# RAD 2018

## SIXTH INTERNATIONAL CONFERENCE
ON RADIATION AND APPLICATIONS IN VARIOUS FIELDS OF RESEARCH

# BOOK OF ABSTRACTS

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# A

# THE EUROPEAN ATLAS OF NATURAL RADIATION

**Peter Bossew[1], Giorgia Cinelli[2], Tore Tollefsen[2], Valeria Gruber[3], Konstantins Bogucarskis[2], Luca De Felice[2], Marc De Cort[2]**

1 BfS (German Federal Office for Radiation Protection), Berlin, Germany
2 EC / JRC, REM group, Ispra, Italy
3 AGES (Austrian Agency for Health and Food Safety), Linz, Austria

Over ten years ago, the Radioactivity Environmental Monitoring (REM) group of the Joint Research Centre (JRC) of the European Commission embarked on the long-term project of generating a European Atlas of Natural Radiation. Since last year, a first online version is available (https://remon.jrc.ec.europa.eu/).

The purpose of the Atlas is to present a geographically resolved inventory of natural sources of exposure to ionizing radiation, and in a future stage, exposure and resulting dose themselves. The legal base of this endeavour is the Euratom Treaty which requires the EC to collect, validate and report information on radioactivity levels in the environment of the EU Member States. As radioactivity does not respect borders – and certainly well within the European spirit -, also non-EU countries have been invited to participate, and information from a number of them has already been integrated into the maps.

Previously, 20 years ago, a similar atlas has been published about Chernobyl fallout over Europe (https://rem.jrc.ec.europa.eu/RemWeb/Browse.aspx?path=Atlas). Also after the Fukushima accident in 2011 (which was without comparable radiological relevance for Europe), geographical assessment was attempted (doi:10.1016/j.jenvrad.2011.11.019). Another mapping project maintained by REM is EURDEP, which shows ambient dose rate at several thousand locations over Europe in near-real time [1]. All these efforts are aimed to provide insight into geographical variability of the respective exposure components, and appreciation of their relative importance for total exposure to ionizing radiation.

In the current (end-2017) first digital version of the "Natural Atlas", maps of the following quantities are included: Annual dose due to cosmic radiation; U, Th and K concentration in topsoil and bedrock; terrestrial ambient gamma dose rate; and most importantly from the point of view of exposure, indoor Rn concentration. The maps are partly incomplete, reflecting the data situation, which is however improving steadily, if slowly, given the substantial but necessary experimental efforts. As a next step, a printed version is under way, which will also contain background information about the quantities displayed in the maps. Options for extension are under discussion, such as maps of geogenic radon, outdoor atmospheric Rn, natural radionuclides in the hydrosphere or radiation anomalies and overall exposure and dose.

# EXPERIMENTAL ACTIVITY IN THE FIELD OF RADON AND THORON MEASUREMENT AT ITALIAN METROLOGICAL INSTITUTE FOR MEASUREMENT OF IONIZING RADIATION

**Francesco Cardellini**

ENEA – INMRI, Roma, Italy

Italian Metrological Institute for Ionizing Radiation Measurement (ENEA INMRI) has developed primary standard for measurement of Radon and Thoron, provides calibration facilities for Italian and foreign laboratories and carries out several experimental activities in this field.

The presentation will be an overview of some of these activities, main topics are listed below.

1) Italian Radon Reference Measurement System (RRMS) is briefly described, focusing on stability and reproducibility of RRMS, quality of the calibration service and results achieved by our customers in international intercomparison.

2*)* A large walk-in radon chamber (WIRC), volume 150 $m^3$, is available at ENEA INMRI and is a unique utility for experiment on airborne radon progeny and radioactive aerosol. A large portable device for radioactive aerosol detection was developed by Jožef Stefan Institute, Ljubljana, in the frame of the European project MetroERM, and tested at ENEA INMRI WIRC.

The device (named MARE) consists of a high flow air pump, airflow monitor, concertinaed filter cartridge, scintillation detector with a cylindrical $CeBr_3$ crystal positioned within the filter cartridge, a pulse processing unit and a central computer. Concentration of airborne radon decay product was simultaneously measured with MARE and with a BWLM PLUS 2 S Radon Daughter Monitor (Tracerlab, Germany) calibrated at the German Federal Office for Radiation Protection. The results are in agreement within the uncertainty (10%).

3) ENEA INMRI developed a thoron chamber (volume 220 L) where stable thoron concentration may be achieved and maintained for several days. Thoron concentration is monitored by a reference monitor based on a scintillation cell and a photomultiplier. These facilities was used for the calibration of AlphaGuard monitors newly equipped with thoron protocol that is based on the different time constant of $^{222}Rn$ and $^{220}Rn$. Good results are achieved showing the reliability of AlphaGuard routine for thoron measurement.

A bigger radon chamber (1 $m^3$) has been equipped with radon and thoron source to test influence of thoron on radon measurement. Experiment show that commercial monitor like Tesys MR1 plus and AlphaGuard, are sensible to thoron even operating in diffusion mode, without the support of a pump for air sampling.

4) INMRI ENEA developed a radon in water standard generator to provide reference solution for the calibration of "aqua kit" of commercial radon monitors, HPGe or NaI gamma spectrometry system and liquid scintillation counter (LSC). The radon concentration achieved is measured in RRMS with 1.5% combined uncertainty. The aim of the circuit is to provide a set of water samples, all with the same radon concentration, to be measured by different measuring systems, without leakage of radon.

Measurement with two different LSC instrument and with AlphaGuard and MR1 "aqua-kit" are presented. The results are in very good agreement with the radon concentration measured in RRMS.

# STRUCTURE, FUNCTION AND APPLICATION OF RHAMNOLIPID AND EXOPOLYSACHARIDE BIOSURFACTANTS OF *PSEUDOMONAS AERUGINOSA*

**Nataša Avramović**

Institute of Chemistry in Medicine "Prof. dr Petar Matavulj", Faculty of Medicine, University of Belgrade, Belgrade, Serbia

*Pseudomonas aeruginosa* belongs to an extremely diverse bacterial genus *Pseudomonas*, everywhere present worldwide. Due to its metabolic diversity, *Pseudomonas* has potential for adaptation, survival and growth in a wide range of environmental conditions. *P. aeruginosa* produces variety of secondary metabolites, including rhamnolipids (RLs), exopolysacharides (EPSs), enzymes, pigments and toxins. Major biosurfactant compounds produced by *P. aeruginosa* are RLs and EPSs involved in bacterial adherence, biofilm formation and maintenance.

RLs are low-molecular mass glycolipid biosurfactants comprise a hydrophilic (one or two L-rhamnose) and a hydrophobic (one or two units of 3-hydroxy fatty acid) moiety. Based on their chemical composition, the principal RLs of *P. aeruginosa* are mono-rhamno-di-lipidic (RL1) and di-rhamno-di-lipidic (RL3) structures. *Pseudomonads* have the potential to produce various types of EPSs such as alginate, levan, marginalan and cellulose, as well as different heteropolysaccharides and protein polysaccharides complexes. *P. aeruginosa* produces alginate as the main acidic EPS. Alginate is polymeric biosurfactant composed of β-1,4-D-mannuronic and L-guluronic acids linked via β-1,4-glycosidic bonds and it is O-acetylated at some of the C-2 and C-3 carbons of the mannuronic acid residues.

Due to their amphipathic structures and physicochemical properties, RLs and EPSs produced by *P. aeruginosa* behave as wetting agents, surface active compounds, emulsifiers and detergents. Their functional groups are, therefore, utilized in enhancing and facilitating bacterial movement, adhesion and contact with surfaces, as well as substrate uptake, or solubilization. They are involved in processes of respiratory mucus alteration, modulation of immune system defense pathways, biofilm development and maintenance and the *P. aeruginosa* mucoid phenotype.

RL and EPS biosurfactants are, currently attracting the most attention, as they are relevant in medicine, environmental protection, food and the pharmaceutical industry. They show many interesting properties like low toxicity, biodegradability and high efficiency in comparison to chemical surfactants. RLs and EPSs produced by *P. aeruginosa* can be potent candidates in biomedicine and therapeutics for their antimicrobial, hemolytic, antiviral, anti-carcinogenic and immune modulating activities as well as they are interesting novel targets for dealing with respiratory infection in Cystic Fibrosis patients.

**Acknowledgments:** This work was supported by project III46010, granted by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

# ENVIRONMENTAL RADIATION MONITORING AND RADIOLOGICAL ASSESSMENTS AT THE IRT_SOFIA NUCLEAR SITE

**Kiril Krezhov, Tzvetana Nonova, Aleksander Mladenov, Dobromir Dimitrov**

Institute for Nuclear Research and Nuclear Energy, Sofia, Bulgaria

The activities in assessing the environmental impact of the IRT-Sofia research reactor site at the Institute for Nuclear Research and Nuclear Energy (INRNE) are reviewed. We consider results from the short and long term studies of the radiation risks to people and to environment that may arise from the use of radiation and radioactive materials conducted in conformity with the radiation protection and monitoring programs of the site. In reasoning to be considered acceptable, the use of radiation and practices involving radiation exposure shall meet the following criteria: a) the benefits derived from the practice shall exceed the detriment it causes (*principle of justification*); b) the practice shall be arranged so that the resulting exposure to radiation hazardous to health is kept as low as is reasonably achievable (*principle of optimization*, ALARA); c) no person shall be exposed to radiation exceeding the maximum values prescribed by actual Ordinance (*principle of limitation*).

