulose membrane studied by DSC**",** J. Therm. Anal. Calorim., **77** 279 – 293 (2004).

[5] P. de Meuter, J. Amelrijcks, H. Rahier and B. van Mele, Isothermal crystallization of concentrated amorphous starch systems measured by modulated differential scanning calorimetry. J. Polym. Sci. 37 2881-2892(1999).

[6] P. de Meuter, H. Rahier and B. van Mele, The use of modulated temperature differential scanning calorimetry for the characterisation of food systems. Internat. J. Pharmaceutics, 192 77 –84 (1999).

PREPARATION AND IONISING RADIATION EFFECT ON THE ACTIVE STARCH-PVA-NANOCELLULOSE FILMS

Joanna Drewnik, Marcela Grabowska, Krystyna Cieśla*

Institute of Nuclear Chemistry and Technology, Dorodna 16 str., 03-195 Warsaw, Poland

Keywords: starch - poly(vinyl alcohol) - nanocellulose, ionising radiation, antioxidant properties, antimicrobial properties, packaging

ABSTRACT

Increasing interest in production of the high quality, safe and durable food of induces the concern in application of the active packaging. The special interest is directed to the antioxidant and antimicrobial systems. Plant extracts and essential oils or antimicrobial polysaccharides alike chitosan, are commonly tried, beside to antibiotics and synthetic antimicrobial or antioxidant substances. It seems worth to mention that these ingredients reveal often both antimicrobial and antioxidant activity. The advantages were also discovered of using the nanocomposite active systems, expected to be more effective as compared to micro or macro scale materials. As it is profitable that the materials reveal appropriate activity at prolonged time duration, the characteristic of release the active component appears an important property. Various strategies are applied for preparation of the active packaging [1-2]. Recent development in packaging materials based on natural and biodegradable polymers directed a search for use such packaging also as matrices for active components. Lately, radiation technologies were applied for manufacturing and modification of the properties of active packaging. The possibility for decontamination of the packed products made additionally interesting to study the irradiation effects on the properties of active packaging.

Our previous work concerned optimization of the methodology for preparation the films based on starch-PVAnanocellulose system supported by gamma and electron radiation. Present studies deal with immobilization of the active components into the polymer network during the films preparation, and the trials of grafting the active components onto the synthetized films, supported or followed by irradiation. Thymol, gallic acid and sorbic acid were introduced into the composition on the various steps of prepration. The methods appropriate in each case for evaluation the activity of the resulting material as well as the method for testing of the release of active components from the irradiated nad nonirradiated materials were adapted.

The results show that it is possible to obtain the materials characterized by antioxidant activity (strong or moderate, depending on composition) basing the starch-PVA-nanocellulose system and to affect this activity, and the characteristic of release the active ingredients, on the way of modification of the films composition and the conditions of preparation and irradiation.

Acknowledgements

The work was sponsored by Polish Ministry of the Science and the Higher Education (co-funded project) and in the frame of the International Atomic Energy Agency Coordinated Research Project F2206, research contract No: 17493

References

[1] P. Criado, C. Fraschini, S. Salmieri, nD. Becher, A. Safrany, M. Lacroix: Free radical grafting of gallic acid (GA) on cellulose nanocrystals (CNS) and evaluation of antioxidant reinforced gellan gum films. Radiat. Phys. Chem. 118 61-69 (2016). [2] N. Benbettaieb, A. Assifaoui, T. Karbowiak, F. Febeaufort, O. Chambin: Controlled release of tyrosol and ferulic acid encapsulated in chitosan-gelatin films after electron beam irradiation. . Radiat. Phys. Chem. 118 81-86 (2016).

[3] K.A.Cieśla, A.Nowicki, M.J. Buczkowski, Radiation modification of the functional properties of the edible films prepared using starch and starch – lipid system. Nukleonika, 55(2) (2010), 233-242.

[4] A. Abramowska, K.A. Cieśla, M. J. Buczkowski, A. Nowicki, W.J. Głuszewski: The influence of ionizing radiation on the properties of starch-PVA films. Nukleonika 60 (3) (2015) 669-677.

[5] K. Cieśla, A. Abramowska, J. Boguski, J. Drewnik. The effect of PVA type and radiation treatment on the properties of starchPVA films. Radiat. Phys. Chem., submitted. [6] K.A. Cieśla, J. Drewnik, A. Abramowska, M.J. Buczkowski, W.J.Głuszewski, A.Nowicki, J. Boguski, G. Strzelczak, B. Sartowska. Based on starch - PVA system and cellulose reinforced packaging materials. The effects of ionising radiation. *in* Report of the 3rd RCM of the CRP on Application of Radiation Technology in the Development of Advanced Packaging Materials for Food Products, 11-15 July 2016, Vienna, Austria. 11-15 July 2016, Ed. A. Safrany, IAEA, Vienna, Austria (2016) pp 232 – 247.

*

* corresponding author: k.ciesla @ichtj.waw.pl

INDUSTRIAL WASTES AS A POTENTIAL SOURCE OF URANIUM

Katarzyna Kiegiel*, Dorota Gajda, Grażyna Zakrzewska-Kołtuniewicz

Institute of Nuclear Chemistry and Technology, Warsaw, Poland

Keywords: uranium, leaching, scare resources

ABSTRACT

Recovery of the heavy metals and other useful materials from industrial wastes are becoming extremely important to the society, industry and environment. The other hand, the selective separation of uranium is a very important in the context of energy production and treatment of nuclear wastes. In the project, three kind of resources are being considered as a potential sources of uranium: flotation tailings from the Polish cooper industry, phosphogypsum - a major product of phosphoric acid production and phosphates rocks using in Polish phosphoric acid industry (from Marocco, Syria and Tunesia). Methods used to extract uranium from its ores may potentially be adapted to recovery uranium from scarce uranium resources.[1]. Apart from uranium other valuable metals (e.g. thorium, vanadium or lanthanides) can be recovered to improve the economy of the process. The leaching of these metals from examined raw material is carried out by leaching in stationary reactor with mixing (a stirred reactor anchor type). The metals can be also leached with using the helical membrane contactor equipped with rotating part [2] and in autoclave. The perolactive leaching is being considered as a leaching method of phosphate rocks. It is a simulation of heap leaching - the industrial mining process that is used for the extraction of precious metals from low-grade gold and copper ores [3]. Appropriate selection of the parameters should allow controlling the process efficiency.

ICP-MS analysis is using to determine the total uranium, thorium and other metals content in post-leaching solution. This analytical technique is favourable since it enables to measure directly the mass concentration of total uranium without any chemical separation. It allows also analysing the content of big variety of other metals that accompany uranium in its resources.

Acknowledgements
The studies were supported by the financial resources for science in the years 2017-2018 granted for the implementation of the international project co-financed 3643/IAEA/16/2017/0, IAEA Research Contract No: 18542.

References

[1] D. Gajda, G. Zakrzewska-Koltuniewicz, E. Chajduk, I. Bartosiewicz, S. Wolkowicz, Mineralogy and uranium leaching of ores from Triassic Peribaltic Sandstones, Journal of Radioanalytical and Nuclear Chemistry, 2015, 303, 521-529

[2] A. Miśkiewicz, G. Zakrzewska-Kołtuniewicz, E. Dłuska, P. F. Walo, „Application of membrane contactor with helical flow for processing uranium ores", Hydrometallurgy 2016, 163, 108–114.

[3] Petersen J (2016) Heap leaching as a key technology for recovery of values from low-grade ores – A brief overview, Hydrometallurgy 165: 206-212

* corresponding author: k.kiegiel@ichtj.waw.pl

INDOOR AIR PARTICULATE MATTER POLLUTION IN HISTORIC CHURCHES

Lucyna Samek

AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Al. Mickiewicza 30, 30-059 Krakow, Poland

Keywords: Indoor and outdoor air, Particulate matter, Energy dispersive X-ray fluorescence analysis, Black carbon, Black smoke

ABSTRACT

Two historic churches were chosen for air particulate matter investigation. The first one located in South Poland and the second in South-West Poland. At both sites samples of PM1 (particulate matter containing particles with aerodynamic diameter less or equal 1 μm) and PM2.5 fractions (particulate matter containing particles with aerodynamic diameter less or equal 2.5 μm) were collected indoor and outdoor, during winter and summer. Concentrations of PM1, PM2.5, the elements as well as black carbon (BC) and black smoke (BS) were determined. Additionally, in a church, the influence of an incense on the concentrations of elements, PM1, PM2.5, black carbon (BC) and black smoke (BS) was evaluated. In winter, in Niegardow church, higher indoor concentrations of K, V, Fe, Cu, Zn and Pb were observed than outdoor ones. In Gryfow Slaski church, the I/O ratio for almost all elements was about one, but for calcium it was equal to 4 in PM2.5 fraction. Ca can be accumulated in the church. In summer, the concentration of Ca inside was significantly higher than outside. The presence of indoor calcium can be explained either as deterioration of walls or this element can be brought on shoes of visitors.

APPLICATION OF THE RADIOMETRIC METHOD FOR MEMBRANE PROCESSES INVESTIGATION

A.Miśkiewicz[*1], G. Zakrzewska-Kołtuniewicz[1], B. Sartowska[1], S.Pasieczna-Patkowska[2]

[1] Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland
[2] Faculty of Chemistry, University of Maria Curie-Sklodowska, Pl. M. Curie-Sklodowskiej 3, Lublin, Poland

Keywords: membrane processes, radiotracers, photoacoustic spectroscopy

ABSTRACT

The aim of the work was an investigation of membrane fouling using radiotracers. Membrane fouling is the process of blocking the membrane due to deposition of particulates, colloids, and other macromolecular compounds on the surface or in the pores of the membrane that results in permanent and often irreversible change in permeability; it causes increase in flow resistance, and in consequence, a decrease in filtration efficiency. There are many methods which are widely applied for membrane fouling investigation [1-3], usually based on the use of sophisticated equipment. Tracer techniques, which are non-invasive methods are the alternative way for the study of processes proceeded inside the membrane apparatus [4]. They do not require complex equipment to be used. Furthermore, radiolabeled compounds have an advantage over non-active tracers because of very high sensitivity of detection, which gives the opportunity for using very low concentration of the tracer, as well as for remote detection of radiation through the layers of other materials present in the apparatus.

In the paper the application of the short lived isotope -^{140}La for the study of the kinetics of the membrane fouling is presented. The results of the studies were confirmed by two other techniques: the Fourier Transform Infrared Photoacoustic Spectroscopy (FT-IR/PAS) and the Scanning Electron Microscopy (SEM).

The results have shown that the radiometric method has a great potential for membrane fouling investigation and can be an alternative to other methods used for investigation of this phenomenon.

Acknowledgments The studies were supported by the National Science Centre Poland, Grant No 2013/11/D/ST8/03328 entitled "Studies on the phenomena occurring in the membrane boundary layer during filtration of aqueous solutions and suspensions in membrane apparatuses of different configurations".

References

[1] L. Benavente, C. Coetsier, A. Venault, Y. Chang, C. Causserand, P. Bacchin, P. Aimar, FTIR mapping as a simple and powerful approach to study membrane coating and fouling. J. Membr. Sci. (2016) 520, 477-489.
[2] J. S. Ho, J. H. Low, L. N. Sim, R. D. Webster, S. A. Rice, A. G. Fane, H. G. L. Coster, In-situ monitoring of biofouling on reverse osmosis membranes: Detection and mechanistic study using electrical impedance spectroscopy. J. Membr. Sci. (2016) 518, 229-242.
[3] W. Li, X. Liu, Y-N. Wang, T. H. Chong, C. Y. Tang, A. G. Fane, Analyzing the evolution of membrane fouling via a novel method based on 3D Optical Coherence Tomography imaging, Environ. Sci. Technol. (2016) 50, 6930-6939.
[4] A. Miskiewicz, G. Zakrzewska-Trznadel, A. Dobrowolski, A. Jaworska-Sobczak, Using tracer methods and experimental design approach for examination of hydrodynamic conditions in membrane separation modules, Appl. Radiat. Isot. (2012) 70, 837-847

[*] corresponding author: a.miskiewicz@ichtj.waw.pl

ELECTRON BEAM FOR PRESERVATION OF WATERDAMAGED PAPER

Marta Wójcik*, Dagmara Chmielewska, Wojciech Migdał

Institute of Nuclear Chemistry and Technology

ABSTRACT

Radiation technologies are successfully applied for the sterilization of medical devices, for the hygienization and preservation of agri-food products, for the modification of materials and in the protection of the environment.

Libraries, museums and archives are still looking for optimal decontamination methods because the commonly used fumigation with ethylene oxide has many disadvantages. Fumigation with ethylene oxide is a time-consuming process. Moreover the toxicity of ethylene oxide to environment and humans leads to gradual withdrawal of this technology by more and more countries. The successful recovery of water-damaged library and archival materials depends on timely response to a disaster. Therefore fast and effective treatment method that enables decontamination of thousand volumes in short time is desired. Previous investigation confirmed that irradiation with high-energy electron beam is very effective and ,simultaneously, safe for the paper object method of paper decontamination.

In this work influence of different drying protocols of paper samples on their mechanical, optical, chemical and thermal properties were studied. Office paper samples were damped in the controlled way in the climatic chamber. Further wet samples were dried by freeze-drying and natural air-drying and finally irradiated with high-energy electron beam of dose 5 kGy. Effect of different drying protocols and irradiation on the tensile strength, color, pH and thermal properties of the office paper was studied.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 730871.

This work was supported by the Polish Ministry of Science and Higher Education, project 3697/H2020/2017/2 Accelerator Research and Innovation for European Science and Society.

APPLICATION OF DIFFERENT METHODS FOR EVALUATION OF PAPER PROPERTIES AFTER DECONTAMINATION WITH ELECTRON BEAM IRRADIATION

Dagmara Chmielewska[*1], Marta Wójcik[1], Wojciech Migdał[1], Jarosław Sadło[1], Kamil Kopeć[2]

[1] Institute of Nuclear Chemistry and Technology
[2] Warsaw University of Technology, Faculty of Chemical and Process Engineering

ABSTRACT

Large volumes of books and archival collections are affected by bioburden because of improper storage conditions or accidents such as floods. The microbiological degradation of archives and books can be efficiently inhibited with radiation processing. However, advanced studies of material properties before and after radiation decontamination should ensure degradation monitoring and process validation. Moreover paper is complex material which properties depends on the manufacturing process, fillers present and further paper application. Because of paper complexity different methods should be used in order to carry out investigation of mechanism of paper degradation.
Some of the research methods appears very suitable for this aim others don't provide information we are looking for.

The aim of this work was to evaluate applicability of different instrumental methods for evaluation of optical, mechanical, thermal and chemical properties of paper after electron beam irradiation. The morphology of samples was evaluated using scanning electron microscopy (SEM) coupled with Energy-dispersive X-ray spectroscopy (EDX) that enabled to determine paper samples composition. The influence of electron beam irradiation on cellulose was observed by pH measurements of paper, thermogravimetric analysis (TGA) and electron paramagnetic resonance (EPR). Paper colour, the most prone to changes paper parameter were studied with colour spectrophotometer. Moreover mechanical properties of paper were examined before and after irradiation as well. Study of the optical properties as well as observation of the radicals created in the result of irradiation with EPR method were very helpful in assessment of dose effect on paper properties. Contrary investigation of mechanical properties of the paper after irradiation with different electron beam doses appeared to be not precise enough method to supply valuable information on paper degradation.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 730871.

This work was supported by the Polish Ministry of Science and Higher Education, project 3697/H2020/2017/2 Accelerator Research and Innovation for European Science and Society.

[*] corresponding author: d.chmielewska@ichtj.waw.pl

SiEA-KNiFe SORBENT –FROM THE SYNTHESIS THROUGH RADIONUCLIDES SORPTION TO THE VITRIFICATION WITH SOL-GEL METHOD

Dagmara Chmielewska[*1], Małgorzata Siwek[2], Marek Henczka[2], Bożena Sartowska[1], Wojciech Starosta[1], Danuta Wawszczak[1], Jakub Dudek[1]

[1] Institute of Nuclear Chemistry and Technology
[2] Warsaw University of Technology, Faculty of Chemical and Process Engineering

ABSTRACT

The most significant source of radioactivity of the cooling water in the nuclear reactor primary circuit and the water in the spent fuel storage basins is radiocesium. ^{137}Cs and ^{134}Cs are two radioactive cesium isotopes produced by nuclear fission of ^{235}U and they are washed out from fuel cladding flaws. These radionuclides pose a potential threat to humans and to environment, because they exhibit high solubility and high mobility in the environment and have long half-live. ^{60}Co is predominant radioisotope produced by activation of corrosion product present in primary cooling water loop as well as in water in spent fuel storage basins. Radiocobalt due to its long half-life and high gamma decay energy is a serious threat for the environment as well as for the humans.

Therefore radioisotepes removal from nuclear wastewater is still an absolutely crucial issue for human health and for the environmental safety. Ion exchange process is very often applied for this purpose, because requires simple and compact equipment and is very effective at low concentration of the radioactive species dispersed in the large volume of liquid into a small volume of solid which can be easily disposed. Moreover presence of different harmful for people and environment radionuclides in the low-level radioactive waste (LLRW) motivates to elaboration of new sorbents effective in multi-ion systems.

Management of the sorbent with radionuclides bound in its matrix is very challenging. Among many methods of radioactive waste immobilization vitrification is considered as the best one. The main advantages of the method are possibility of the incorporation of large number of the elements into the matrix and production of durable and small volume wastes which prevents leaching of radionuclides to the environment.

In this work the complete method beginning from synthesis of silica modified with potassium-nickel hexacyanoferrate and ethanolamine (SiEA-KNiFe) sorbent through different radionuclides sorption in different process configurations to the vitrification of the spent sorbent with sol-gel method is presented. Influence of process parameters on sorption efficiency of different radionuclides was studied in order to process optimalization. Moreover morphology and composition of glasses obtained after spent sorbent vitrification was determined with SEM and EDX methods. Finally, leaching test was carried out in order to confirm stability of sorbent embedded in obtained glasses.

[*] corresponding author: d.chmielewska@ichtj.waw.pl

APPLICATION OF ISOTOPIC TECHNIQUES USING MATHEMATICAL MODELS IN ENVIRONMENTAL PROCESSES

Wafaa M. M. Salem*

Egyptian Nuclear and Radiological Regulatory Authority

ABSTRACT

During the last few decades, the use of tracer techniques in dealing with a variety of hydrological and hydrogeological problems have proved their value in improving the assessment , development of water resources. In this regard , the methodologies based on observations of temporal and spatial variations of naturally occurring isotopes, often referred to as { environmental isotope techniques} , are widely employed as an integral part of the routine investigations related to various hydrological systems, and particularly in regional groundwater aquifers.

A substantial amount of isotope data was so far collected and published from hydrological applications of natural isotopes, however, it is often used for qualitative inferences to be made of the system under study, and improve understanding of processes and dynamics of water circulation. The need for improved methodologies for quantitative evaluations to be made from isotope data with regards the relevant physical parameters of the system has been recognized. This has been the main motivation to intent the progress on mathematical models for quantitative evolution of isotope data in hydrology.

Isotope-hydrology (Stable and Radio isotopes) have been previously used to investigate water resources, interconnection between different aquifers ,relationship between surface and groundwater as well as direction of recharge ,etc. Now a day ,mathematical modeling by using isotopes are used in modern ecosystem studies, for investigating the source, direction, quantity and transport of pollutant, moisture isotope fluxes in present and past climate systems ,as well as transit time estimation in catchments hydrology.

Focusing our discussion on the use of environmental tracers in water molecule itself such as , 18O, 2H, and 3H. These ideal tracers are applied by precipitation and are generally distinct isotopically, which makes them reliable tracers of subsurface flow and groundwater recharge mechanism.

Two case studies were chosen, the first case illustrate calculation of the mean residence time for groundwater in the investigated area, using Tritium isotope. The age of groundwater was found in the range from few tens to several hundreds of years, reflecting the recharge mechanism and possibility of contamination. The second case study was applied using deuterium isotope balance approach to separate evaporation and seepage rates per year in lake area.

* corresponding author: Wafaasalem21@yahoo.com

ILU-6 TYPE ELECTRON ACCELERATOR MODIFICATION FOR LOW ENERGY ELECTRON BEAM SURFACE MICROBIOLOGICAL DECONTAMINATION.

S. Bułka, U. Gryczka, Z. Zimek, W. Migdał

Keywords: electron accelerator, electron beam, low energy electrons, surface irradiation

ABSTRACT

Accelerator ILU-6 was installed in 1988, at the Department of Radiation Chemistry and Technology pilot plant for the purposes of research and technology applications using the electron beam within the range of energy 0,5 – 2 MeV. This device is standard produced in the Institute of Nuclear Physics in Novosibirsk, the above range of electron energy is typical for industrial applications, eg. radiation modification of plastics (polymerization, cross-linking). The development of technologies related to surface treatment (grain hygienisation, thin foil crosslinking) requires the use of electron beams with energies in the range of 300keV or less. This has created a need to examine the possibility of the accelerator systems operating parameters change to lower energy of accelerated electrons while ensuring the safety and stable operation with regard to design requirements and constraints.

Analysis of accelerator equipment work conditions have shown, that reducing the electron energy level to 0.15 MeV - 0.3 MeV requires pulse power supply switching system modifications in order to lower high frequency power generator voltage, while maintaining the actual current level of RF generator pre-excitement pedestal.

Electrical tests of existing pulse modulator for RF generator provided information that there is a certain limit of voltage pulse power reduction possibility, the major reason is thyristor switch instability at low current rates. In this case, an alternative system has been proposed. Based on transistor switches having no such restrictions and ensuring flexibility of generated pulse parameters selection. The change in electron gun circuitry was also necessary in order to improve electrons emission at low electric field strengths in the space around the cathode.

The electron beam produced by IŁU-6 accelerator was tested by irradiation of dosimetric foils (200 m thick PVC and 19 m B3). For this energy range more suitable dosimeter is B3, due to its low thickness, it is possible to draw more accurate layer-by-layer dose depth profile in B3 stack.

Now the range of electron beam energy possible to obtain is from about 120keV (limited by electrons absorption in 50 m titanium foil) to 350 keV at pulse current of 50mA. Other parameters of accelerator i.e. pulsing rate selection, pulse duration and scanning width remain unchanged.

Acknowledgements

The work was supported by the Polish Ministry of Science and Higher Education [grant number 3495/IAEA/15/2016/0] and by the International Atomic Energy Agency under the Coordinated Research Project D61024 [Research Contract 19000].

THE USEFULNESS OF DIFFERENT ANALYTICAL METHODS FOR THE ELEMENTAL ANALYSIS OF TISSUE SAMPLES

A. Skoczen[*1], K. Planeta[1], K. Matusiak[1], Z. Setkowicz[2], A. Kubala-Kukus[3], I. Stabrawa[3], J. Chwiej[1]

[1] AGH-University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
[2] Jagiellonian University, Institute of Zoology and Biomedical Research, Department of Neuroanatomy, Krakow, Poland
[3] Jan Kochanowski University, Laboratory of X-ray Methods, Kielce, Poland

Keywords: tissue samples, body organs, elemental analysis, total reflection X-ray fluorescence

ABSTRACT

The trace elements play an important role in human health and their imbalance may be involved in the pathogenesis of different diseases [1]. Therefore, the monitoring of their concentrations in various tissues and body fluids may be of great importance for nowadays medicine and biology [2]. The modern analytical methods are mainly focused on the elemental speciation and on measuring low concentrations of elements. In the present study the literature based comparison of advantages and disadvantages of different analytical techniques (AAS – *atomic absorption spectrometry*, AES – *atomic emission spectrometry*, ICP-AES – *emission spectrometry with inductively coupled plazma*, ICP-MS – *inductively coupled plasma mass spectrometry*) used for the evaluation of elemental content within samples of biological origin was done. Moreover, the typical methods of tissue samples preparation were discussed.

The total reflection X-ray fluorescence (TXRF) spectroscopy offers very low detection limits (ppm-ppb) and the same it may be extremely useful for the detection of even very subtle anomalies in the elemental composition of the tissue [3]–[5]. In the present study the TXRF method was used for the determination of major, minor and trace elements in the body organs taken from the normal male Wistar rats. The brain, heart, liver, kidneys, spleen and muscles were the subject of the study. The results from the TXRF study were compared with the available literature data obtained with other analytical techniques and using different ways of sample preparation.

References

[1] R. Chitturi, V. R. Baddam, L. Prasad, L. Prashanth, and K. Kattapagari, "A review on role of essential trace elements in health and disease," *J. Dr. NTR Univ. Heal. Sci.*, vol. 4, no. 2, pp. 75–85, 2015.
[2] M. Nordberg and G. F. Nordberg, "Trace element research-historical and future aspects," *J. Trace Elem. Med. Biol.*, vol. 38, pp. 46–52, 2016.
[3] P. Wobrauschek, "Total reflection x-ray fluorescence analysis - a review," *X-Ray Spectrom.*, vol. 36, pp. 289–300, 2007.
[4] L. Borgese, F. Bilo, E. Bontempi, L. Seralessandri, A. Cinosi, G. Siviero, and E. Laura, "Total Reflection X-Ray Fluorescence (TXRF) spectroscopy for environmental and biological analysis.," in *16th International Congress of Metrology*, 2013, vol. 10010.
[5] S. A. Bamford, D. Wegrzynek, E. Chinea-cano, and A. Markowicz, "Application of X-ray fluorescence techniques for the determination of hazardous and essential trace elements in environmental and biological materials," *Nukleonika*, vol. 49, no. 3, pp. 87–95, 2004.

[*] corresponding author: Agnieszka.Skoczen@fis.agh.edu.pl

EFFECT OF IONIZING RADIATION ON THE PROPERTIES OF PBAT

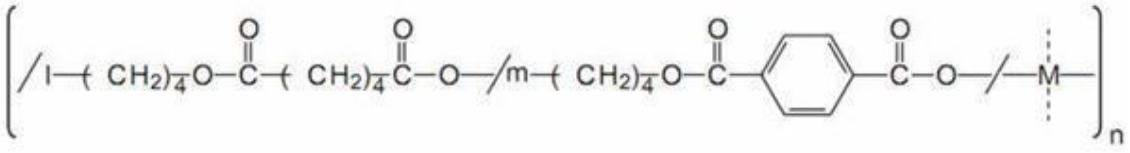
Grażyna Przybytniak, Magdalena Rzepna*, Jarosław Sadło

Institute of Nuclear Chemistry and Technology, Dorodna str. 16, 03-195 Warsaw

Keywords: aliphatic-co-aromatic polyesters, electron beam, biodegradable

ABSTRACT

The growing concern over the environmental pollution of non-biodegradable polymer wastes has been triggered a tremendous amount of research on the development of biodegradable polymers [1,2]. A variety of biodegradable aliphatic and aliphatic-co-aromatic polyesters has been developed to replace non-biodegradable polymers. Among these biodegradable polyesters, PBAT (Fig.1.) is a polymer derived from oil with mechanical properties similar to those of polyethylene. 1,4-Butanediol along with the terephthalic acid monomer are responsible for the rigid domain, while 1,4-butanediol along with the adipic acid monomer are responsible for polymer flexibility. PBAT is one of the most flexible biodegradable polyesters with one of the highest elongation at break values [3].