Planning of activities, appropriate working methods, up-to-date protection methods, instruments and protective equipment are essential part of the measures ensuring compliance with the basic safety standards for protection of workers and public. Also, previous experience is utilized and co-operation between the different organisation units is demanded since commitment to the radiation protection objectives concerns the entire personnel. In addition to introductory training of employees, refresher training is given at regular intervals with instructions for their duties appropriate to the kind of work and to the workplace conditions with emphasis to information on the health hazards of radiation and on safety enhancing work procedures in order to prevent unnecessary exposure to radiation. The basic principles followed are: a) the radiation exposure to which workers and visitors are subjected and the factors affecting this exposure shall be examined in advance, also accounting for extraordinary working conditions, b) working areas shall, where necessary, be classified as controlled areas and supervised areas, and c) workers who must be individually monitored for radiation exposure shall be classified in a separate group.

The radiation monitoring of the site is performed at a grid of pre-selected observation posts. Additionally, the level and distribution of effective doses are derived from gamma background measurements and analyses of alpha, beta and gamma emitters in randomly and purposely taken smears and environmental samples aimed to specify the radionuclide contents in air (aerosols), water (groundwater and rainfall), soils and selected plants—bio-indicators. The surveys trace contaminants' levels and reveal trends in the changes in the concentrations of harmful substances, including radon, effects and causes for such changes. The guiding idea is that use of measured data (historic records) is preferable rather than using models in a dose reconstruction project.

# LEAD OXIDE PHOTOCONDUCTOR FOR APPLICATION IN DIRECT CONVERSION X-RAY DETECTORS

**Alla Reznik[1], Olexander Semeniuk[1], Gytis Juska[2], Sergei Baranovskii[3]**

1 Lakehead University, Thunder Bay, Canada
2 Vilnius University, Vilnius, Lithuania
3 Philipps University, Marburg, Germany

Semiconductor-based direct-conversion X-ray detectors have been actively sought for a wide range of x-ray applications in the fields of domestic security and medical imaging. Polycrystalline Lead Oxide (PbO) is one of the most promising high Z (atomic number) candidates for this purpose due to high X-ray stopping power, high theoretical X-ray-to-charge conversion gain and proven technological compatibility with a-Si electronics required for a large detector area coating. The current challenges are from incomplete charge collection and a residual signal after exposure termination, called signal lag, which are largely related to transport and recombination mechanisms. Those, however, have never been assessed in the polycrystalline PbO, despite continuous interest in this promising material.

Here, the transport of the charge carriers and charge recombination are evaluated by combining the conventional time-of-flight (TOF) and the photo-generated charge extraction by linear increasing voltage (photo-CELIV) techniques. We show that both electrons and holes in poly-PbO undergo dispersive transport. In order to analyze the transport features quantitatively, the theory of the photo-CELIV is extended to account for the dispersive nature of charge transport. Our study explains why conventional approaches to material optimization for applications of thick PbO layers in direct conversion medical imaging detectors are not efficient and suggest a way to make detector-grade PbO layers free of lag.

# USE OF RADIATION IN NON-CONVENTIONAL MEDICAL DIAGNOSTIC PROCEDURES

**Ana Pejovic-Milic**

Ryerson University, Toronto, Canada

*In vivo* elemental analysis of human tissue is an approach that is not widely available in clinical practices worldwide. Instead of collecting a sample, such as blood and urine, from a person for *in vitro* chemical analysis, the stored quantity of a toxic element is determined *in vivo*. It is desirable that the *in vivo* elemental analysis be non-invasive, thus no sample is taken and by extension, there is no discomfort to the patient. This presentation will address non-conventional, *in vivo,* radiation-based tissue analysis of human tissues.

The relationship between chronic exposure to an element and the health effects of this exposure are best explored by examining the quantity of the element in question that is stored in the body *in vivo*. Depending on the site of measurement in the body, detection and quantification of these elements can provide information on long-term exposure to an element that is distinct from other, more conventional, methods of exposure assessment. The limiting factor of these approaches, however, is that the radiation dose must be kept as low as reasonably possible, and within the range of other diagnostic procedures.

Several elements are toxic when present in excessive amounts and such overexposure typically occurs in an occupational setting, although some environmental exposures and medical treatments are also of concern. While the most fully developed techniques are for lead and cadmium in bone, this talk will present two *in vivo* nuclear analytical methods, namely neutron activation analysis and X-ray fluorescence, used to measure aluminum (Al), manganese (Mn) and strontium (Sr), lanthanum (La) stored in the human bone.

# NOVEL METHODS AND DEVELOPMENT OF RADIATION-INDUCED OPTICALLY STIMULATED LUMINESCENCE (OSL) MEASUREMENTS

**Arkadiusz Mandowski**

Institute of Physics, Jan Dlugosz University, Częstochowa, Poland

Optically stimulated luminescence (OSL) is a two-stage luminescence phenomenon. First, the material is irradiated. The metastable excited state after irradiation may last for many years. Luminescence is triggered by optical stimulation. Typically, the light emission is observed at shorter wavelengths than the stimulation wavelength. In most cases the light output is proportional to the absorbed dose of ionizing radiation. These features allowed this phenomenon to be applied to dosimetry of ionizing radiation as well as dating of archeological and geological samples.

Theoretical explanation of the OSL phenomenon is based on the concept of charge carrier traps and recombination centers that are populated during excitation. Luminescence emission depends strongly on absorbed dose and various parameters of traps. Typically the continuous wave mode (CW-OSL) is used for detecting the emission. In typical applications it allows to estimate the dose of absorbed radiation by integrating the decay curve. Unfortunately, the information concerning important trap parameters is lost.

In recent years, the OSL method has been significantly improved. New methods of optical stimulation and theoretical analysis allow to get knowledge concerning e.g. the distribution and properties of recombination centers and very long lasting luminescence phenomena such as fading, inverse-fading and regeneration which are important for characterization of OSL detectors. The change of stimulation wavelength allows to get an information relation the energy distribution of traps, i.e. in a similar manner as in thermoluminescence (TL) method. These possibilities pose a challenge for the constructors of currently used OSL readers. Implementation of these new techniques is not easy.

This lecture presents a review of recent development and novel methods for the measurement of OSL phenomena in solid state detectors. It presents also mathematical background of the analysis of the OSL response under various modes of stimulation. Examples of recent development as well as hardware and software implementation of these techniques in modern OSL readers are shown. It seems that the significant progress in OSL measurements will create a new quality in the field of luminescence dosimetry.

RAD 2018

Keynote Talks

B

# IS THE RADIOACTIVE DECAY CONSTANT REALLY CONSTANT?

**Kristina Bikit-Šreder, Ištvan Bikit, Dušan Mrdja**

Department of Physics, Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

The exponential law of radioactive decay is one of the most trusted laws of nuclear physics. The basics of this law is the decay constant which is the transition probability between two nuclear states, an intrinsic property of nuclear species, thus not subject to any changes.

In our paper we will present some exceptions from this statement. Some significant changes in the decay constant can be understood by perturbations in the atomic electron structure, while some recently published results on the influence of the solar neutrino flux and the Earth to Sun distance on the decay constant cannot be incorporated into the Standard Model of fundamental interactions. About 50% of published papers confirm some half life changes, while in the rest of reports the authors do not see any statistically significant changes of half life or any periodicity. Thus this issue needs both experimental and theoretical clarification. The recent discovery of gravitational waves might provide an explanation for some of the anomalies detected without any periodicity.

# PERSONALIZED THERAPY IN CANCER AND THERANOSTIC APPROACHES IN NUCLEAR AND MOLECULAR MEDICINE

**Neşe İlgin Karabacak**

Gazi University Medical School, Ankara, Turkey

The term theranostics in nuclear medicine is used for diagnosis and therapy using personalised approach. This phenomenon also refers to the use of molecular targeting vectors labeled with diagnostic radionuclides (e.g. positron or gamma emitters), and thereafter using therapeutic radionuclides for therapy respectively of a particular disease, targeted specifically by the vector at its molecular level. These probes can be used for molecular imaging with specific ligands using positron emission tomography (PET), single photon emission computedtomography (SPECT), magnetic resonance imaging (MRI), so that the treatment is specifically targeted against the tumor and its environment. The need to define the targets, ligands, also requires multidisciplinary approach for coupling and labeling chemistry with the most appropriate radionuclides, biodistribution modifiers and selection of the right patients. This approach for the personalized treatment will also incorporate clinical applications of liquid biopsy in the near future. Currently, theranostics of neuroendocrine tumors (NETs) using Ga-68labeled tracers for diagnostics with hybrid positron emission tomography/(PET/CT/MR), and using Lu-177 or other metallic radionuclides for radionuclide therapy as well as prostate cancer by applying PSMA related imaging and therapy prove that personalized radionuclide therapy today is already possible with some degree of success. The heterogeneous nature, frequently indolent course and possibility of multiple and variable anatomic sites of the primary tumor make it difficult to evaluate patients with NETs. Multifocal presentation of prostate cancer with castration resistant and non-resistant types need different approaches for staging and therapy using PET/CT/MR. Ga-68 PET/CT/MR provides a “one-stop shop” whole-body investigation of NETs and prostate cancer for staging, including evaluation of liver, lymph nodes, bone, lung, brain and other possible tumor sites.

**Key words:** Theranostics, molecular imaging, personalized radionuclide therapy

# CANCER IMMUNOTHERAPY WITH LOW-LEVEL WHOLE-BODY EXPOSURES TO IONIZING RADIATION

**Marek Janiak**

Military Institute of Hygiene and Epidemiology, Warsaw, Poland

Evidence amassed over the last several decades from epidemiological, experimental, and clinical studies indicates that whole-body exposures at low doses (i.e., ≤100 mGy delivered over a short time) of low-LET ionizing radiation inhibit the development and/or progression of various neoplasms. The primary mechanism of such effects is thought to be stimulation of both the innate and adaptive arms of anti-cancer immunity.

Indeed, the immune system is regarded as the most potent guardian of the organism against neoplastic disease. However, as defined by the recently accepted cancer immunoediting hypothesis the immune system protects the host against the incipient cancer at the early stages of carcinogenesis, but later 'edits' the immunogenicity of the extant neoplastic cells and supports remodelling of the tumour microenvironment towards the immunosuppressive and pro-neoplastic state.

The presentation will review immunosuppressive mechanisms induced by growing tumours as well as immunomodulatory effects of whole-body low-dose exposures to X or gamma rays directly or likely associated with cancer-inhibiting outcomes of such exposures. Suggestions will be provided how such exposures can possibly restore and/or stimulate effective anti-tumour immunity during the more advanced stages of carcinogenesis. Finally, we will postulate that, based on epidemiological and experimental data accumulated over the last few decades, whole or half-body exposures to low-dose low-LET radiation should be viewed and further examined as a viable immunotherapeutic treatment option for patients with systemic and metastatic cancer.

# US DOE TECHNICAL STANDARD "CLEARANCE AND RELEASE OF PERSONAL PROPERTIES FROM ACCELERATOR FACILITIES"

**James Liu[1], Ryan Ford[1], Sayed Rokni[1], Scott Davis[2], Elaine Marshall[3], Scott Schwahn[4], Keith Welch[5]**

1 SLAC National Accelerator Laboratory, Menlo Park, United States
2 Department of Energy, Washington DC, United States
3 Sandia National Laboratories, Albuquerque, United States
4 Oak Ridge National Laboratory, Oak Ridge, United States
5 Thomas Jefferson National Accelerator Facility, Newport News, United States

The U.S. Department of Energy Order 458.1-2013, *Radiation Protection of the Public and the Environment*, (hereafter O458.1) prescribes a general process with a Total Effective Dose constraint of 0.01 mSv above background in any calendar year for each specific radiological clearance of personal property with potential residual radioactivity. Based on the dose constraint, the ANSI N13.12-2013 Standard, *Surface and Volume Radioactivity Standards for Clearance*, derives and establishes the volume and surface screening levels (SLs) of various radionuclides for the clearance of materials. To facilitate implementation of the O458.1 requirements, a DOE Technical Standard (hereafter the Standard or DOE-STD-6004) was developed and published in 2016 to support the control, clearance and release of personal property (materials, equipment and items) from accelerator facilities (electrons and protons up to GeV levels) and modules thereof. The Standard provides a 3-tier clearance criteria (related to volume SLs) and guidance for DOE accelerator facilities to develop and implement site-specific programs (including management, technical, and operational aspects) for the radiological clearance and release of personal property. The Standard focuses on common metals (aluminum, copper, iron and steel) and concrete that has the potential to be radiologically impacted by accelerator operations. The appendices of the Standard provide general process knowledge (Appendix B), technical bases for volumetric activation (Appendices C and D), and measurement methods (Appendix E) for the preferred clearance criterion of Indistinguishable from Background.

RAD 2018

# Special Talk

# C

# CURRENT STATUS AND FUTURE PERSPECTIVES OF ADVANCED RADIATION TECHNOLOGY INSTITUTE (ARTI)

**Byung Yeoup Chung**

KAERI, Jeongeup, South Korea

The Advanced Radiation Technology Institute (ARTI) is under the Ministry of Science and ICT of Republic of Korea, established in 2006 as an affiliate of the Korea Atomic Energy Research Institute (KAERI). The ARTI has various irradiation facilities, including two gamma irradiators (490 kCi, 3kCi, Co-60), an ion implanter (300 keV), two electron beam (EB) accelerator (10 and 0.2 MeV), a gamma phytotron (400 Ci, Co-60), a mobile EB accelerator (0.65 MeV), and a cyclotron (30 MeV). In addition, a Large-Scale Multipurpose EB Irradiation Centre (17 M$) harboring two EB accelerators (10 and 2.5 MeV) will also be constructed by 2018, aiming to accommodate up-scaled large products. The ARTI, a state-of-the-art research institute, is specialized in multidisciplinary research subjects such as 1) radiation material science including radiation environmental remediation, 2) radiation biotechnology including radiation food science, 3) radiation breeding, and 4) radiation equipment. We have launched a radiation big data-based new project (10 M$/5 years) in 2016, so called a Radiation Reaction Map (RRM), to build up a bioinformatic platform by collecting a radiation-related research outputs, scattered around a radiation society and elsewhere. It will convey web-based core information on radiation reactions to industrial and academic users. Future perspectives on radiation technology are as follows: Development of a radio-vaccine for animal disease control, Development of an inspection system for cargo containers, Development of a microneedle patch for efficient drug delivery, and Development of preservation techniques for cultural heritage.

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# European LED Academy Session

## Photonic Signalling and Clinical Photobiomodulation

D

# PHOTONIC SIGNALLING IN ACNE VICIOUS CIRCLE

**Linda Fouque**

European LED Academy, Nice, France

Acne vulgaris is the most common skin disorder. Consequently it can be responsible for profound psychological and social impact on patients. For these reasons, a lot of alternative treatments emerged over the last decade; among these, the use of blue light emitting diodes (LED) was significantly and clinically proven to reduce mild to moderate acne.

Acne vulgaris is characterized by multifactors as keratinocyte over-proliferation, sebum excess, *P. acnes* colonization and pro-inflammatory cytokine stimulation. All of these parameters interact with one another and create a vicious cycle.

The purpose of this study was to investigate some possible mechanisms of action implicated in blue wavelengths effectiveness on acne vulgaris.

Cells and *ex vivo* skin biopsies were exposed twice a week, with 12 J/cm² and 20 J/cm² (respectively) of combined 415 nm and 465 nm blue wavelengths.

In a preliminary work, we ensured that blue wavelenghts emitted by TRIWING device were safe on keratinocytes, inducing no modification of mitochondrial reactive oxygen species (ROS) production.

Subsequently, in the present experiment, we showed that these LED stimulated the natural production of LL37 human cathelicidin C-terminal fragment, which belongs to the antimicrobial peptides (AMPs) family, well-known for their direct anti-microbial activity. Taking this into account, the stimulation of the LL37 cathelicidin could be one of the pathways limiting *P. acnes* development in acne disorders.

In another approach, we simulated a pro-inflammatory event, inducing interleukin-8 (Il-8) production by the keratinocytes exposition to lipopolysaccharide (LPS). We noticed that on inflamed keratinocytes, repeated LED treatments led to a significant reduction of Il-8 production.

From a clinical point of view, 11 patients were exposed to blue LED (420 nm) during one hour per day for 90 days. Several clinical benefits were observed after 30, 60 and 90 days of the treatment: an improvement of inflammatory lesions, a decrease of whiteheads and a decrease of seborrhea. Interestingly, these beneficial effects were still visible 1 month after the end of treatment.

In addition, post inflammatory hyperpigmentation may also appear in acne disorder. In this way, we performed Fontana-Masson melanin staining on *ex vivo* skin biopsies. Obtained results showed that poorly and highly pigmented zones had been homogenized after blue LED exposures, indicating that the treatment could reduce post inflammatory hyperpigmentation disorders.

Clinically, it was also observed a homogenization of the pigmentation after 90 days of the blue LED treatment.

Taken together, these results strongly suggested that blue LEDs might represent a multi-pathway effective alternative in acne treatment.

# MANAGEMENT OF SWELLING DUE TO AESTHETIC PROCEDURES BY LED DEVICE

**Suzanne Hausdorfer**

European LED Academy, Hamme-Mille, Belgium

Injury of the epidermis due to Aesthetic procedures such as lasers, liftings, peelings etc., always generates swelling which can be a cause for severe complications.