Chemical structure of poly[(butylene adipate)-co-terephthalate]

The study aimed to investigate the direct effects of electron beam radiation on physical and chemical properties of PBAT at regular intervals. PBAT (Ecoflex f blend c1200) was provided by BASF. Copolyesters films were irradiated in the atmosphere air at ambient temperature with a 10 MeV electron beam generated in a linear electron accelerator Elektronika 10/10. The total absorbed dose ranged from 25 to 200 kGy.

The obtained results indicate the low impact of radiation processes on the mechanical and thermal properties of the samples for the studied dose range. The macroscopic consequences of the processes involve crosslinking, chain scission and oxidation that influence significantly physicochemical features. The material exhibits a linear relationship between both the volume of hydrogen emitted and the volume of oxygen consumed as a function of the absorbed dose. Determined radiation yield of emitted hydrogen is 0,02 □M/J. The crosslinking process is confirmed by decreasing melt flow index and increasing viscosity in moltenstate as a function of dose. DRS spectroscopy showed the relationship between increasing dose and normalized intensity of absorption band (350 nm) is monotonic in the range of use dose.

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

[1] I. Vroman, L. Tighzert, *Materials* 2009, 2(2), 307-344
[2] G.E. Luckachan, C.K.S. Pillai, *Journal of Polymers and the Environment*, 19 (2011), pp. 637–676
[3] [3] V. Ojijoa, S.S. Ray, *Progress in Polymer Science*, Volume 38, Issues 10–11, 2013, pp 1543–1589

* corresponding author: m.rzepna@ichtaj.waw.pl

MONTE CARLO MODELLING OF TH-PB FUEL ASSEMBLY WITH CALIFORNIUM NEUTRON SOURCE

Mikolaj Oettingen*, Przemysław Stanisz

AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Krakow, Poland

Keywords: Californium, Thorium, Lead, Monte Carlo, MCB

ABSTRCT

The paper describes methodology developed for the numerical reconstruction and modelling of Th-Pb (Thorium - Lead) assembly available at the Department of Nuclear Energy, Faculty of Energy and Fuels of AGH University in Krakow, Poland. The numerical study is the first step towards integral irradiation experiments in Th-Pb environment. The Continuous Energy Monte Carlo Burnup code (MCB) available on supercomputer Prometheus of ACK Cyfronet AGH, was applied for numerical modelling [1]. The assembly consists of a hexagonal array of ThO_2 fuel rods and metallic Pb rods [2]. The design allows different arrangements of rods for various types of irradiations and experimental measurements. The intensity of the fresh neutron source, intended for integral experiments equals about 10^8 n/s, which corresponds to the mass of about 43 μg ^{242}Cf. The source was modelled in the form of Cf_2O_3-Pd cermet wire embedded in two stainless steel capsules [3]. In the paper we present a set of neutronic parameters obtained in numerical simulations related to the interaction of neutron radiation with matter in the vicinity of Cf sources i.e.: cross sections, reaction rates, activities and doses. In addition, we consider neutron induced isotopic changes in ThO_2 rods for various irradiation times.

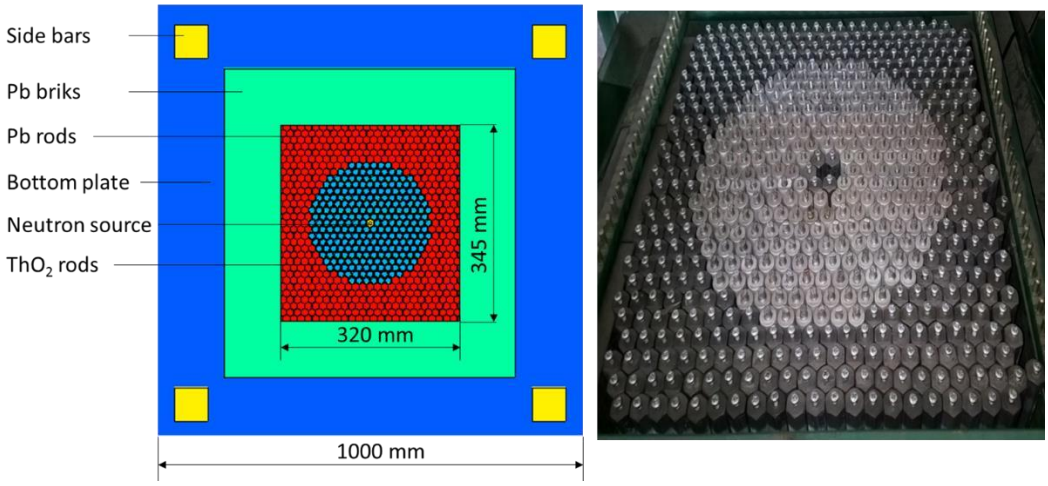


Fig. 1 Th-Pb fuel assembly (right) and its numerical reconstruction (left).

References

[1] M. Oettingen, J. Cetnar, T. Mirowski, CSCI, *The MCB code for numerical modeling of fourth generation nuclear reactors*, 16, 329–350, (2015)

[2] S. I. Abdel-Khalik, P. A. Haldy, A. Kumar, FUSION SCI TECHNOL, *Blanket Design and Calculated Performance for the Lotus Fusion-Fission Hybrid Experimental Devices Test Facility*, 2, 189-208, (1984)

[3] R. Radev, T. McLean, Lawrence Livermore National Laboratory, LLNL-TR-664160, *Neutron Sources for Standard-Based Testing*, (2014)

* corresponding author: moettin@agh.edu.pl

APPLICATION OF ^{210}Po RADIONUCLIDE ACTIVITY DISTRIBUTION IN DIFFERENT PARTS OF MOSSES FOR TRACING AIR POLLUTION SOURCES

Magdalena Długosz-Lisiecka*

Technical University of Lodz, Institute of Applied Radiation Chemistry, Wróblewskiego 15, 90-924 Łódź

Keywords: biomonitor, pollution source identification, air monitoring, ^{210}Po activity concentration in the air

ABSTRACT

First order kinetic of ^{210}Po and ^{210}Pb bioaccumulation in each of the morphological moss parts has been used as a simple method of ^{210}Po source identification in the air. In this study estimation of supported and unsupported ^{210}Po contribution in the air has been also realized. PCA and CA statistical methods confirm source apportionment. Significant content of anthropogenic ^{210}Po radionuclide in relation to measured value of specific activity in leaves has been observed.

The aim of this study is applying of the interesting ^{210}Pb and ^{210}Po radionuclides distribution in moss body profile to identification of ^{210}Po sources and estimation of its contribution.

Sampling sites were selected in two regions: first in Lodz city Centrum and second in non-polluted forest located tents of km from residential region.

The uptake of mineral nutrients, including natural radionuclides, by moss is a complex, dynamic process, consisting of direct transport via leaves and slow migration from adjacent soil. The analysis of the natural ^{210}Po and ^{210}Pb radionuclides' distribution in the different parts of moss can provide valuable information concerning the levels and sources of atmospheric pollution. Disproportions in the ^{210}Po and ^{210}Pb accumulation in different parts of the moss have been measured. The highest specific activities of both radionuclides were found in the rhizoids, and the lowest in the leaves.

Moss leaves are the best parts to use for analysis of the level and origin of fresh aerial particulate matter pollution. Comparison of the ^{210}Po specific activities in the moss leaves from unpolluted areas with those from urban sites allows an estimation of the additional, anthropogenic influx of ^{210}Po into the atmosphere.

Based on the radiometric and statistical analysis results one can conclude that the ^{210}Po and ^{210}Pb concentration distributions depend on seasonal changes in contributions of different emission sources. The pollutants accumulated in the moss tissues rather come from sources of the atmospheric deposition, than from contaminated soil.

Acknowledgements
This research work is supported by the National Science Centre under SONATA grant no. UMO2012/07/D/ST10/02874.

* corresponding author: mdlugosz@mitr.p.lodz.pl

APPLICATION OF CHEMICAL AND ENERGY SECTOR BYPRODUCTS FOR RADIOACTIVE WASTE IMMOBILIZATION IN MINERAL-POLYMER COMPOSITES

Piotr Szajerski*, Andrzej Gąsiorowski, Magdalena Długosz-Lisiecka

Institute of Applied Radiation Chemistry, Lodz University of Technology, Wroblewskiego 15, 93-590 Lodz, Poland

Keywords: radioactive waste, byproducts, immobilization, polymer composites

ABSTRACT

Operation of nuclear power reactors results in generation of radioactive waste in various chemical and physical forms. Next to the most problematic high level radioactive waste (HLW), not less attention is paid to separation and immobilization of low (LLW) and intermediate level waste (ILW). These wastes are mostly generated as a result of the pellet-cladding interactions, thermal and radiation degradation and construction materials corrosion processes occurring in reactor core and followed by releasing radioactive contaminants into primary cooling circuit. Separation of radioactive isotopes from cooling media is a main goal of the continuous water purificationprocesses.Resulting concentrated radioactive solutions, sludges and solid wastes must be subsequently immobilized in a safe and long-term stable waste forms.

The choice of the proper waste matrix material must take into accountchemical properties, physical form and activity of the radioactive waste to be disposed. For low and intermediate level waste the most common matrices areasphalts, bitumens, polymeric resins and cementitious composites. Technologies used for radioactive waste immobilization are being continuously improved. One of such new group of materials being developed are mineralpolymeric materials based on sulfur polymers – sulfur polymer concrete (SPC). Sulfur polymer composites seem to be very attractive materials due to their properties: good mechanical behavior, very good properties of radionuclides retention and very low diffusivity within the SPC matrix.

In this work long term stability and leaching behavior of SPC composites based on mineral fillers will be presented regarding immobilized Sr-90 and Am-241 radionuclides – typical radioactive contaminants generated during nuclear power reactors operation. As mineral fillers phosphogypsum, fly ash and lignite slag were used as the main radionuclides immobilization phases stabilized by various continuous phase components – sulfur polymers. Experimental procedure was based on a hot mixing (ca. 140°C) and pressing of sulfur polymer and mineral fillers with
Sr-90 and Am-241 radioactive tracers. For verification of immobilization efficiency of the prepared composites, static IAEA long-term leaching test for solidified radioactive waste forms (ISO 6961:1982) was applied. Experimental results suggest good and satisfacory leaching behavior of fly ash and slag based SPC composites and much worse in case of phoshogypsum based matrix. Minor effect is observed in case of application of different sulfur polymer binder.

Acknowledgements

This research project was supported by the Polish National Center for Research and Development (NCBR) under the Grant No.: GEKON1/O5/213122/26/2015.

* corresponding author: szajer@mitr.p.lodz.pl

ORIGINS OF SILVER AND PRODUCTION OF JEWELRY (SŁUSZKÓW) AND COINS IN EARLY MEDIEVAL POLAND

P. Kalbarczyk[*1], E.A. Miśta[2], E. Chajduk[1], J. Dudek[1], W. Duczko[2], A. Turos[3,5], D. Wyczółkowski[2], M. Widawski[4]

[1]Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland

[2]Institute of Archaeology and Ethnology Polish Academy of Science, Al. Solidarności 105, 00-140 Warsaw, Poland

[3]National Centre for Nuclear Research, A.Sołtana 7, 05-400 Otwock, Poland

[4]National Museum of Archaeology, Długa 52, 02-441 Warsaw, Poland

[5]Institute of Electronic Materials Technology, Wólczyńska 133, 01-919 Warsaw, Poland

Keywords: Isotope ratio, archeometallurgy , LA – ICP – MS, SEM/EDX.

ABSTRACT

Modern archeometallurgy is employing many analytical methods which are able to give answers concerning deposit and technological provenience of objects. The paper will present introductory results obtained during the realization of a research project which is devoted studies of silver coins and jewelry from Xth and XIth century in Poland.

Until now there were no certain knowledge about sources of silver for making those objects. Of great need is data from ornaments which are a very large material, one of the largest in Europe, consisting of female earrings, pendants and other pieces of various types formally with origin in late antique art and further development in the first Slav state of Great Moravia in the ninth century AD.

For studies of this material, at this stage 60 pieces, coming from Polish hoards, was used micro - invasion method LA – ICP – MS (Laser Inductively Coupled Plasma Mass Spectrometry), with specially constructed statistical method which allowed to obtain isotopic [Pb] composition. By using SEM/EDX allowed to trace morphological changes and obtain quantitative elemental composition.

References

[1] Merkel S., Sverchkov L., Hauptman, A., Hilberg V., Bode M. and Lehmann R., 2013. *Analysis of Slag, Ore and Silver from the Tashkent and Samarkand Areas: Medieval Silver Production and the Coinage of Samanid Central Asia. ArchäometrieundDenkmalpflege* 2013. MetallaSonderheft 6, pp. 62-66, [2] Kędzierski A., Ziąbka L., Miłek S., *Wczesnośredniowieczny skarb z Kalisza-Dobrzeca. Informacja wstępna. Rocznik Kaliski*, 2011, t. XXXVIII, pp.219-222.

* corresponding author: p.kalbarczyk@ichtj.waw.pl

OPTICALLY STIMULATED LUMINESCENCE (OSL) READER "HELIOS" MADE IN POLAND

Krzysztof Maternicki[1*], Arkadiusz Mandowski[1]

[1] Institute of Physics, Jan Dlugosz University ul. Armii Krajowej 13/15, 42-202 Częstochowa, Poland

Keywords: optically stimulated luminescence (OSL), dosimetry, optical dating, portable device, radiological protection.

ABSTRACT

The "Helios" reader is equipment for optically stimulated luminescence measurements that could be used in dosimetry of ionizing radiation (e.g. energy, healthcare) as well as optical dating (e.g. archeology and conservation of art). Our innovative approach is to significantly simplify and miniaturizing of the device has enabled to reduce costs of manufacturing. The OSL nondestructive readout allows achieving information about the absorbed dose of radiation from the material without heating of the sample (as it is in the TL readout case). Moreover, the "Helios" reader ~~also~~ is dedicated to performing non-standard luminescence measurements in the basic physics research.

The first "Helios" reader was prototyping and manufacturing in 2009 in the Institute of Physics Jan Dlugosz University in Czestochowa (AJD) by DSc Arkadiusz Mandowski Prof. AJD.

Today exists a six prototype devices of this type. These devices work at the AJD and the Institute of Nuclear Physics, Polish Academy of Sciences in Cracow. The results of the OSL studies of the various compounds obtained using of the "Helios" readers were published in 17 high indexed scientific papers, which confirms the level of technological readiness of the device. First information of this solution was announced in 2010 [1].

This work presents the latest achievements on technological adaptation to the commercial use of the "Helios" reader. This portable device is equipped with durable outer casing and illumination to facilitate its operation. In addition, a user-friendly dedicated software will be available for installation on any Windows-based personal computer. We hope that the ease of use and the relatively low cost of the device will make it "must-have" in any given dosimetry laboratory and everywhere where measurements of ionizing radiation will be desirable.

[1]. Mandowski, A., Mandowska, E., Kokot, L., Bilski, P., Olko, P., Marczewska, B. (2010). Elektronika: konstrukcje, technologie, zastosowania, 51(2), 136-138.

Acknowledgements: This work was partly supported by development project The Ministry of Science and Higher Education, "Innovation Incubator +".

* corresponding author: k.maternicki@ajd.czest.pl

Poster Session II

HONEY AS BIOINDICATOR OF LESSER POLAND AND LOWER SILESIAN VOIVODESHIPS POLLUTION

Alicja Boryło*, Grzegorz Romańczyk, Bogdan Skwarzec

University of Gdańsk, Faculty of Chemistry, Katedra Chemii i Radiochemii Środowiska,
Wita Stwosza 63, 80-308 Gdańsk

Keywords: honey, effective dose, polonium-210, uranium mines

ABSTRACT

Environmental samples are complex most often in terms of composition and structure, very often heterogeneous and sometimes variable over time, resulting in lack of repeatability at sampling due to rapid changes in material being analyzed. The purpose of the study was to determine the radionuclide. ^{210}Po in honey samples of nectar and honeydew collected for analysis from two Polish voivodships: Lesser Poland and Lower Silesian Voivodeships.

Bioindicators are organisms used as an indicator of the state of the environment. These are species with a low tolerance index, or in a specific way responsive to the substance. Popular bioindicator is honey. Bees collecting nectar, pollen and honeydew are often exposed to harmful substances used in agriculture collected on plants and carry these contaminants on the body surface to the hive, and as a consequence impurities get into the honey. Bee honey can be contaminated by various treatments related to apiculture as well as xenobiotics in the environment. Its healing properties may be weakened by foreign substances that have come into contact with honey from the following sources: environment (ecotoxins), agricultural and apiculture practices, honey processing and storage. Increasing the intensity of agrochemicals associated with the desire to meet greater crop yields and the use of pesticides to control plant diseases or antibiotics in animals can lead to contamination of crops and food products, including honey produced by bees. Taking into account the fact that bees use the benefits of a radius of up to 3 km from the hive, the origin of the nectar can be determined with great accuracy. Bearing this in mind, bee products can be used as indicators of environmental pollution in a given area.

The concentration of ^{210}Po in the analyzed honey samples was in the range from 0.008±0.001 Bq/kg to 1.182±0.065 Bq/kg for Lesser Poland Voivodeship and from 0.012±0.001 Bq/kg to 7.564±0.036 Bq/kg for Lower Silesian Voivodeship. The highest concentration of ^{210}Po was measured in both analyzed voivodships for honeydew honey. The smaller concentrations of analyzed radionuclides in the samples of honey, both nectar and honeydew, were characterized for Lesser Poland Voivodeship, where the average ^{210}Po concentration was 0.390±0.026 Bq/kg for all analyzed honey samples, the higher values were noted for the Lower Silesian Voivodeship (0.777±1.711 Bq/kg) (Table 1, 2 and Fig 1). In the Lower Silesian Voivodeship there can be differentiated two areas: one area is concentrated around uranium mines (Kowary, Kletno) and gold mine (Złoty Stok) and the second one is the rest of the voivodeship. At present, uranium and gold mines are closed: uranium mining continued until the 1970s, while in the mine Złoty Stok exploited arsenic ore and recovered gold until 1962, when, as a result of unclear reasons, the mining and production of this ore was stopped and the mine was closed. The highest average ^{210}Po concentration in the area around uranium mines (Kowary, Kletno) and gold mine (Złoty Stok) (within a radius of up to 10 km) was 2.451±2.509 Bq/kg, while the average ^{210}Po in the rest of this voivodeship was only 0.094±0.091 Bq/kg. The average ^{210}Po concentration in area around mines was 26 times higher than the average ^{210}Po concentration in the rest of this voivodeship.

Each honeybee plant has different characteric biological properties and each apiary has different characteristics, so that even within a single variety there may be differences. As a result of the study, an annual effective dose was calculated on the basis of ^{210}Po concentration and the consumption in honey (assuming the annual consumption of honey in Poland is estimated to be about 0.61 kg per person), which was 0.286±0.294 μSv·rok^{-1} for Lesser Poland Voivodeship and 0.569±1.252 μSv·rok^{-1} for Lower Silesian Voivodeship respectively (1.794±1.837 μSv·rok^{-1} for area around mines and 0.069±0.067 μSv·rok^{-1} for the rest of the voivodeship).

Acknowledgements: The authors would like to thank the MNiSW for financial support under grant: DS-530-8635-D646-17.

* corresponding author: alicja.borylo@ug.edu.pl

LICHENS AS BIOINDICATORS OF ENVIRONMENTAL POLLUTION IN POLAND (POMERANIAN, KUYAVIANPOMERANIAN, LOWER SILESIAN AND LESSER POLAND VOIVODESHIPS)

Alicja Boryło*, Grzegorz Romańczyk, Bogdan Skwarzec

University of Gdańsk, Faculty of Chemistry, Department of Chemistry and Environmental Radichemistry
Wita Stwosza 63, 80-308 Gdańsk

Keywords: polonium ^{210}Po, radiolead ^{210}Pb, uranium ^{234}U and ^{238}U, lichen

ABSTRACT

Environmental samples are complex most often in terms of composition and structure, very often heterogeneous and sometimes variable over time, resulting in lack of repeatability at sampling due to rapid changes in material being analyzed. The purpose of the study was to determine the radionuclides ^{210}Po and ^{210}Pb in lichen samples (Xanthoria parietina, Parmelia sulcata), Physcia adscendens, Physcia tenella, Caloplaca saxicola, Verrucaria Nigrescens, Lecanora conizaeoides and Amandinea punctata) collected for analysis from four Polish voivodships: Pomeranian, Kuyavian-Pomeranian, Lower Silesian and Lesser Poland Voivodeships.

Bioindicators are organisms used as an indicator of the state of the environment. These are species with a low tolerance index, or in a specific way responsive to the substance. Popular bioindicators are lichens.

The highest concentrations of ^{210}Po, ^{210}Pb and ^{234}U and ^{238}U were measured for each province in lichen samples with crustose thallus (*Caloplaca saxicola*, *Verrucaria nigrescens*, *Lecanora conizaeoides* and *Amandinea punctata*), while smaller were observed for lichen samples with foliose thallus (*Xanthoria parietina*, *Parmelia sulcata*, *Physcia adscendens* and *Physcia tenella*) (Tab. 1, Fig. 1, 2). In the Lesser Poland Voivodeship the lichens are classified into 3 groups of organisms growing in highly polluted air, which is probably related to the recent high concentrations of particulate matter: PM10, PM2.5 and benzopurene in southern Poland. The norms of particulate matter in the air were practically all the time exceeded. This can be attributed not only to the high emission of industrial dust, but also to the high supply of these elements to the environment with fertilizers and plant protection agents. Changes in the natural environment also entail changes in the composition of plants, which indicates the need for constant analysis of particular elements. The content of these radionuclides in the test samples may also be a good reference in later studies of environmental conditions in these areas.

Acknowledgements: The authors would like to thank the MNiSW for financial support under grant: DS-530-8635-D646-17.

* corresponding author: alicja.borylo@ug.edu.pl

EXTRACTION EFFICIENCY OF ^{210}Po IN POLISH HERBAL TEAS

Grzegorz Olszewski*, Dagmara Strumińska-Parulska, Monika Szymańska, Marcin Westa, Alicja Boryło, Bogdan Skwarzec

Uniwersytet Gdańsk, Wydział Chemii, Katedra Chemii i Radiochemii Środowiska, Wita Stwosza 63, 80-308 Gdańsk

Keywords: polonium ^{210}Po, herbal tea, extraction, effective radiation dose

ABSTRACT

Air and food are the main sources of many chemical elements, also natural and artificial radionuclides transferred to human organisms. The intensity of radioisotopes intake depends on the place of residence, local radiation quantity, diet habits and food origin. So far, during annual radiation doses evaluations in Poland, the most often consumed food products were taken into account [1,2]. Also type of agriculture could affect the natural radionuclides content in food. Among naturally occurring radionuclides, their potential ingestion and internal expose, the most important seems to be ^{210}Po and its parent nuclide ^{210}Pb.

The aim of the study was polonium ^{210}Po activity determination in popular herbal teas available in Poland as well as its extraction efficiency when brewed. Previous research on maté teas showed that 15-21% of ^{210}Po diffuse to water during infusion [3]. Obtained results allowed for calculating ^{210}Po extraction from herbs to tea as well as estimating the annual effective radiation doses from ^{210}Po decay ingested with tea.

Acknowledgements
The authors would like to thank the MNiSW for financial support under grant: DS-530-8635-D646-17.

References

[1] D.I. Strumińska-Parulska, J. Environ. Radioact., 2015, 150, 121–125.
[2] K. Szymańska, G. Krasińska, B. Skwarzec, J. Falandysz, D.I. Strumińska-Parulska, Environ. Sci. Poll. Res., 2016, 23(22), 22606-22613.
[3] M.S. Al-Masri, A. Nashawati, Y. Amin, B. Al-Akel, J. Radioanal. Nucl. Chem., 2004, 160(1), 27-34.

* corresponding author: grzegorz.olszewski@ug.edu.pl

^{210}Po AND ^{210}Pb IN POPULAR FOOD PRODUCTS FROM DIFFERENT TYPES OF AGRICULTURE

Dagmara Strumińska-Parulska*, Grzegorz Olszewski, Alicja Boryło, Bogdan Skwarzec

Uniwersytet Gdańsk, Wydział Chemii, Katedra Chemii i Radiochemii Środowiska, Wita Stwosza 63, 80-308 Gdańsk

Keywords: ecological and commercial agriculture, polonium ^{210}Po, radiolead ^{210}Pb

ABSTRACT

Air and food are the main sources of many chemical elements, also natural and artificial radionuclides, transferred to human organisms. The intensity level of radioisotopes intake depends on the place of residence, local contamination quantity, diet habits and food origin. So far, during annual radiation doses evaluations in Poland, only basic, the most often consumed food products were taken into account. Also type of agriculture could affect the natural radionuclides content in food. Among naturally occurring radionuclides, their potential ingestion and internal expose, the most important seems to be ^{210}Po and its parent nuclide ^{210}Pb.

Considering food origin, some products could be enriched with natural radionuclides when cultivated on soil with higher natural radioactivity background, e.g. Iran, India, Brazil, Sudan, China or Pakistan. These agriculture products would have higher amount of natural radionuclides due to accumulation and deposition processes. But some research showed higher topical radionuclides concentrations in soil of an arable fields when compared to surrounding ground. These situation was probably connected to fertilizers used in agriculture [1]. Manufactured phosphate fertilizers and their agricultural applications are considerable sources of environmental pollution [2]. Opposite, organic farming methods combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes. While conventional agriculture uses synthetic pesticides and water-soluble synthetically purified fertilizers, organic farmers are restricted by regulations to using natural pesticides and fertilizers.

The aim of the study was polonium ^{210}Po and radiolead ^{210}Pb activity determination in popular food products in Poland: fruits, vegetables and cereal products that came from different, mainly Polish, traditional and certificate Polish ecological agriculture. Researches showed the mineral fertilizers can impact on uranium and its daughter nuclides, as ^{210}Po and ^{210}Pb, content in soil, so plants and animals can accumulated heightened radioisotopes values. The idea was to compare products of two types of agriculture: traditional, where different types of fertilizers are allowed and applied; and ecological where natural fertilizers are allowed; and search for dependency between ^{210}Po and ^{210}Pb concentrations in food products and agriculture type. Further the aim was to estimate the radiation doses from ^{210}Po and ^{210}Pb decays ingested with analyzed food products and answer the question: is more expensive ecological food is worth buying in case of ^{210}Po and ^{210}Pb?