Led irradiation (630/850nm) of healthy skin leads to mobilisation of fibroblats and proinflammatory cells, like mast cells, macrophages and other white blood cells 48 hours after irradiation.

Normally, Led 630/850nm are used to accelerate wound healing.

Pretreating the skin with these wavelenghts before aesthetic invasive procedures prevents all swelling. Electron microscopy reveals a tissue without any inflammatory signs and shows fibroblasts containing vesicles of phagocytosis. Tissue without Led pretreatment shows all inflammatory signs : oedema, dilated vessels with vesicles of micropynocytosis in the endotheliocytes and the presence of macrophages, lymphocytes and fibroblastes.

It should therefore be systematically done before aesthetic invasive procedures to avoid complications.

# HEALING CASES: CLINICAL DYNAMICS SEQUENCES OF PBM EFFECT

**Karim Abdi**

European LED Academy, Ariana, Tunisia

As a film unrolled slowly before our eyes, we will discuss the different phases of healing through clinical cases: They represent alone a unique story.

In the early phase, if the wound is “a fresh”, recent one, the PBM, offers a fast repair on inflammatory phase

In the chronic stage (Old burns, for example), it remains a challenge for the future....

The clinical effects of PBM make us clear that it is not simply the result of a local action.

A diabetic foot, a leg ulcer are “the tip of the iceberg” of an alteration of the patient’s health condition. Taking these factors into account is a guarantee of the success of the physiological photonic action.

The overall result is probably the culmination of a “coherent” signaling regulated by photons?

Let images speak...

# THE "PHOTO BIO-FLEXIBLE" FIELD

**Michele Pelletier**

European LED Academy, Toulon, France

Dynamic Phototherapy (PDT) brought the concept of field of cancerization. "Genetic alterations detected in the pathological area in the environment of the tumor are correlated to repeated exposure to various carcinogens. These alterations constitute the field of cancerization. Such concept considers the tumor as the secondary lesion and the field as the original modification. The latter will then induce visible injury.

What about the PBM* process?

The PBM process is that by which specific wavelengths are absorbed by cellular photo-acceptors triggering major signaling processes in cellular biological exchanges

The sequence of the process can also be made relevant to many physio-pathological mechanisms such as:

The field of healing;

The field of rejuvenation;

The field of hair regrowth... Etc.

Clinical evaluation is a major step in the development of care protocols

It should be conducted at 3 levels: the pathological gradation of the lesion, the photo biomodulation field, and the general health condition of the patient.

The delayed effect: The expected result, after a biological time, is always delayed and is sustained (the delay probably depends on each indication). It would be useful, through multiple studies, to assess "these delayed effects" in order to fully define the regimen of the treatment (therapeutic education, modalities of the sessions: number, intervals and maintenance).

Loco-regional or even systemic effects can be observed at a distance from the illuminated zone (clinical cases of cicatrization).
Considering *photo-regulation* of the field (as the background to the lesion) may help to prevent the occurrence of secondary lesions, as we can learn from dynamic phototherapy and field cancerization. This leads to the global concept of photo prevention, itself part of the valuable and necessary public health objective of regenerative preventive medicine.

PBM*: Photobiomodulation

# IMMUNOLOGICAL EFFECTS OF LIGHT THERAPY

**Valeriy Zaporozhan[1], Michele Pelletier[2], Andrey Ponomarenko[1]**

1 Odessa National Medical University, Ukraine

2 LED Academy, France

It was shown that photobiomodulation therapy (PBM) has anti-inflammatory and pain relief effects. M. Pelletier et al. demonstrated that PBM also have delayed effects comprising restoration of tissue alterations (healing, rejuvenation) and hair growth. Different research implies activation of mitochondrial functions, stimulation of ATP synthesis and cell membrane ion channel regulation as mechanisms of the PBM effects. We suggested participation of immunological mechanisms in local and system responses to PBM. To check possible effects of the PBM on cell immunity we evaluated relative contents of peripheral blood (PB) lymphocyte subpopulations before and after skin irradiation with long wavelength light. Near Infrared Lamp RIGHT HAUSEN 125W E27 emitting red and near infrared light (600-950 nm wavelength band) was used for one hour irradiation of chest region in healthy volunteers. Comparative evaluation of PB lymphocyte subpopulations was performed using Flow cytometry method (DACO Galaxy instrument). Four lymphocyte subpopulations were evaluated: **CD3+** (T-cells); **CD3+CD4+** (T-helper cells); **CD3+CD8+** (T-suppressor / cytotoxic cells) and **CD4+CD25+** Immunoregulatory T-cells (T-regs).

**Results:** Skin irradiation with near-infrared lamp caused certain differences in relative contents of studied cell subpopulations in peripheral blood of volunteers. Statistically significant 26% increase of T-regs in PB after skin irradiation was shown: average contents of **CD4+CD25+** lymphocytes before irradiation – 1.9% of total lymphocyte count, after irradiation – 2,4%.

**Discussion:** various factors influence absolute counts and relative contents of lymphocyte subsets in PB: hormone concentration, emotional and environmental conditions among others. Redistribution of the lymphocyte subsets between blood and different tissues has also diurnal (circadian) variations. Obtained results indicate possible reaction of immune system on skin irradiation with near-infrared light which usually is used in PBM. Immunoregulatory T-cells plays key role in orchestration of immune reactions, they are crucial in suppressing aberrant pathological immune responses. Significant role in the maintenance of T-regs function plays dendritic cells (DC). We suggest that PBM influence DC-T-regs cooperation that can stimulate anti-tumor immune responses and switch immune reactions from pro-inflammatory to regeneration type. In previous studies we demonstrated direct correlation between PB concentrations of CD34+ progenitor cells and T-regs. Therefore, increase of the T-regs contents after skin irradiation may indicate increase of the progenitor cell concentration in peripheral blood that can explain healing, rejuvenation and hair growth-stimulation effects of the PBM therapy (delayed effects). There are reports indicating that CRY DASH photolyase which perform light-dependent DNA reparation are detected in vertebrates. Therefore we suggest that blue light may also contribute to anticancerogenic and regeneration effects of phototherapy by activating photolyase DNA-repair mechanism.

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# Radiobiology 01

# ASSESSMENT OF THE ADAPTATION OF PATIENTS WITH ARS, THE VICTIMS OF ChNPP AND DIFFERENT RADIATION ACCIDENTS, PAST PSYCHOPHYSIOLOGICAL EXAMINATION

**Naly Metlyaeva, Andrei Bushmanov, Valery Krasnuk, Olga Shcherbatykh, Lyubov Yunanova**

FSBI GSC FMBC of A.I.Burnazyan FMBA of Russia, Moscov, Russia

The aim of this work is to evaluate the adaptation of patients with ARS, the victims of ChNPP and in the different radiation accidents, who past psychophysiological examination in dynamics. A clinical-psychophysiological examination in the dynamics of 32 patients with ARS, including 11 patients with ARS, severe and extremely severe degree affected by the accident at ChNPP and 21 patients with ARS from different radiation accidents. As a result of studies, shown that the leading role in the reduction of stenical and integrative behavior of such psychological manifestations as hypochondria, concerns about the health, emotional tension, anxiety, inclination to depression, to frustration of tension, suspiciousness, insecurity, affective rigidity, dissatisfaction with the situation and his position in it, the limitation of contact with others, which led to the violation of the adaptation processes in long-term period in patients with ARS, the victims of the ChNPP accident and patients with ARS of different radiation accidents, with the peculiarities of its manifestations depending on the stressful situation and the personality of the patient. Intelligence, according to Kettell test, and figuratively-logical thinking test (Raven) in patients affected by radiation accidents not only hurt, but were above average ARS in patients affected by the Chernobyl accident, especially in the first 15 years of observation and equal to the level of intelligence of patients with ARS of different radiation accidents in the subsequent 15 years of follow-up, which, in comparative terms with them, a decline in intelligence. The speed of simple sensorimotor reaction to light, complex sensomotor reaction to color and sound, as well as the reaction to a moving object was reduced and they made a large number of omissions, inaccuracies and errors. The severity of asthenic and asthenic-neurotic type of reaction is represented by the predominance of hypochondriacal and anxious-depressive responses like, especially pronounced in patients with ARS, victims of the Chernobyl accident, and patients with ARS of different radiation accidents, with the accession of the latter demonstrative and original trends, and dependent on the individual characteristics of the local population, causing tension and strain psychophysiological adaptation.

# GENETIC EFFECTS AFTER IRRADIATION OF HEAVY IONS IN HAPLOID AND DIPLOID YEAST CELLS

**Natalia Koltovaya, Ksenia Lyubimova, Nadya Zhuchkina**

Joint Institute for Nuclear Research, Dubna, Russia

Interest in studying the biological effects of heavy ions has grown in connection with active space exploration and considering future Mars missions. Cosmic radiation is primarily composed of protons (~95%) and heavy ions. It is possible to model the action of cosmic radiation by using heavy ion accelerator beams at JINR, Dubna. Unicellular yeast cells were chosen as a model eukaryote. They are convenient for studying the dose dependence of mutagenic effects with different genetic assays. Additional interest is aroused by using yeast to detect, measure, and correlate the impact of space radiation on living organisms over long durations beyond Low Earth Orbit and heliocentric orbit in Bion-M and NASA's BioSentinel mission.

The purpose of this study is to investigate the biological effects induced by different accelerated ions ($^{4}He$, $^{11}B$, $^{12}C$, $^{20}Ne$) with different energy and linear energy transfer (LET) and to determine their relative biological effectiveness (RBE) for lethal damage as well as gene mutations. Particularly, in the present work, we investigated the differences of base pair substitution induction by ionizing radiation in haploid and diploid cells.

# BIOCHEMICAL ASPECT OF ADAPTATION OF *PLANTAGO MAJOR* L. SEED PROGENY FROM RADIOACTIVE CONTAMINATED AREA

**Nadezhda Shimalina, Vera Pozolotina, Natalya Orekhova, Elena Antonova**

Institute of Plant & Animal Ecology, Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russia

**Introduction.** In 1957 the serious nuclear accident took place at the Production Association "Majak" in Southern Urals, Russia. About 74 PBq of radioactive wastes were released into the atmosphere, which resulted in Eastern Ural Radioactive Trace (EURT). The main contaminant (from long-lived radionuclides) was $^{90}$Sr. Additional contamination of this zone occurred in 1967 as a result of the wind transfer of radioactive sand from the shores of the Karachay Lake, which had been used as a reservoir for radioactive wastes (the main contaminant was $^{137}$Cs). Currently, the inventiry of $^{90}$Sr, $^{137}$Cs and $^{239,240}$Pu in the EURT's soil cover consist of 571, 66 TBq and 1.7 TBq, respectively.

**Purpose of the study:** evaluate the prooxidant and antioxidant status of *Plantago major* L. seedlings from the East Urals Radioactive Trace zone and from background sites.

**Methods.** For assessment of biochemical parameters dried seedlings were used, which were cultivated in laboratory conditions from seeds, collected from natural populations of *Plantago major* L. Three populations were exposed for a long time to radioactive contamination; three background plots were beyond the contamination zone. We analyzed the activities of antioxidant enzymes (catalase, peroxidase, and superoxide dismutase), and contents of lipid peroxidation products (malondialdehyde) in seedlings.

**Results.** There were no significant differences of biochemical parameters between background populations. The same was true of differences between impact populations. Enzyme activities in pooled samples from the EURT zone significantly differed from those in background pooled samples. In the samples from EURT zone superoxide dismutase and catalase activities were significantly higher (200-270%, $H = 4.3$-$11.2$, $p < 0.05$), while POX activity was lower (44 %; $H = 6.5$, $p < 0.01$). Furthermore, MDA concentrations were significantly higher in EURT samples (228 %; $H = 14.7$, $p < 0.001$). Evaluation of the Integrated prooxidant-antioxidant PAI index revealed occurrence of the significant prooxidant shift in populations from EURT zone (331%, $H = 24.8$, $p < 0.001$).

**Conclusion.** Analysis of our data shows that under equal conditions of enzymatic protection, which carries out the deactivation of active forms of oxygen ($O^*$, $H_2O_2$, ROOH), the rate of accumulation of secondary lipid peroxidation products in seedlings from impact populations was 3.3 times greater than in background samples.

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# CELL SENSITIVITY TO DOXORUBICIN AFTER APPLICATION OF ULTRASOUND

**Anna A. Oleshkevich**

Moscow State Academy of Veterinary Medicine and Biotechnology, Moscow, Russia

The authors studied the possibility of a combined effect of cytostatic drugs and physiotherapy on living proliferating cells. The problem is topical. The choice of a continuous ultrasound (frequency of 0.88 MHz, the $I_{SATA}$ intensity ranged from 0.05 to 1.5 W/cm$^2$, an exposure time 3–5 min) is explained by the wide application of ultrasonic therapy in veterinary medicine and diagnostics. The aim of the work is to reveal the specific influence on the cell cultures of continuous ultrasonic waves of low therapeutic intensities combined with the xenobiotics. We obtained detailed characteristics and analyzed the separate and combined effects of cytostatic doxorubicin and physical factor on the culture of marine luminescent bacteria *Aliivibrio fischeri 6*.

The results of the studies showed that significant stimulation of growth and intensity of luminescence of *A. fischeri* bacteria by ultrasonic treatment was established. Exposure to ultrasonic intensity of 0.4 W/cm$^2$stimulated the bioluminescence and the growth rate of *A. fischeri*. The authors explain the change in the growth of organisms by a general increase in membrane permeability, which leads to activation of cellular respiration and substrate consumption. Doxorubicin, as we expected, suppressed the development and function of luminescence of bacterial cells. The optimal concentration of the drug was 0.8 mg/ml of medium. The combined use of ultrasound and medicine irreversibly suppressed the proliferative and emission activity of cells. We obtained data on the possibility of reducing the dose of doxorubicin during the ultrasonic therapy.

# INTER-INDIVIDUAL VARIABILITY IN BIOLOGICAL RESPONSE TO IONIZING RADIATION MEASURED BY DICENTRICS AND MICRONUCLEI

**Jelena Pajić[1], Dubravka Jovičić[2], Aleksandar P. S. Milovanović[1,3]**

1 Serbian Institute of Occupational Health, Belgrade, Serbia
2 Singidunum University, Faculty of Applied Ecology Futura, Belgrade, Serbia
3 Belgrade University, Faculty of Medicine, Belgrade, Serbia

Ionizing radiation can induce a wide range of DNA damage that leads to chromosomal aberrations. Some of those aberrations (dicentrics and micronuclei) are applied in biodosimetry. Biological dosimetry assumes similar radiosensitivity of each donor but it does not exclude inter-individual variations in radiation susceptibility. Therefore, for biological reasons, it is always challenging to investigate inter-individual variability in response to radiation. For mechanistic reasons, it is also interesting to investigate the correlation between dicentric and micronuclei formation in response to radiation.

In this experiment, irradiated blood specimens from 14 healthy male and female donors has been used to evaluate inter-individual variability in response to the genotoxic effects of X-ray radiation, as well as the dose response relationship and test sensitivity using two endpoints (dicentrics and micronuclei).

The results showed similar patterns of cytogenetic biomarker distribution between donors, but differences in the response of some donors at some doses. Data also showed that responses of male donors were better detected using the dicentric test, while for females micronuclei frequencies were higher in response to the same dose of radiation. No influence of smoking status or age on specific responses was observed. Group variability in response to radiation was evaluated using coefficient of variation (CV) for each group of individuals irradiated with the same doses; as the dose increases group variability becomes substantially lower.

Despite sporadic inter-individual variability, trend of radiation induced changes were similar. Produced calibration curves for both types of damage revealed dicentrics as genetic damage are more typical for radiation than micronuclei.

# MICRONUCLEI FREQUENCY IN PERIPHERAL BLOOD LYMPHOCYTES OF THE SERBIAN ADULT POPULATION: DATABASE FOR DOSE ASSESSMENT BY BIODOSIMETRY TOOLS

**Jelena Pajić[1], Dubravka Jovičić[2], Aleksandar P. S. Milovanović[1,3]**

1 Serbian Institute of Occupational Health, Belgrade, Serbia
2 Singidunum University, Faculty of Applied Ecology Futura, Belgrade, Serbia
3 Belgrade University, Faculty of Medicine, Belgrade, Serbia

The cytokinesis-block micronucleus cytome assay (CBMNCyt) was used to assess the variability and determine possible influences of external and internal factors on the background levels of cytogenetic damage in peripheral blood lymphocytes (PBL) of randomly selected healthy volunteers from the general Serbian population. The mean micronuclei (MN) frequency for all subjects was 8.31 ± 3.88 per 1000 binuclear (BN) cells. The number of micronuclei ranged from 1 to 21 per 1000 BN cells, while most subjects had 6 and 7 MN. The frequency of nucleoplasmic bridges (NPB) for all subjects was 0.23 ± 0.47 and of nuclear buds (NB) 3.15 ± 1.41. The mean nuclear division index was 1.63 ± 0.18. The number of apoptotic cells ranged from 0 to 6 per 1000 BN cells, with a mean value of 1.74 ± 1.23, while the number of necrotic cells ranged from 0-7 per BN 1000 cells, (mean value 2.27 ± 1.63). The canonical correlation analysis showed a positive significant correlation between the MN frequency and age, gender and smoking habits. Results of factor structure and canonical weights showed that age and gender rather than smoking habits control the incidence of MN in PBL of healthy volunteers.