The results of ^{210}Po and ^{210}Pb determination showed their highest concentration were found in red currant, both traditional and ecological: 1.73±0.07 and 0.67±0.03 Bq·kg^{-1} dry mass for ^{210}Po and 1.15±0.03 and 0.10±0.01 Bq·kg^{-1} dry mass for ^{210}Pb respectively. However, the statistical tests showed there were no statistically significant differences among majority of results. Only "traditional apples and pears" contained more ^{210}Po when compared to those "ecological", Mann-Whitney (U test) p=0,12. ^{210}Po concentration in traditional apples was calculated at 0.72±0.02, while in ecological at 0.30±0,02 Bq·kg^{-1} dry mass.

Acknowledgements
The authors would like to thank the MNiSW for financial support under grant: DS-530-8635-D646-17.

References:
[1] Olszewski, G., Boryło, A, Skwarzec, B., 2015. J. Environ. Radioact., 146, 56-66. [2] Khater, A.E., 2012. Health Phys., 102(1), 63-70.

* corresponding authors: dagmara.struminska@ug.edu.pl

EVALUATION OF POSITION CORRECTION WITH PRETREATMENT VERIFICATION SYSTEM IN RADIOTHERAPY

S. Petkovska[*1], M. Ginovska[2], H. Spasevska[2], Y. Acarbas[1], A. Krleski[2]

[1]Radiotherapy and Oncology Department, Clinical Center Acibadem Sistina, Skupi 5A, 1000 Skopje, Republic of Macedonia
[2]
Faculty of Electrical Engineering and Information Technologies (FEEIT), "Ss. Cyril and Methodius" Univerzity in Skopje, Ruger Boskovic b.b., P.O.Box 574, 1000 Skopje, Republic of Macedonia

Keywords: radiotherapy, on-board imaging, verification

ABSTRACT

The distribution of the prescribed dose in certain physical limits is one of the most important goals that determine the effectiveness of radiotherapy treatment, directly and indirectly, through the preservation of healthy tissue around the tumor of concern. In planning the boundaries of space that need to be treated, all factors such as movement of internal organs, or those related to breathing, should be taken into account. The better these factors are accounted for, the position correction could be evaluated more precisely, which will contribute to decreasing the margins that are added towards ensuring that the tumor is in the range of radiation field. As a result of this approach, less healthy tissue is irradiated. In this line, the long-term data collection on repositioning could provide improvements of the protocol for positioning verification in radiotherapy. The pre-treatment repositioning system in radiotherapy, also known as onboard imaging system (OBI), could detect movement of internal organs at high resolutions, by use of low-dose digital imaging which provides simultaneous refocusing on the current location of the tumor with the reference point of the treatment plan. The absorbed dose from radiation exposure before the treatment is insignificantly small in comparison to the dose of radiotherapy, which justifies its use. Patient is on-line repositioned by visualizing bone-soft tissue anatomy in kV-kV or MV native imaging and cone-beam CT images. The analysis of position corrections data has been performed for 87 patients, considering different region of radiotherapy treatment: abdominal, thoracal, head and neck, and breast. Measurements data for 1998 repositions have been performed in three directions (x; y; z) by use of the kVkV system, out of which 317 have been additionally analyzed with the CBCT method, and 550 with the MV system. Every reposition measurements contains data on the movement of patients, the average change made for every patient and uncertainty, represented in three directions (vertical, longitudinal, and lateral). As a conclusion, the analysis of the position corrections provide the evaluation model for verification system in radiotherapy, in order to increase the accuracy of radiotherapy treatment delivery and to reduce the side effects by reducing the margins of the radiation field during the treatment.

[*] corresponding author: sonja.petkovska@acibademsistina.mk

IRRADIATION OF WASTEWATER FROM SOLVAY PROCESS

Marcin Sudlitz, Zbigniew Zimek, Andrzej G. Chmielewski, Wojciech Głuszewski

Institute of Nuclear Chemistry and Technology, 16 Dorodna Street, 03-195
Warsaw, Poland

ABSTRACT

Soda ash is an important substrate for production of glass, food or detergents. Most often Solvay process is used to obtain this product but the significant problem about that method is production of enormous amounts of wastes, solid as well as liquid, containing magnesium hydroxide, calcium carbonate and sodium chloride. These wastes are beeing stored nearby the factory or dumped into the groundwater, which cause severe environment pollution [1,2]. One of the way to solve that problem is to use sludge from process as a fertilizer. The condition is low concentration of sodium chloride. Use of ionising radiation can make sludge clearage proces easier by increasing sedimentation speed and easing filtration [3].

To study the influence of ionosing radiation on Solvay proces waste research on the suspension from brine purification has been carried out. Raw brine was purified in laboratory scale using solution of sodium carbonate and limewash. Obtained suspension was irradiated in gamma source and speed of sedimentation was measured. A positive effect of ionising radiadiation on sedimentation speed occured in comparison to non-irradiated suspension. To obtain constant composition of examined suspension model brine containing sodium chloride, magnesium sulfate and calcium chloride was developed. Measuring speed of sedimentation of solid particles precipitaded from model brine after irradiation shown that ionising radiation had no influence on that parameter. Experiments were carried out again but with addition of ferrous chloride and silicates (both occuring in brine as a pollutants) respectively. Only addition of silicates shown small efect in increasing speed of sedimentation after irradiation.

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 + FLAGA

[1] A. Bukowski et.al., Technologia Sody – Praca Zbiorowa, Państwowe Wydawnictwo Techniczne, 1959

[2] G.Steinhouser, Cleaner production in the Solvay Process: general strategies and recent developments, Journal of Cleaner Production, 2008, 16, 833 – 841

[1] Z.Zimek, W.Głuszewski, Laboratory and Feasibility study for industrial wastewater Effluents Treatment by Radiation, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/46/015/46015377.pdf

CONSERVATION OF WILD MUSHROOMS THROUGH ELECTRON BEAM IRRADIATION

Ângela Fernandes[1,2], Amilcar L. Antonio[1,3], Andrzej Rafalski[4], João C.M. Barreira[1,2], M. Beatriz P.P. Oliveira[2], Anabela Martins[1], Isabel C.F.R. Ferreira[*1]

[1] Centro de Investigação de Montanha (CIMO), ESA, Instituto Politécnico de Bragança, Portugal.

[2] REQUIMTE/LAQV, Faculdade de Farmácia, Universidade do Porto, Portugal.

[3] IST/CTN, Campus Tecnológico e Nuclear, Universidade de Lisboa, Portugal.

[4] INCT, Centre for Radiation Research and Technology, Warsaw, Poland.

Keywords: electron beam irradiation, mushrooms, nutritional value, chemical composition

ABSTRACT

The high perishability is a characteristic of the mushrooms consumed in fresh. Therefore, it is mandatory the application of effective conservation technologies to preserve and protect their chemical composition and nutritional value. Drying processes are widely used, but do not avoid the development of bacteria and fungi which have the ability to survive for long periods of time in dry foods, causing the loss of some nutrients and leading to food browning and oxidation of lipids and vitamins [1]. Irradiation appears as an alternative to food preservation assuring and maintaining its quality [2]. In this work, the effects of electron beam irradiation and storage time on nutritional and chemical parameters of wild samples of *Macrolepiota procera* (Scop.) Singer, previously submitted to a drying process (oven at 30 ºC), were assessed. The wild mushroom samples were collected in Trás-os-Montes; electron beam irradiation (doses 0.5, 1 and 6 kGy) was carried out in the INCT- Institute of Nuclear Chemistry and Technology in Warsaw, Poland and the analyses were performed over the storage period (0, 6 and 12 months). The results were compared with a control (non-irradiated samples). The nutritional value was determined according to the official procedures of food analysis, while the profiles of fatty acids, tocopherols, mono and oligosaccharides were obtained by chromatographic techniques [1]. The irradiation showed a better capacity to maintain the nutritional and chemical profile, in comparison with the storage time. Effectively, the storage time had a significant effect in all parameters, but fatty acids undergone significant changes both with irradiation doses and storage time. Electron beam irradiation can be considered a suitable technique for conservation of mushrooms for long periods of time, attenuating the changes caused by the drying treatment.

Acknowledgements

The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) and FEDER under Programme PT2020 for financial support to CIMO (UID/AGR/00690/2013), A. Fernandes (SFRH/BPD/114753/2016) and J.C.M. Barreira contract.

References

[1] Fernandes, Â.; Barreira, J.C.M.; Antonio, A. L.; Oliveira, M.P.P.; Martins, A.; Ferreira, I.C.F.R. Food and Bioprocess Technology, 2014, 7, 1606-1617.

[2] União Europeia, Jornal Oficial C 112 de 12/05/2006 p. 6-7.

[*] corresponding author: iferreira@ipb.pt

EXTRACTION OF MUSHROOMS RELEVANT COMPOUNDS THROUGH GAMMA AND ELECTRON BEAM IRRADIATION

Ângela Fernandes[1,2], Amilcar L. Antonio[1], Pedro M. P. Santos[3], Sandra Cabo Verde[3], João C.M. Barreira[1,2], M. Beatriz P.P. Oliveira[2], Anabela Martins[1], Isabel C.F.R. Ferreira[*1]

[1] Centro de Investigação de Montanha (CIMO), ESA, Instituto Politécnico de Bragança, Portugal.

[2] REQUIMTE/LAQV, Faculdade de Farmácia, Universidade do Porto, Portugal.

[3] IST/C2TN, Campus Tecnológico e Nuclear, Universidade de Lisboa, Portugal.

Keywords: irradiation, gamma, electron beam, mushrooms

ABSTRACT

Irradiation technologies are being used by the food industry as an alternative to other preservation processes. Its impact in minor compounds or different food matrices is still an open field. The use of irradiation to improve bioactive properties has been reported as a result of an increase in the levels of phenolic compounds in the extracts obtained from cooked and derived plant products. Previous results [1] indicated higher values of phenolic compounds concentration on irradiated food products compared with those found in non-irradiated samples. In this work, the effect of gamma and electron beam radiation processing on fresh and dried mushroom compounds extractability was studied. The mushroom samples were bought directly from the producer and divided in two groups, fresh to be immediately irradiated and to dry, before irradiation with gamma and electron beam (doses 0, 1, 2 and 5 kGy), that was carried out in the irradiation facilities of C2TN (Lisbon, Portugal). The irradiated fresh samples were immediately lyophilized for subsequent analysis by High Performance Liquid Chromatography (HPLC) and the dried samples were grounded into powder also to be analyzed after irradiation. The results were compared with a control (non-irradiated sample), obtaining the yield for each irradiation process (gamma and e-beam) or sample type (fresh or dried). Food irradiation besides being a preservation technology, suggested to promote food bioactive compounds.

Acknowledgements

The authors are grateful to the Foundation for Science and Technology (FCT, Portugal) and FEDER under Programme PT2020 for financial support to CIMO (UID/AGR/00690/2013), A. Fernandes (SFRH/BPD/114753/2016), J.C.M. Barreira contract and C2TN (RECI/AAG-TEC/0400/2012 and UID/Multi/04349/2013 projects); International Atomic Energy Agency (IAEA) Coordinated Research Project "D61024 - Development of Electron Beam and X-Ray Applications for Food Irradiation (DEXAFI)"

References

[1] Fernandes, Â.; Barreira, J.C.M.; Antonio, A. L.; Oliveira, M.P.P.; Martins, A.; Ferreira, I.C.F.R. Food and Bioprocess Technology, 2014, 7, 1606-1617.

[*] corresponding author: iferreira@ipb.pt

GAMMA RADIATION-INDUCED EFFECTS ON THE RECOVERY OF PHARMACOLOGICALLY ACTIVE POLYPHENOLS FROM *TUBERARIA LIGNOSA* MEDICINAL PLANT

José Pinela[1,2], M.A. Prieto[1,3], Lillian Barros[1], Amilcar L. Antonio[1], Sandra Cabo Verde[4], Ana Maria Carvalho[1], M. Beatriz P.P. Oliveira[2], Isabel C.F.R. Ferreira[*1]

[1] CIMO/ESA, Centro de Investigação de Montanha, Instituto Politécnico de Bragança, Portugal.
[2] REQUIMTE/LAQV, Faculdade de Farmácia, Universidade do Porto, Portugal
[3] Nutrition and Bromatology Group, Faculty of Food Science and Technology, University of Vigo, Spain
[4] IST/C2TN, Campus Tecnológico e Nuclear, Universidade de Lisboa, Portugal.