# BIODOSIMETRY AND PHYSICAL DOSIMETRY TOOLS IN RADIATION EXPOSURE ASSESSMENT

**Dubravka Jovičić[1], Jelena Pajić[2], Aleksandar P. S. Milovanović[2,3]**

1 Singidunum University, Faculty of Applied Ecology Futura, Belgrade, Serbia
2 Serbian Institute of Occupational Health, Belgrade, Serbia
3 Belgrade University, Faculty of Medicine, Belgrade, Serbia

Occupational exposure to ionizing radiation (IR) involves operations with unsealed or sealed sources. Nuclear medicine staff using unsealed sources is of particular interest for dosimetry research, because they are exposed to extremely inhomogeneous fields of ionizing radiation with an increased risk of internal contamination

The findings for two technicians, who were unintentionally exposed to IR while operating unsealed sources in the Nuclear Medicine Department, are presented here. Exposure evaluation was conducted at the Radiation Protection Center of the Serbian Institute of Occupational Health (SIOH). Values for the personal dose equivalent at a body depth of 10 mm at the point of application of the personal dosimeter [Hp(10)], the dose equivalent at a body depth 0.07 mm at the application point of the personal dosimeter [Hp(0.07)], and the results for chromosomal aberrations (CA) and micronuclei (MN) analysis after the first and control examinations in the Cytogenetic Laboratory (SIOH) are presented. The case report for technician1 is an example of agreement between the findings obtained by physical dosimetry and cytogenetic analysis in detecting unintentional exposure and internal contamination with high doses of radionuclides.

The results also showed that the cytokinesis block micronucleus (CBMN) test is a more sensitive technique in detecting internal contamination than CA analysis. Multiple MN are an unequivocal indicator of genetic damage. Since radiation is a strong inducer of MN, these genetic changes may be a certain biomarker of internal contamination.

# CYTOGENETIC CHANGES IN PERSONS OCCUPATIONALLY EXPOSED TO RADIONUCLIDES

**Dubravka Jovičić[1], Jelena Pajić[2], Aleksandar P.S. Milovanović[2,3]**

1 Singidunum University, Faculty of Applied Ecology Futura, Belgrade, Serbia
2 Serbian Institute of Occupational Health, Belgrade, Serbia
3 Belgrade University, Faculty of Medicine, Belgrade, Serbia

The paper presents research results of cytogenetic and molecular cytogenetic analyses applied in persons occupationally exposed to radionuclides. The aim was to establish correlation between the frequencies of premature centromeric division (PCD) and chromosomal aberrations (CA) in their metaphases. Both parameters were analyzed by conventional cytogenetic technique. The presence of PCD was confirmed by fluorescent in situ hybridization (FISH). The assay of pL1. 84a repetitive DNA for chromosome 18 was used for detection of centromeric region.

The analysis included 50 subjects exposed to radionuclides ($I^{131}$) (group C) (the average age of 45.24 ± 1.18 years and the average exposure time 17.96 ± 1.15 years) and 40 control subjects (group K) (the average age of 44.40 ± 0.98 years and the average time of employment 19.67 ± 0.98 years), which were not exposed to genotoxic agents in their workplaces.

The results showed that frequencies of CAs and PCDs were statistically significantly higher in subjects exposed to radionuclides than in the control group. (Mann-Whitney U test, $P < 0.01$). Analysis also showed positive correlation between PCD and dicentric, acentric fragments and chromatid breaks ((Spearman's test, r = 0:49, 0:54, 0:29, $P < 0.05$). The FISH method confirmed the presence of PCD in metaphases but also in interphase nuclei of subjects exposed to radionuclides.

Since PCD may be observed as a phenomenon representing the manifestation of chromosomal instability in the exposed persons, our study led us to consider PCD as a possible parameter of genotoxic risk for individuals occupationally exposed to radionuclides.

# DNA REPAIR PROCESSES IN HUMAN LYMPHOCYTES IRRADIATED WITH 60 MeV PROTON RADIOTHERAPEUTIC BEAM AT IFJ PAN

**Agnieszka Panek, Justyna Miszczyk**

Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland

Despite the undeniable successes contributing to the prolongation of the patients' life, there is still a significant difference between treatment potential and patient expectations. Recently, particular attention is paid to patients' life quality after the treatment. It is assumed that the size of the major complications after irradiation is equally important criterion for assessing treatment methods as survival time. For this reason, predicting the normal tissue response of cells to ionizing radiation would be very useful in the process of qualifying patients for radiotherapy. One of the main factors that differentiate people in terms of the effectiveness of therapeutic procedures or side effects is variability in DNA repair capabilities.

The aim of the study was to investigate mechanisms differentiating response of DNA damage repair systems in human lymphocytes irradiated with the therapeutic proton beam in the Bronowice Cyclotron Center IFJ PAN. Lymphocytes from healthy donors were irradiated in the Spread-Out Bragg Peak of the proton beam or as a reference X-rays. For both sources of radiation, the kinetics of the DNA damage repair capabilities using the comet assay method (0-120 min.) and H2AX test (0-24h) were estimated. Preliminary results from comet assay show similar time and repair efficiency of induced DNA damage for both types of radiation. However in group involving X-rays radiation significant inter-individual differences were observed. These findings indicate that an induced DNA damage repair mechanism after proton irradiation may be different when compared to X-rays.

**Key words:** Protons, X-rays, DNA damage response/repair

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# EFFECTS OF LOW-LEVEL RADIATION OF ALPHA, BETA AND GAMMA TYPE ON SIMPLEST BIOLOGICAL SYSTEMS - DESCRIPTION IN TERMS OF HORMESIS AND THRESHOLD MODELS

**Nadezhda Kudryasheva[1], Tatiana Rozhko[2], Alena Petrova[1], Gennadii Badun[3], Oleg Guseynov[2], Dmitriy Dementyev[1], Alexander Bolsunovsky[1]**

1 Institute of Biophysics SB RAS, Krasnoyarsk, Russia
2 Siberian Federal University, Krasnoyarsk, Russia
3 Moscow State University, Moscow, Russia

Radiosensitivity of organisms is usually expressed as a dose/effect relationship. In addition to the "linear" dose-effect dependence, low-dose studies can be based on a "threshold" or "hormesis" models. "Hormesis" suggests that low dose radiation can be favorable for organisms. Current work studies biological effects of different radiation types – alpha, beta, and gamma. The exposures to alpha- and beta-emitting radionuclides (americium-241 and tritium), and gamma radiation ($^{137}$Cs-containing particles) were studied under conditions of chronic low-dose irradiation (< 0.2 Gy) in aqueous media. Simplest luminescent bioassays – luminous marine bacteria (a), their enzyme reactions (b) and fluorescent proteins (c) were applied as bioassays; luminescent intensity was used as a tested physiological parameter. The luminescent bioassays are proper tools for study the low level exposures due to simplicity and high rates of procedure, providing a proper statistical treatment. Non-linear dose-effect dependencies were demonstrated. Three successive stages in the bioluminescent response to alpha- and beta-emitting radionuclides were found in assays (a) and (b): 1 – absence of effects (stress recognition or threshold effect), 2 – activation (adaptive response), and 3 – inhibition (suppression of physiological function, i.e. radiation toxicity). Gamma irradiation revealed only stages 1 and 3, while the activation stage (2) was not found. The bacterial response was found to be independent on activity concentrations of radionuclides or dose rates of gamma-radiation. The nonlinear dose-effect dependencies of ionizing radiation with activation phenomenon included (stage 2), were ascribed to the "hormesis" phenomenon. The effects of gamma-radiation were described in terms of "threshold" toxicity model. Experiments with tritiated water and tritium-labeled polyethylene films (liquid and solid courses of beta-particles, respectively) showed that activation of the intracellular bioluminescence process can take place without penetration of tritium into the cells. Sequence analysis did not reveal mutations in bacterial DNA under conditions of all the experiments. The results give preference to a "non-genomic" mechanism of bioluminescence activation. Biological role of reactive oxygen species, secondary products of radioactive decay, is discussed. Probably, the activation effects of alpha- and beta-emoting radionuclides result from ionization of aqueous media followed by the intensification of cellular membrane processes.

# THE IMPACT OF THE EXTRACELLULAR MATRIX PROTEINS ON THE RADIATION-INDUCED DNA DAMAGE RESPONSE

**Stanislav Vasilyev[1], Renata Savchenko[1], Anastasia Murashkina[2], Veniamin Fishman[3], Oleg Serov[3], Igor Lebedev[1]**

1 Research Institute of Medical Genetics, Tomsk National Research Medical Center, Tomsk, Russia
2 National Research Tomsk State University, Tomsk, Russia
3 Institute of Cytology and Genetics SB RAS, Novosibirsk, Russia

An increasing role in the response to DNA damage has been assigned to signaling pathways involving interaction with the extracellular matrix and paracrine signaling. Moreover, some authors even cite studies of the role of the extracellular matrix in the list of key directions determining the future of radiobiology. The important role of the extracellular matrix proteins is indicated also by our preliminary results. The transcriptome-wide analysis carried out in the lymphocytes of individuals with different efficiency of DNA double-strand break repair has shown that the majority of differentially expressed genes are involved in signaling pathways, and not directly in DNA repair. In addition, the identified genes with the most significant differences in expression encode the extracellular matrix proteins thrombospondin-1 and ADAMTS1. This study was aimed to identify the impact of these extracellular matrix proteins on the radiation-induced DNA damage response.