Keywords: *Tuberaria lignosa*; γ-rays irradiation, hot-water extraction, ellagitannins, HPLC-DAD-ESI/MS

ABSTRACT

Ionizing radiation has been used for many years as a safer and environmentally friendly alternative comparatively to chemical fumigants to decontaminate medicinal plants and other food commodities [1]. Perennial spotted rockrose (*Tuberaria lignosa* (Sweet) Samp.) is a highly quoted medicinal plant in the northeast region of Portugal rich in ellagitannin derivatives [2,3]. As polyphenols, these compounds play an important role in human nutrition and display several biological effects, including antioxidant, anti-inflammatory, antitumor, antibacterial, and anti-HIV replication activities [2-4]. However, little is known about the impact of ionizing radiation on the integrity and extractability of these high added-value compounds. This work aimed to investigate the effects of γ-rays irradiation on the extraction and/or degradation kinetics of ellagitannins from *T. lignosa* aerial parts. The plant material was submitted to irradiation doses up to 10 kGy in a cobalt-60 experimental chamber. Then, the non-irradiated and irradiated plant material was submitted to different solid-liquid extractions, according to a three-level full factorial design, using boiling water as extraction solvent. The ellagitannins were analyzed in a high-performance liquid chromatography (HPLC) system connected to a diode array detector (DAD) and a mass spectrometer (MS). Punicalin, punicalagin isomers, and punicalagin gallate isomers were the most abundant compounds. In general, the extractability of this group of phytochemicals was improved by the irradiation treatment (5 kGy) and longer extraction times (10 min). In addition, the 10 kGy dose did not induced adverse effects. In conclusion, this study demonstrated the suitability of γ-rays irradiation for preserving or improving the extractability of pharmacologically active compounds from *T. lignosa* aerial parts.

Acknowledgments
To PRODER research project no. 53514, AROMAP, for financial support of the work; to FCT/MEC (Portugal) for financial support to CIMO (UID/AGR/00690/2013), REQUIMTE (UID/QUI/50006/2013 - POCI/01/0145/FEDER/007265), J. Pinela (SFRH/BD/92994/2013) and L. Barros (SFRH/BPD/107855/2015); and to the Xunta de Galicia for financial support to the post-doc M.A. Prieto.

References
[1] H. Molnár, *et al*. *Food Control*, **2017**, In press.
[2] J. Pinela *et al*., *Food Chem*., **2012**, *135*, 1028.
[3] J. Pinela *et al*., *RSC Adv*., **2015**, *5*, 14756.
[4] J. M. Landete, *Food Res. Int.*, **2011**, *44*, 1150.

[*] corresponding author: iferreira@ipb.pt

THE STUDIES ON SILICON INCORPORATION INTO ZIRONIUM ALLOY SURFACE LAYER USING TIG TECHNOLOGY FOR HIGH TEMPERATURE CORROSION RESISTANCE IMPROVEMENT OF ZIRCONIUM CLADDINGS.

Marek Barlak[1], Paweł Kołodziejczak[2], Wojciech Starosta[*3]

[1] National Centre for Nuclear Studies, Andrzeja Sołtana 7, 05-400 Otwock, Świerk, Poland
[2] Institute of Manufacturing Technologies, Warsaw University of Technology, 02-524 Warszawa, Narbutta 85, Poland
[3] Institute of Nuclear Chemistry and Technology, 03-195 Dorodna 16, Warszawa, Poland

ABSTRACT

The unsatisfactory low oxidation resistance of zirconium alloys claddings in air-water steam environment at elevated temperatures typical for the case of LOCA nuclear accident stimulated the research efforts on finding the solution to this problem. One of the method possibly to implement in short time perspective consists in applying external coatings to zirconium nuclear claddings made of materials that are able to develop protective scale in high temperature water vapor environment and thanks to that are much less prone to oxidation. The problem need to be urgently solved in order to preserve the position of nuclear energy in global electric power production and to increase the safety of nuclear installations and to avoid in the future consequences of such costly, catastrophic disasters like in Chernobyl in 1986 and in Fukushima in 2014. Possible candidates include MAX ceramic, zirconium silicide or zirconium silicate coatings.

The zirconium silicide or zirconium silicate coatings are known for good resistance in high temperature conditions and for that reason are considered for application as environmental barrier coatings for high-temperature gas-turbine components. Up to now they are less explored for application as corrosion protective coatings for nuclear fuel pellets. However, review of existing literature and analysis of thermodynamic data indicates that silicon based coatings may offer excellent prospects in this field. Particularly, they may provide a more protective barrier than the native ZrO_2 films formed on alloy cladding during routine nuclear plant operations, and to provide an exceptional protective barrier during high-temperature accident scenarios. Phase diagram for zirconium-silicon systems clearly show existence of intermetallic compounds with different Zr/Si ratios and stability regions. For example $ZrSi_2$ is stable up to 1620°C and ZrSi is stable up to 2210°C etc. Temperature range of stability for zircon ($ZrSiO_4$) extends to 1673°C, were it thermally decomposes by solid state reaction giving ZrO_2 and SiO_2

The present work is aimed on the development of the synthesis method of silicon-based coatings on zirconium alloys claddings and on evaluation of their properties at accident scenario as well as in the reactor normal working conditions. The TIG (Tungsten Inert Gas) welding method has been selected as primary modification method. The zirconium alloy samples externally coated with slurries containing silicon, silicon carbide or zirconium fine particles by dipping method were treated with TIG electrode at different current values and different velocities of electrode. During the treatment the melting of the surface layer has been observed. The surface TIG treated layer have been characterized by different methods like SEM taken on the surface and of the cross sections, XRD, EDX. The results of the experimental works concerning synthesis method, physicochemical properties of coatings and conclusions on applicability of the TIG method for surface layer modification of zirconium alloys will be presented.

Acknowledgments
The financial support from Polish Ministry of Science and Higher Education under decision 3578/ZIBJ Dubna/2016/0 and from IAEA Research Contract No. 19026/R0, Polish Ministry of Science and Higher Education under decision 3689/IAEA/2017/0 gratefully acknowledged.

[*] corresponding author: w.starosta@ichtj.waw.pl

RADIONUCLIDE NEUTRON SOURCE TRAJECTORIES IN CLOSE NUCLEAR FUEL CYCLE

Przemysław Stanisz*, Jerzy Cetnar, Mikołaj Oettingen

[1]AGH – University of Science and Technology, Faculty of Energy and Fuels, Al. Mickiewicza 30, 30-590 Krakow, Poland

Keywords: transmutation dynamics, equilibrium fuel cycle, LFR, trajectory period folding

ABSTRACT

The highest efficiency in usage of the nuclear energy resources can be implemented in fast breeder reactors of Generation IV. It is achieved thanks to the ability of consuming Minor Actinides (MA) in the production of energy. One of the option to realize this benefit is full recycle of MA in order to close the nuclear fuel cycle. MCB, an integrated burnup calculation code, deals with the complexity of burnup process, which are applied to the European Lead-cooled Fast Reactor (ELFR). It copes with continuous energy representation of cross section, spatial effects of full core reactor model, yet automatically calculates nuclide production in all possible reaction or decay channels. The MA multirecycling can cause curium, berkelium and californium intensified buildup. Some of their isotopes are strong neutron emitters from spontaneous fission, which hinders the process of reprocessing. The implementation of novel methodology for trajectory period folding allows us to trace the life cycle of crucial minor actinides from the beginning of reactor life towards the state of adiabatic equilibrium. The result of performed analysis is presented showing the sources of strong contribution to the neutron production rate. Parametric sensitivity analysis method for selected reactions is carried out, revealing sensitivity of transmutation chains for production of neuron-emitter isotopes.

* corresponding author: pstanisz@agh.edu.pl

THE STUDIES ON SILICON INCORPORATION INTO ZIRONIUM ALLOY SURFACE LAYER USING TIG TECHNOLOGY FOR HIGH TEMPERATURE CORROSION RESISTANCE IMPROVEMENT OF ZIRCONIUM CLADDINGS.

Marek Barlak[1], Paweł Kołodziejczak[2], Wojciech Starosta[*3]

[1] National Centre for Nuclear Studies, Andrzeja Sołtana 7, 05-400 Otwock, Świerk, Poland
[2] Institute of Manufacturing Technologies, Warsaw University of Technology, 02-524 Warszawa, Narbutta 85, Poland
[3] Institute of Nuclear Chemistry and Technology, 03-195 Dorodna 16, Warszawa, Poland

ABSTRACT

The unsatisfactory low oxidation resistance of zirconium alloys claddings in air-water steam environment at elevated temperatures typical for the case of LOCA nuclear accident stimulated the research efforts on finding the solution to this problem. One of the method possibly to implement in short time perspective consists in applying external coatings to zirconium nuclear claddings made of materials that are able to develop protective scale in high temperature water vapor environment and thanks to that are much less prone to oxidation. The problem need to be urgently solved in order to preserve the position of nuclear energy in global electric power production and to increase the safety of nuclear installations and to avoid in the future consequences of such costly, catastrophic disasters like in Chernobyl in 1986 and in Fukushima in 2014. Possible candidates include MAX ceramic, zirconium silicide or zirconium silicate coatings.

The zirconium silicide or zirconium silicate coatings are known for good resistance in high temperature conditions and for that reason are considered for application as environmental barrier coatings for high-temperature gas-turbine components. Up to now they are less explored for application as corrosion protective coatings for nuclear fuel pellets. However, review of existing literature and analysis of thermodynamic data indicates that silicon based coatings may offer excellent prospects in this field. Particularly, they may provide a more protective barrier than the native ZrO_2 films formed on alloy cladding during routine nuclear plant operations, and to provide an exceptional protective barrier during high-temperature accident scenarios. Phase diagram for zirconium-silicon systems clearly show existence of intermetallic compounds with different Zr/Si ratios and stability regions. For example $ZrSi_2$ is stable up to 1620°C and ZrSi is stable up to 2210°C etc. Temperature range of stability for zircon ($ZrSiO_4$) extends to 1673°C, were it thermally decomposes by solid state reaction giving ZrO_2 and SiO_2

The present work is aimed on the development of the synthesis method of silicon-based coatings on zirconium alloys claddings and on evaluation of their properties at accident scenario as well as in the reactor normal working conditions. The TIG (Tungsten Inert Gas) welding method has been selected as primary modification method. The zirconium alloy samples externally coated with slurries containing silicon, silicon carbide or zirconium fine particles by dipping method were treated with TIG electrode at different current values and different velocities of electrode. During the treatment the melting of the surface layer has been observed. The surface TIG treated layer have been characterized by different methods like SEM taken on the surface and of the cross sections, XRD, EDX. The results of the experimental works concerning synthesis method, physicochemical properties of coatings and conclusions on applicability of the TIG method for surface layer modification of zirconium alloys will be presented.

Acknowledgements
The financial support from Polish Ministry of Science and Higher Education under decision 3578/ZIBJ Dubna/2016/0 and from IAEA Research Contract No. 19026/R0, Polish Ministry of Science and Higher Education under decision 3689/IAEA/2017/0 gratefully acknowledged.

[*] corresponding author: w.starosta@ichtj.waw.pl

EXHALATION RATE OF RADON-222 FROM CONCRETE AND CEMENT MORTAR

Allan Felipe Nunes Perna[1]; Sergei Anatolyevich Paschuk[1]; Janine Nicolosi Corrêa[1]; Valeriy Denyak[2]; Flávia Del Claro[1]; Danielle Cristine Narloch[*1]

[1]Federal University of Technology – Paraná, UTFPR, Brazil.
[2]Pelé Pequeno Príncipe Research Institute. Brazil.

Keywords: Radon, ^{222}Rn, Exhalation rate, Concrete, Cement mortar.

ABSTRACT

The main sources of radon in the air of dwellings are soil, building materials and groundwater. Residential environments are built using materials that are manufactured from the raw ingredients extracted from the soil. Therefore, these materials can significantly contribute to the activity concentration of indoor radon if its exhalation rate is high. This study is aimed to determine the exhalation rate of ^{222}Rn from different building materials as well as to evaluate the hazard indexes associated with other radionuclides (^{238}U/^{226}Ra, ^{232}Th and ^{40}K) present in studied samples by means of gamma spectrometry with hyper pure germanium semiconductor detector (HPGe, CANBERRA) with high efficiency (15%) and high resolution. Present study was conducted using the samples of materials widely used in various masonry buildings as, for example, the specimens of concrete and cement mortar. Obtained results allowed to compare the exhalation rate of radon using theoretical calculations based on one-dimensional and three-dimensional models. The activity concentration of radon in air was performed by AlphaGUARD instant radon detector connected to sealed up chamber with stored inside sample of building material. The radon exhalation rate, in $Bq \cdot h^{-1} \cdot m^{-2}$, found to the concrete was: 2.55 ± 0.03 for the one-dimensional model and 0.461 ± 0.008 for the three-dimensional model. The exhalation rate of radon, in $Bq \cdot h^{-1} \cdot m^{-2}$, found for the cement mortar was: 1.58 ± 0.03 for the one-dimensional model and 0.439 ± 0.011 for the three-dimensional model. Calculated concentration index of activity was found of 0.3395 ± 0.0017 and 0.3106 ± 0.0017 and the radium equivalent (Ra_{eq}) index was found of 89.8 ± 0.4 Bq/kg and 82.8 ± 0.4 Bq/kg for concrete and mortar cement, respectively. Furthermore, obtained results were tested by building a concrete test cell (a cubic chamber with solid walls and hollow interior) using studied construction materials with the aim to simulate a dwelling in small dimensions to evaluate indoor radon activity associated only to concrete. Obtained results with such test cells extrapolated to common dimensions of a human living environment, produced the radon activity in air of 112 ± 9 Bq/m^3, which is below the limit of 300 Bq/m^3 recommended by the International Commission on Radiological Protection (ICRP) as well as below 148 Bq/m³, recommended limit by the US Environmental Protection Agency (EPA). Even so, this value should be the subject of concern since that activity is related only to the contribution of concrete walls. These results show also that concrete and cement mortar can significantly contribute to the concentration of indoor radon of dwellings that are built with these materials.

* corresponding author: daninarloch@hotmail.com

^{99}Mo /^{99m}Tc GENERATOR BASED ON ALUMINA ^{99}Mo-MOLYBDATE (VI) GEL OF HIGH RADIONUCLIDIC PURITY

M.A. El-Absy[a], M.A. El-Garhy[a], T.W.Fasih[*,a], M.A. El-Amir[a], H.E.Ramadan[a], M.F. El-Shahat[b]

[a] Radioactive Isotopes and Generators Department, Hot Laboratories Centre, Atomic Energy Authority, P.O. Code 13759, Cairo, Egypt
[b] Chemistry Department, Faculty of Science, Ain Shams University, Cairo, Egypt

ABSTRACT

In this work high radionuclidic pure alumina ^{99}Mo-molybdate (VI) gel is synthesis for separation of the generated ^{99m}Tc radionuclide from small chromatographic columns. Mixtures of MoO_3 powder wrapped in pieces of aluminum foil and $FeCl_3.6H_2O$ are tagged with ^{99}Mo radiotracer and dissolved. Thereafter, 0.5 ml H_2O_2 is added to product solute to oxidize Fe(II) to Fe(III) left to stand at room temperature for ~ 90 min. the formed Fe(III) mineral and the co-precipitated radionuclide impurities and separated by centrifugation. Supernatant is acidified to pH 5.5 with concentrated HNO_3 acid to precipitate dissolved $NaAlO_2$. In situ precipitated pseudoboehmite incorporated the ^{99}Mo-eluatable ^{99}Mo/^{99m}Tc generators. ^{99m}Tc radionuclide is eluted in 10 ml 0.9% saline solution at a flow rate of 1.0 ml/min with high elution yield, concentrated in 5 ml eluate and chemical, radiochemical and radionuclidic purity ≥ 99.99% suitable for use in nuclear medicine application.

* corresponding author: tharwatfaseih@yahoo.com

DETERMINATION OF ^{6}Li ABUNDANCE IN Li_2O AND LiOH APPLYING THERMAL NEUTRON ABSORPTION TECHNIQUE

Tadeusz Kuc[1], Marek Ciechanowski[*,1], Władysław Pohorecki[2]

[1]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Poland
[2]Faculty of Energy and Fuels, AGH University of Science and Technology, Poland

Keywords: ^{6}Li abundance, neutron absorption, MCNP, Trithum production

ABSTRACT

Application of the Lithium Lead eutectic (LiPb) concept to the planed Test Blanket Modules (TBM) needs reliable determination of the produced Tritium. Thus radiometric measurement of the Tritium Production Rate (TPR) in LiPb using Liquid Scintillation technique (LS) seams relatively easy, however this method needs validation. Presence of generated in Pb parasitic activities in thermal neutron field coming mainly from ^{2013}Pb makes radiometric determination of Tritium content in LiPb in short time after irradiation impossible in practice. In this situation application of the calibrated monitors e.g. Li_2O or LiOH becomes the most promising solution.

We propose for calibration of the used Li_2O or LiOH, commercially available, application of the thermal neutron absorption method with parallel LS measurement of the generated in ^{3}H in the irradiated samples. Computed ^{3}H activity by the program MCNP utilizing depletion of the thermal neutron flux is then compared with radiometric measurement results. Irradiated small samples of Li_2O and LiOH (mass not exceeding 0.5 g) in neutron flux from ^{252}Cf source thermalised in polyethylene block for period not less than 14 days showed ^{3}H activity well agreeing, within measurement uncertainty, with that calculated for given Li isotopic composition. This method enables experimental determination of ^{6}Li abundance in lithium compounds - the abundance is a parameter of the used program.

* corresponding author: marek@ftj.agh.edu.pl

NEW KINDS AND PROPERTIES OF TRACK MEMBRANES PRODUCED WITH HEAVY ION BEAM IRRADIATION

O. Orelovich[1], B. Sartowska[2], A. Presz [3]

[1]Joint Institute for Nuclear Research, Dubna, Russian Federation
[2]Institute of Nuclear Chemistry and Technology, Warsaw, Poland
[3]Institute of High Pressure Physics, Warsaw, Poland

Key words: accelerators, heavy ions, track membranes

ABSTRACT

The heavy ions accelerators are useful in wide range of human scientific activity. The use of this technique takes a place in fundamental and applied physics. The accelerators of heavy ions can be used for the irradiation of polymer foils. One of applications of ion track technologies is track membrane production based on etching of polymer foils irradiated with accelerated heavy ions. Combination of different physical and chemical treatments brings to appearance of special features of produced. As examples, the irradiation of foils with ions of non-identical energies from different sides brings the appearance of hybrid massive of pores. In recent years, special interest was paid to the asymmetrical membranes with the conical pores. Their fabrication includes the irradiation of a polymer foil with accelerated ions followed by one-sided chemical etching. Also the additional physical treatment was used for achievement of pore formation. As result the pore channels with non-cylindrical "bullet-like" shapes were produced (fig. 1).

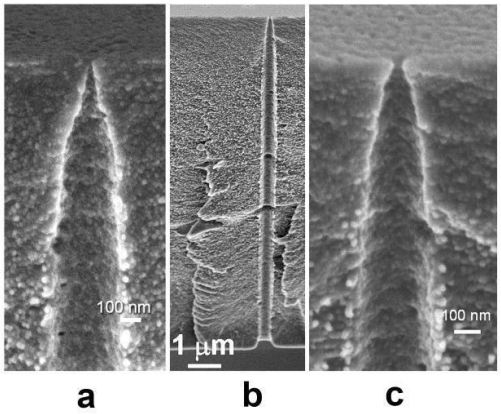


Figure 1. Several kinds of bullet-like pores produced by etching with non-symmetrical conditions from different sizes of membrane: a) one part of etching vessel contained the alkaline etchant and the other part was filled with a stopping solution [1]; b), c) the surfactants were used during etching and preliminary physical processing of irradiated foil was applied [2].

New interesting effects were found during the observation of asymmetric membrane properties. For example diode-like ionic conductivity was developed. It was found that under the asymmetric etching conditions an intense osmotic flux develops and has a strong effect on the nanopore geometry [3]. The surfaces and cross-sections of the obtained asymmetric pores were investigated with the use of field emission electron microscopes (FESEM) Hitachi SU8020 (Japan) and Zeiss Ultra Plus (Germany). The process of pore formation remains a subject of further studies. In this paper we introduce the examples of new properties and effects revealed during modification of membranes produced with irradiation by accelerated heavy ions.

References

1. *Apel P.Yu., Korchev Yu.E., Siwy Z., Spohr R., Yoshida M.* // Nucl. Instrum. Meth. Phys. Res. 2001. V. B184. P. 337-341
2. *P.Yu. Apel, I.V. Blonskaya, O.L. Orelovitch, S.N. Dmitriev //* Nucl. Instrum. Meth. Phys. Res. 2009. V. B267 1023–1027
3. *Apel P.Yu., Bashevoy V.V., Blonskaya I.V., Lizunov N.E., Orelovitch O.L., Trautmann C.* // Phys. Chem. Chem. Phys. 2016. V. 18. P. 25421-33.

PRECISE SOURCE OF HIGH VOLTAGE AND LOW POWER, REGULATED TO 65 000,000 V APPLIED TO RESEARCHES WITH MAKING AND DETECTING X-RAY RADIATION.

T. Kotowski

zrkcolor Zambrów
zrkcolor@poczta.onet.pl

keywords: x-ray, high voltage, source

ABSTRACT

Initially, high voltage source was developed and used in integrated with low power lamp- source of the x ray radiation. In consequence of developing works, in this supplier there has been widened his regulation range from 50,000 V to 65 000,000 V with step of regulation 0,125V and maximum outputing electricity to 0,5 mA.In elaborating of source, main pressure was placed in gaining max stability for short and long term and to minimalize distortions like hum on the output in all range of working.For this purpose there has been designed and made special divider of high voltage.It is made of 176 well connected resistors, immersed in isolating oil and additional thermostatically maintained in temperature 55 celsius degree.

Voltage reference has been built of 10 V integrated circuits with accuracy 0,5 ppm.

To limit influence of noises from external electrostatic field, whole electronic system and high voltage divider have been made in elecstrostatic shielding.

Specific feature of this electronic system is stability of parameters in full range of voltage regulations and very fast reaction of response for regulations changes.

The most important advantages of the device are also the long-term stability of the Vn work about +- 10ppm/6 months, lower limit of regulation from 50,000 V, resolution of regulations - 0,125 V and efficiency of converting energy (power) low voltage to high voltage of about 84%.

The basic limitations are the low power of the high voltage source, the stability of the reference voltage and limited upper value of high voltage control up to 65 kV.

Source can have different usage. In low power of the x ray lamp sourcesand can be use to making didactic systems.

We are still working to increase upper range of regulating and achieve much better parameters of high voltage source.

SUITABILITY OF ROCKS AND SEDIMENTS FROM BRZESZCZE AND SILESIA COAL MINES AS BUILDING MATERIALS

M. Śleziak*, M. Duliński

AGH – University of Science and Technology, Faculty of Physics and Applied Computer Science, al. Mickiewicza 30, 30-059 Kraków

Keywords: sedimentation pond, radiological hazard, Ra-226, Th-228, K-40

ABSTRACT

Exploitation of coal is inevitably linked with the necessity of drainage of mines and removal of gangue. Water and rocks are treated as waste products. They contain elevated concentrations of natural radionuclides, mostly radium and thorium. In water environment these isotopes either due to co-precipitation or adsorption on particles are removed from water column and stored in the bottom sediments. Waste rocks (ca. 0.4 t of rock per one tone of coal) are stored in gangue repositories and form reservoirs of elevated concentrations of radioactive isotopes.

Results of measurements of radium ^{226}Ra, thorium ^{228}Th and potassium ^{40}K activities in rocks and sediments originating from mines have been used for estimation of radiological hazard associated with exposure and usage of these materials. They helped to assess suitability of rocks and sediments as construction materials. Coefficients f_1 and f_2, radium equivalent, internal and external hazard index and absorbed dose rate are the most important parameters used in the evaluation of analysed samples of rocks and sediments.

According to the widely accepted standards, gangue can be used as construction material even in densely populated areas. Their calculated factors f_1 and f_2 vary between 0.103 and 0.901 and from 14,0 to 85.9 Bq/kg, respectively. The maximum value of radium equivalent is equal to 251.1 Bq/kg. The internal and external hazard indexes are lower than 1. Gangue accumulated in repositories can be used for roads building or ponds and rivers embankment construction. Bottom sediments from the Brzeszcze retention pond are suitable for underground construction (railway and road tunnels). However, bottom sediments from Kaniów and Rontok Duży tanks could create serious problems in future because they do not meet radiological standards. All exposure factors are exceeded in this case. The f_1 and f_2 factors are between 14.4 and 212.6 and between 2394 and 35490 Bq/kg respectively. The maximum value of radium equivalent is equal to 63170 Bq/kg. The absorbed dose rate is also very high, between 0.8 and 27.8 μGy/h.

* corresponding author: monika.sleziak@gmail.com

RADIOACTIVITY IN THE GAS PIPELINE NETWORK IN POLAND

J. Nowak[*1], P. Jodłowski[1], J. Macuda[2], C. Nguyen Dinh[3] and K. Liszka[2]

[1] Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Kraków, Poland
[2] Faculty of Drilling, Oil and Gas, AGH University of Science and Technology
[3] Faculty of Geology, Geophysics and Environmental Protection, AGH University of Science and Technology

Keywords: natural gas, radon, Pb-210, NORM.

ABSTRACT

The radiological risk in natural gas pipeline transport is mostly connected with radon (Rn-222) and its progeny: Po-218, Pb-214, Bi-214, Po-214 and Pb-210. The radon activity concentration in natural gas transported by gas pipelines varies in a wide range from dozens of Bq/m3 to several thousand Bq/m3 and mainly depends on the proximity of mines and geological structure of the deposit from which natural gas is extracted and transported. Additionally, radon progeny together with aerosols (in contrast to radon) are retained on filters. In the aftermath of successive radioactive decay of short-lived radon progeny, long-lived Pb-210 is accumulated on filters. The paper presents the study of the Rn222, Pb-210 and gamma radiation dose rates connected with the transport of natural gas by the gas pipeline network in Poland. In the scope of the study the measurements of activity concentration of radon (Rn-222) in the gas samples (with alpha scintillation cells), radiolead Pb-210 in spent filter cartridges and dust samples collected from the gas pipeline network (with gamma-ray spectrometry) were performed. Additionally, gamma radiation dose rate at the selected points of the gas pipeline network were measured. The results show that the Rn-222 activity concentration in natural gas varies from the detection limit of the applied method (30 Bq/m3) to around 1400 Bq/m3. The elevated radon activity concentrations in natural gas of several hundreds of Bq/m3 and more are observed at locations where the gas directly comes from local gas mines or where there is a blend of the national gas with imported one. Relatively low radon concentration in imported natural gas is connected with the fact that this gas was imported from Russia. Therefore, the time elapsed from the gas extraction to the collection of samples was relatively long. In consequence, the concentration of Rn-222 in the gas significantly decreased due to radon decay (3.8 days). The Pb-210 activity concentration in dust ("blackpowder") from gas filters and spent filter cartridges is high and varies from 500 to 17000 Bq/kg and from 200 to 2900 Bq/kg respectively. The gamma radiation dose rates measured at the selected elements of the gas pipeline network are at the level of the natural background.