We generated knockout cell lines based on HeLa by frameshift mutations generated by CRISPR/Cas9 system. *THBS1* knockout lead to 1.4-fold decrease of plating efficiency (p=0.0002) and *ADAMTS1* gene knockout lead to 1.9-fold decrease of clonogenic survival after irradiation with 2 Gy of γ-rays (p=0.014). Thus, these genes differentially affect the survival and the ability to colony formation of non-irradiated and irradiated cells. Moreover, the level of spontaneous γH2AX and 53BP1 foci was also increased after *THBS1* knockout (1.3- and 1.9-fold, respectively), which indicate the role of this gene in DNA double-strand break repair. Finally, *THBS1*knockout also significantly increased the levels of histone H3K27 and H3K9 trimethylation (1.8-fold, p=0.003 and 1.2-fold, p=0.005, respectively). Perhaps, thrombospondin can significantly affect radiation-induced transcriptional response. This finding is confirmed by the up-regulation of *RBFOX2* gene after the knockout of both *THBS1* (3.5-fold, p=0.044) and *ADAMTS1* genes (5.2-fold, p=0.008).

Thus, we revealed the genes affecting the efficiency of DNA double-strand break repair and cell survival. This effect can be realized by epigenetic mechanism through a change in the level of H3 histone methylation. In this connection, it is possible that signaling pathways involving the components of the extracellular matrix can play an important role in the mechanisms of cell response to radiation-induced DNA damage and contribute to individual human radiosensitivity.

# *IN VIVO* IRRADIATION HAS EFFECT ON ACTIVATION OF SPLEEN DENDRITIC CELLS IN MICE

**Eszter Persa, Katalin Lumniczky, Geza Safrany**

Public Health Institute Radiobiology, Budapest, Hungary

Mature dendritic cells (DCs) are the most effective antigen presenting cells of the immune system. They have active role in initiating and promoting cellular immune response via T cell – DC interaction and cytokine secretion. The diversity of their cell surface molecules and their cytokine production provide the basis for their activation. DCs can also stimulate anti-tumor immunity by capturing and presenting tumor antigens. Danger signals (e.g. HMGB1) released by dying tumor cells after radiotherapy may facilitate DC activation.

The aim of our studies was to determine the effect of ionizing radiation on phenotypical and functional parameters of DCs relevant in stimulating anti-tumor immune response. By *in vivo* animal studies we would also like to describe the role of irradiation on DCs.

Mice were total-body irradiated with 0 (control), 0.1, 0.25 and 2 Gy X-rays. Spleen cells were isolated 24h after irradiation and DC cell surface markers were analysed by flow cytometry. Expression of costimulatory (CD40, CD80, and CD86), coinhibitory (B7-H1 (PD-L1)), danger responding (TLR-4) and antigen capturing (DEC205) molecules was determined. For testing antigen capture and antigen presentation isolated DCs and FITC labeled OVA peptide were used. The amount of OVA captured by DCs was followed by flow cytometry, as well. DC cytokine expression was measured by real-time qPCR. In *in vivo* studies mice were immunized two times with DCs before tumor delivery and tumor volume was measured every second day.

Our results showed a slight raise in the level of costimulatory molecules CD80 and CD86 after low dose irradiation and significant increase after 2 Gy. Irradiation seemed to have no effect on the expression of CD40 molecules, but level of DEC205 decreased after 0,25 Gy and B7-H1 level increased after higher doses. DCs irradiated with 2 Gy had unchanged ability to capture and present OVA peptids compared to non-irradiated DCs. Evaluation of cytokine gene expression data is in progress. According to animal studies we can state that 2 Gy irradiation has pronounced effect on DCs which manifest on decreased tumor growth.

We showed that 2 Gy irradiation had a massive effect on activation status of DCs appeared in higher expression of costimulatory molecules and increase in their functional abilities. Pronounced activation status can reflect in more effective role of DCs in anti-tumor immune response. In addition, our findings point to a synergistic effect between radio- and immunotherapy.

# RADIATION-INDUCED LONG-TERM CHANGES IN THE NON-PIGMENTED COMPOUNDS IN LEAVES OF *ARABIDOPSIS THALIANA (L.) HEYNH.*

**Sergii Litvinov, Namik Rashydov, Marina Krivohizhaya**

Institute of Cell Biology and Genetic Engineering, National Academy of Sciences of Ukraine, Kiev, Ukraine

The study of long-term effects of radiation on plants involves a comprehensive analysis of qualitative and quantitative structural and metabolic changes that occur over a long period of time after irradiation. 30 days after irradiation of model plants *Arabidopsis thaliana Col-0* in a dose of 21 Gy, which had been shown to be at the lower border of inhibitory doses interval, we observed 1.5-fold decrease in the number of live rosette leaves of irradiated plants compared to the non-irradiated control. In order to analyze the biochemical composition of the leaves, the Fourier-transform infrared spectroscopy (FTIR) was used. The advantages of this method are the speed, simplicity, reliability and reproducibility of the results, the possibility of simultaneous measurement of the content of the most vital biochemical components of cells without violating the integrity of the object.

On the basis of the analysis of the FTIR spectrograms of the lyophilized rosette leaves of Arabidopsis 30 days after irradiation it can be concluded that there are significant changes in the content of polysaccharides, nucleic acids and proteins. In particular, in the leaves of irradiated plants the content of proteins and nucleic acids was greatly reduced, pectin and lignin were replaced by cellulose and hemicellulose, starch was accumulated. The composition of fatty acids in the cutting in the leaves of irradiated plants undergoes certain structural changes, as evidenced by the increase of the ratio of symmetric oscillations / asymmetric oscillations of C-H bond. Also, a slight increase in the ratio of the number of beta-sheets to the number of alpha-helix domains of proteins has been observed.

The biochemical changes can be related to the induction of the biochemical response of plant cells to the stress caused by ionizing radiation, which leads to the degradation of DNA and RNA, modification of the cell wall, accumulation of starch, proteolysis and conformational changes in proteins.

# CIRCULAR RNA CBL.11 MEDIATES THE PROLIFERATION OF COLON CANCER CELLS VIA SPONGING UP MIR-6778-5P AND REGULATING THE YWHAE EXPRESSION

**Hongbin Li, Qiang Li**

Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, China

Noncoding RNAs (ncRNAs) play important roles in several cancer cellular processes. Accumulating evidence indicates that ncRNAs are widely involved in various oncology treatments, providing potential targets for cancer intervention. Radiotherapy is one of the most effective therapeutic strategies for colon cancer patients. However, the expression profile and function of ncRNAs in radiotherapy for human colon cancer remain to be investigated. We performed a comprehensive study of microRNA (miRNA) in human colon cancer HCT116 cells using microarrays, and found that the expression of miR-6778-5p was downregulated in response to carbon ions. Bioinformatic and luciferase reporter analyses showed that YWHAE (14-3-3e), a member of the 14-3-3 protein family, was the direct target of miR-6778-5p, which mediated the function of miR-6778-5p in proliferation of colon cancer cells through inhibiting the activation of p38 MAP kinase. Furthermore, we found that circRNA CBL.11 was significantly up-regulated in HCT116 cells after irradiation, and functioned as an endogenous miR-6778-5p sponge to inhibit the miR-6778-5p activity. Silencing circRNA CBL.11 in HCT116 cells could down-regulate YWHAE, resulting in the inhibition of cell proliferation. In addition, the tumor inhibition effect of circRNA CBL.11 silencing was blocked by miR-6778-5p inhibitor. Taken together, we conclude that circRNA CBL.11 may function as a competing endogenous RNA to regulate the YWHAE expression through sponging up miR-6778-5p and exert regulatory functions for colon cancer. Thus, circRNA CBL.11 might be a potential target for colon cancer radiotherapy.

# THE INFLUENCE OF ACCELERATED 1 MeV ELECTRON BEAM ON MICROBIOLOGICAL PARAMETERS OF CHILLED TROUT

**Ulyana Bliznyuk, Polina Borschegovskaya, Felix Studenikin, Alexander Chernyaev**

Lomonosov Moscow State University, Moscow, Russia

The development of radiation technologies to extend the shelf life of foodstuffs without compromising the quality is one of the areas of researches conducted by Lomonosov MSU Physics Department. Recently our researchers have made experiments involving ionizing radiation to prolong the storage life of fresh fish and meat.

The study illustrates the impact of accelerated electron beams on microbiological parameters of chilled trout. The experiment described in this study was conducted to determine the optimal dose to decrease the development of pathogenic microorganisms and bacteria in trout. Pieces of chilled trout 0.7 cm wide were treated with 1 MeV electrons using Continuous Electron Beam Accelerator with the average beam power of 25 kW. Samples were exposed to radiation at 18 C from both sides to ensure uniform irradiation using 5 different doses.

Further, the irradiated and non-irradiated samples which had been stored at 6 C were monitored on day 3, 6, 9 after irradiation to determine the amount of mesophilic aerobes and facultative anaerobes. To estimate the absorbed ionizing radiation dose in trout computer simulation, was performed using source code GEANT4, taking into account the key parameters of accelerator.