[*] corresponding author: jakub.nowak@fis.agh.edu.pl

^{47}Sc and ^{67}Cu AS NOVEL RADIOISOTOPES FOR RADIOPHARMACEUTICALS

Izabela Cieszykowska*, Dariusz Pawlak, Wioletta Wojdowska, Małgorzata Żółtowska, Tomasz Janiak, Józef Leon Parus, Renata Mikołajczak

National Centre for Nuclear Research, Radioisotope Centre POLATOM, 05-400 Otwock, Poland

ABSTRACT

Radiopharmaceuticals are the important tool in nuclear medicine application based on the use of specific radionuclides in the appropriate form for diagnosis and therapeutic applications. Very important issue in choosing appropriate radioisotopes for the therapeutic radiopharmaceuticals is the possibility of performing both "therapy" and "diagnosis" applications based on the decay characteristics, usually known as "Theranostics". For instance, a single radionuclide such as ^{177}Lu (with photon emission and beta decay) can possess both decay characters, or two radioisotopes of the same element (or similar elements) which exist with different decay characteristics (such as ^{67}Cu as a beta emitter and ^{64}Cu as a positron emitter) can be used for these dual purposes. Very promising theranostic radionuclides are ^{67}Cu and ^{47}Sc. In 2016 the IAEA arranged a Coordinated Research Project (CRP) " Novel methods for production of ^{47}Sc and ^{67}Cu in nuclear reactor and cyclotron" focused on the development of radiopharmaceuticals labelled with new beta emitter radionuclides with theranostic properties.

The target materials for ^{47}Sc production in a nuclear reactor can be ^{46}Ca and ^{47}Ti for (n,□) and (n,p) reactions, respectively, and ^{67}Zn and ^{68}Zn for production of ^{67}Cu using (n,p) and (n,d) reactions in nuclear reactor or ^{64}Ni in (α,p) and the zinc isotopes in reaction with protons and deuteron in cyclotron.

We are trying to develop the separation methods of microamounts of these radioisotopes from macroamount of target materials. We will present some preliminary results obtained with the use of precipitation, ion exchange chromatography, liquid-liquid extraction or extraction chromatography. Main objective in these methods will be the highest yield in the shortest time with a lowest amount of carrier.

* corresponding author: izabela.cieszykowska@polatom.pl

DEGRADATION OF THE ANTIHYPERTENSIVE LOSARTAN IN AQUEOUS SOLUTION BY GAMMA RADIATION

Amira Zaouak[1,2], Ahlem Noomen[1], Haikel Jelassi[1]

[1]Laboratoire de Recherche Energie et Matière pour les Développement des Sciences Nucléaires & Direction de la Recherche sur l'Energie et la Matière, Centre National des Sciences et Technologies Nucléaires, Sidi Thabet Technopole 2020, Ariana, Tunisia.
[2]Laboratoire de Chimie Analytique et d'Electrochimie, Faculté des Sciences de Tunis, Département de Chimie, Université El Manar, Campus Universitaire, 2092 Tunis, Tunisia

Keywords: Losartan, gamma radiation, hydroxyl radicals

ABSTRACT

In this work, the gamma radiation of losartan, an emerging pharmaceutical polluant was studied. Losartan, one of the most consumed antihypertensive drug was irradiated at doses of 0.5 -7 kGy in aqueous solutions. Measuring the reduction in Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) during the irradiation process shows that the mineralization efficiency increases with increasing radiation dose. During the mineralization, four aromatic intermediates were identified by LC/MS/MS showing that irradiation process starts with the fragmentation of the molecule followed by reaction involving the hydroxyl radical, which is generated by the discharge of water.

Finally, a kinetic study based on spectrophotometric measurement showed that the degradation process is a pseudo-first order.

GAMMA RADIATION INDUCED COLORIMETRIC PROPERTIES OF E127AND E 132 DYES : ROUTINE DOSIMETRIC USE

Amira Zaouak, Ahlem Noomen and Haikel Jelassi*

Laboratory on Energy and Matter for Nuclear Sciences Development, LR16CNSTN02, Tunisia.
National Centre for Nuclear Sciences and Technologies, Sidi Thabet Technopark 2020 Ariana Tunisia.

Keywords: Dyes, gamma radiation, colorimetric study, Dosimetry.

ABSTRACT

The effect of ^{60}Co source γ –radiation on Erythrosine and Indigotine dyes solutions has been investigated by colorimetric measurements with doses varying from 0.1 to 5 kGy. Colors changes were observed and studied by the measurements of the variation of the a*, b* and L* as function of the dose. Color changes (ΔE*) were also calculated. For the reactive dyes, the result obtained shows that the degree of decoloration and the value of color difference (ΔE*) increases quadratically with increasing of the value of radiation dose (D). Those color difference (ΔE*) variations shows a remarkable dependence on the observed doses, signature of the optical activation of the color centers. The observed decoloration processes are described in terms of first-order kinetic equation. Fitted parameters allowed us to discuss the kinetic of the reaction and the possibility of use of those dye pigments as a routine dosimeter or irradiation indicator in the studied dose range.

* corresponding author: haikel.jelassi@gmail.com

PRE-TREATMENT OF RADIOACTIVE WASTE USING DESTRUCTIVE PROCESSES OF ORGANIC COMPOUNDS FOLLOWED BY CONCENTRATION OF RADIONUCLIDES

Dorota Gajda*, Anna Abramowska, Agnieszka Miśkiewicz, Katarzyna Kiegiel, Barbara Filipowicz, Grażyna Zakrzewska-Kołtuniewicz

Institute of Nuclear Chemistry and Technology, 16 Dorodna Street, 03-195 Warsaw

Keywords: radioactive waste, oxidation, sorption, membrane processes

ABSTRACT

In Poland, radioactive waste comes from operation of the Maria research reactor, medicine, research institutes and industry. Liquid radioactive waste may contain a number of various compounds that hinder their processing. These may include organic compounds (oils, liquid scintillators, extracting solvents), heavy metals and large quantities of salt (high-salinity wastes). The special methods of treatment are needed to process such waste to assure safe disposal.

The main method of liquid low-level radioactive waste (LLW) treatment is volume reduction by evaporation followed by solidification in concrete [1]. Such a method is not efficient for specific waste of more complex composition, energy consuming and non-selective. Institute of Nuclear Chemistry and Technology proposes new, less energy consuming technology based on hybrid methods. This technology consists of a few steps such as adsorption of organic compounds, destruction of residue organic matter suspended in water phase, membrane processes for concentration of radionuclides and capture of selected radionuclides.

First step of liquid LLW treatment was sorption of organic matter on chemically modified activated carbon [2]. The destruction of organic residue in ozone stream [3] or under UV light [4] was carried out. After destruction of structure of organic ligands that complexed radionuclides they are released into the solution. In the final step the concentration of radioisotopes by the nanofiltration method was accomplished.

The concentration of radionuclides was determined by using gamma spectrometry and ICP-MS method. Commercially available spectrophotometric tests (OWO® Nanocolor) were adapted for determination of TOC (Total Organic Carbon) in liquid phase.

Acknowledgements

The research was supported by IAEA Research Contract No: 18539/R2 and from the Ministry of Science and Higher Education budget for science for the years 2016-2017.

References

[1] Radioactive Waste Management Plant (ZUOP) webpage: www.zuop.pl
[2] I.H. Suffet, M.J. McGuire, *Advanced Carbon Adsorption*, Ann Arbor Science, 1980 Michigan, USA
[3] U. Gunten, *Water Research*, 37 (2003) 1443-1467
[4] D.W. Sundstrom, B.A. Weir, H.E. Klei, *Environ. Prog. & Sustain. Energy*, 8 (1989) 6-11

* corresponding author: d.gajda@ichtj.waw.pl

NAA AND XRF STUDY OF ARCHAEOLOGICAL BRONZES

Ewa Glimos[*1,2], Andrzej Bolewski[1], Beata Ostachowicz[1], Paweł Wróbel[1], Karol Dzięgielewski[2], Edyta Przytarska[3]

[1]AGH University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland

[2]Jagiellonian University, Institute of Archaeology, Krakow, Poland

[3]Heritage Monuments Protection Office,Gdańsk, Poland

Keywords: NAA, XRF, bronzes, archeology

ABSTRACT

A subject of this study was a set of 6 bronze artefacts from Pomerania and one from Silesia, Poland. The main goal was to identify types of the materials in use and their origin. To achieve that goal two analytical methods capable of elemental analysis: neutron activation (NAA) and micro X-Ray Fluorescence technique were applied.

The neutron activation analysis (NAA) was achieved with ^{239}Pu-Be isotopic neutron source ($5x10^6$ neutrons/s; ca 2,5 Ci) with the paraffin moderator and HPGe detector. Due to the different shapes of the tested samples and the lack of standard reference materials, the quantitative analysis of the chemical composition of the bronze was not performed. The lines 559 keV, 657 keV and 602 keV, 693 keV, characteristic of As and Sb respectively were registered. Characteristic gamma rays for isotopes Cu, such as the energy 1345 keV, due to the small neutron flux were observed, but the count rate was relatively small.

The micro XRF analysis was done with use of the in-house developed laboratory setup consisting the low-power X-Ray tube with polycapillary lens and SDD detector. Due to the very small spot size of the primary beam (~20 μm) it was possible to perform the analysis in the areas not covered by the corrosion. The XRF analysis confirmed the presence of As and Sb and additionally some traces of Fe, Cr, Sn, Pb and Ni were detected.

In this work the results obtained for all the samples with NAA and micro-XRF are compared and the capabilities of both methods are discussed. The presence of Cu, As, Sb and Sn in bronzes was detected which proves that the raw material was imported. Additionally the variable content of these elements proves that the tested samples have different origins. This indicates an intensive commercial trade occurring in northern Poland during the bronze age.

* corresponding authors: 6glimos@fis.agh.edu.pl

APPLICATION OF LOW ENERGY ELECTRON BEAM IN ELIMINATION OF PLANT PATHOGENS FROM ORNAMENTAL BULBS

U. Gryczka[*1], W. Migdał[1], S. Bułka[1], D. Chmielewska-Smietanko[1], M. Ptaszek[2], A. Jarecka-Boncela[2]

[1] Institute of Nuclear Chemistry and Technology

[2] Research Institute of Horticulture

ABSTRACT

International trade of flower bulbs, in addition to the positive, also has negative effects, including transfer of pathogens on the plant material. The most dangerous fungal disease of ornamental bulbous plants is fusariosis, caused *by Fusarium oxysporum*, which is a soil-borne pathogen. *F. oxysporum* produces mycotoxins which are highly dangerous to humans and animals. From the plant material these pathogens can get into the soil and gardening substrates, where they can survive for even over ten years. Currently to minimize the risk of pathogen spread, the flower bulbs are recommended to be soaked in fungicides solution.

An alternative to the currently used chemical methods may be ionizing radiation. New approaches for microbiological decontamination process using ionizing radiation is related to limited penetration of electrons having energy below 300 keV. The advantage of such solution is that low energy e-beam machines do not require thick shields and can be applied for in-line irradiation. In previous experiments using a high energy electrons, laboratory and greenhouse experiments have shown that ionizing radiation eliminates or minimizes soil pathogens that infest the plants in greenhouse crops without affecting their growth and development.

The aim of this work is to evaluate the effectiveness of low energy electron beam in elimination of plant pathogens and determination of germination properties of treated ornamental bulbs.

The work programme of work to be performed include:

- Determination of penetration ability of electrons having energy below 300 keV for selected ornamental bulbs, Determination of surface dose used for pathogens elimination,
- Evaluation of the effectiveness of low energy electron beam in elimination of *F. oxysporum* from ornamental bulbous on different development stages

Acknowledgements

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 730871.

This work was supported by the Polish Ministry of Science and Higher Education, project 3697/H2020/2017/2 Accelerator Research and Innovation for European Science and Society.

[*] corresponding authors: u.gryczka@ichtj.waw.pl

STUDY OF CHEMICAL SPECIATION OF TRACE ELEMENTS IN INFANT FORMULAS BY NEUTRON ACTIVATION ANALYSIS AND OTHER TECHNIQUES

Ewelina Chajduk*, Marta Pyszynska, Paweł Kalbarczyk, Halina Polkowska-Motrenko

[1]Institute of Nuclear Chemistry and Technology, Dorodna 16, 03-195 Warsaw, Poland

Keywords: trace elements, LC-NAA, speciation

ABSTRACT

Chemical, biological or toxic properties mainly depend on the form in which the element occurs. In the case of low total content of the element in the sample, the contents of the various chemical forms will be correspondingly lower. It is necessary to have analytical methods that can determine the content at levels of at least one order of magnitude smaller than in the case of the determination of the total content. The infant food products contain selected trace elements at very low level (of the order of several ng/g or less). Simultaneously, there is not known in the chemical form which they occur. Therefore, there is a need to develop such analytical techniques to ensure the extraction of analytes from the test material in unchanged chemical form, their enrichment, separation and determination. Unquestionable advantage of the NAA is independency of obtained results on the chemical form of determined element. NAA is based on physical phenomena which takes place in the nuclei. There are no chemical matrix effect as may occur in analytical techniques based on atomic properties and changes therein. Novel application of LC-NAA method for speciation of As, Fe and Se in infant formula insure the determination of their species at very low level and insure the determination compounds which could be "invisible" (or dependent on atomic binding) the for other analytical methods.

Acknowledgements

The studies were supported by the National Science Centre, in the frame of the scientific project: New analytical procedures for the determination of chosen Se, As and Fe chemical forms in infant formulas based on neutron activation analysis (No. 2014/15/B/ST4/05047).

* corresponding author: e.chajduk@ichtj.waw.pl