It was determined that the amount of microorganisms and bacteria decreased with the increase of irradiation dose from 20 Gy to 20 kGy. Notably, the content of microorganisms in irradiated samples was considerably lower than in non-irradiated samples with the increase in time between irradiation and post-irradiation monitoring.

# MAGNETIC RESONANCE IMAGING VERSUS CBCT IN DIAGNOSTICS OF TEMPOROMANDIBULAR JOINT INTERNAL DERANGEMENT

**Milica Jeremic Knezevic[1], Aleksandar Knezevic[2], Dubravka Markovic[3], Tatjana Puskar[3], Daniela Djurovic Koprivica[1], Jasmina Boban[4]**

1 University of Novi Sad, Medical Faculty, Department for Dentistry, Novi Sad, Serbia
2 Clinical Center of Vojvodina, Clinic for Rehabilitation; University of Novi Sad, Medical Faculty, Novi Sad
3 Clinic for Dentistry, University of Novi Sad, Medical Faculty, Novi Sad, Serbia
4 Oncology Institute of Vojvodina, Center for Diagnostic Imaging, Sremska Kamenica, Serbia

Temporomandibular joint (TMJ) internal derangement represents abnormal changes of the articular disc position between mandibular condyle and temporal bone glenoid fossa.

Magnetic resonance imaging (MRI) has been considered the standard, non-invasive, diagnostic imaging tool for patients with clinical symptoms of TMJ soft tissues and disc pathology. Nevertheless, osseous structures are best seen on CT. Cone beam CT (CBCT) has a substantially lower radiation dose compared to helical CT and has become the predominant diagnostic approach in TMJ assessment-fractures, congenital, developmental and acquired disorders of TMJ.

Hybrid MRI and CBCT imaging has been recently introduced in assessment of TMJ pathology.

**Key words:** magnetic resonance imaging, cbct, temporomandibular joint, temporomandibular dysfunction

# RADIATION-INDUCED BYSTANDER SIGNALS IN THE BLOOD CAN BE MEDIATED BY EXTRACELLULAR VESICLES

**Tünde Szatmári, Enikő Kis, Eszter Persa,**
**Géza Sáfrány, Katalin Lumniczky**

Public Health Directorate, Division of Radiobiology and Radiohygiene, Budapest, Hungary

**Introduction.** The main systemic effects of radiotherapy in the blood are the inflammatory reactions. Beside direct effects, radiation induced bystander effects (RIBE) are important in generating these reactions. RIBE manifest on cells not directly irradiated, as a consequence of signals received from irradiated cells. They can be mediated also by extracellular vesicles (EV) released in the extracellular medium by the irradiated cells. Here we studied the direct and bystander effects of total body irradiation on blood and the role of EVs in the RIBE.

**Methods.** We irradiated C57BL/6 mice with low or high doses of X-rays (0.1 and 2 Gy). Mice were sacrificed 24 hours later. Blood plasma was isolated and analyzed using a proteome profiler antibody array. EVs were isolated from plasma and bone marrow (BM) supernatant. Total RNA was isolated from EVs and subjected to miRNA profiling and were assessed by bioinformatical tools. We generated bystander animals by intravenously injecting the BM derived EVs into unirradiated mice. We studied the cytokine expression in the plasma of these mice; the effects of EV transfer in bystander mice were compared to effects in the directly irradiated mice.

**Results.** Both irradiation and EV transfer changed the level of plasma proteins. Pentraxin-3 and M-CSF were altered irrespective of the irradiation dose in direct and bystander mice as well. In 2 Gy direct and bystander groups, expression level of 2 further proteins (Lipocalin-2 and CXCL16) changed compared to their sham-treated controls. Two proteins, CCL11 and CCL5 changed only in the bystander animals. In the BM-derived EVs 8 miRNAs were affected by both low and high dose irradiation with predicted involvement in pathways related to DNA damage repair and immune system regulation. In EVs isolated from plasma of irradiated mice 7miRNAs were differentially expressed following low-dose irradiation and 11 after high dose, respectively. Five of these miRNAs were overlapping with miRNAs from EVs from BM. A target prediction and pathway analysis showed that 26 signaling pathways, such as acute myeloid leukemia (AML) and T cell receptor (TCR) signaling were altered by both low and high dose irradiation. Several signaling pathways related to DNA damage repair (TGFβ, FOXO, MAPK) were altered by miRNAs irrespective of the origin (BM or blood) of the EV or irradiation dose.

**Conclusion.** EVs mediated certain radiation induced bystander signals *in vivo* in the blood plasma of bystander mice both in case of low and high-dose irradiation. Total body low dose irradiation has comparable effects on immune and inflammatory markers in the blood with higher doses. EVs are able to transmit bystander effects *in vivo* systemically, by changing the levels cytokines in the recipient mice. We identified potential miRNAs carried by EVs which might participate in mediation of these effects

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# DNA DAMAGE AND REPAIR IN U2OS CELLS EXPOSED TO MIXED BEAMS OF X-RAYS AND ALPHA PARTICLES

**Beata Brzozowska[1], Alice Sollazzo[2], Maciej Gałecki[1], Adrianna Tartas[1], Lei Cheng[2], Lovisa Lundholm[2], Harry Scherthan[3], Andrzej Wojcik[2]**

1 Biomedical Physics Division, Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland

2 Stockholm University, Centre for Radiation Protection Research. Department of Molecular Bioscience, The Wenner-Gren Institute, Stockholm, Sweden

3 Bundeswehr Institute of Radiobiology, Munich, Germany

Radiation induces various DNA lesions but these can be grouped in 3 major categories: base damage (BD), single strand breaks (SSB) and double strand breaks (DSB). These lesions also occur spontaneously, mainly as the result of metabolic processes and oxidative stress. What makes the radiation-induced DNA damage so unique is the spatial distribution. While spontaneously induced lesions are sparsely distributed in the DNA and can be regarded as simple and repairable in an error-free way – radiation deposits energy locally, leading to the formation of complex DNA damage. The complexity of DNA damage increases with ionisation density and this is the reason why alpha particles have a higher biological effectiveness than X-rays. An interesting question is if a combined action of alpha particles and X-rays results in an interaction of lesions leading to increased damage complexity and impaired damage repair. An interaction of the two types of radiations should thus lead to an increase in biological effectiveness of mixed beam, beyond the level expected from additivity.

The goal of this study was to analyse the induction and repair of ionising radiation-induced foci (IRIF) in U2OS osteosarcoma cells exposed to densely ionising alpha particles, sparsely ionising X-rays and a mixed beam of both radiations. The treated cells were transfected with plasmids coding for the DNA repair the protein 53BP1 that are tagged with the green fluorescent protein. Cells were exposed to mixed beams in a dedicated exposure facility built at Stockholm University. The facility is composed of a 50 MBq Am-241 alpha source and an YXLON 200 X-rays source. The alpha source is mounted on an inversed plate in a custom-designed irradiator which is kept inside a 37°C cell incubator. Spatiotemporal dynamics of 53BP1 foci formation and repair were recorded by time-lapse photography and image analysis. The distributions of cell frequencies with the specific size of foci and the size of foci itself were analysed. Moreover, Monte Carlo simulations (the PARTRAC code) were used not only for calculating radiation hits, but also for the biological damage in the DNA in terms of single and double strand breaks.

Exposure to a mixed beam induces complex DNA damage above the level expected from the additive action of both radiations. Clustered DNA damage poses serious problems for the DNA repair and error-prone repair of DNA damage is associated with cancer induction. Increased damage complexity following exposure to mixed beams will suggest a higher than expected risk of cancer induction in modern radiotherapy. The results are consistent with the previous studies carried out at Stockholm University with different cell types and different biological assays. A synergistic interaction of the beam components was observed at the level of micronuclei, gammaH2AX foci and chromosomal aberrations.

# EFFECT OF IRRADIATION WITH GAMMA RAYS ON CHEMOTACTIC RESPONSE AND MOTILITY OF *ESCHERICHIA COLI*

**Kei Wakimura, Mikio Kato**

Biology Laboratory, Faculty of Liberal Arts and Science, Osaka Prefecture University, Sakai, Japan

*Escherichia coli* is a peritrichously flagellated bacterium that can swim in liquid medium by rotating its bundled flagella. As we have shown before, bacterial motility is robust against ionizing radiation. Chemotactic response to a repellent, however, has been lost due to the gamma irradiation. Susceptibility to radiation damage of chemotactic system (sensor-transducer-effector) may relate to the huge complex of chemotactic sensors at the pole of bacterial cell, since the radiation dose causing crucial damage to the proteins can be smaller for larger complex and vice versa. To test the hypothesis, we are examining chemotaxis and motility of *Escherichia coli* mutant strains that lack chemoreceptors, coupler protein, associated kinase, response regulator and motor components, respectively, after gamma irradiation or without gamma irradiation.

# RADIOPROTECTIVE ACTIVITY OF CHITABIS

**Elena Gulik, Nikolayi Kostesha**

Tomsk State University, Tomsk, Russia

The radioprotective effect of low molecular weight chitosan dissolved in an aqueous extract of *Abies sibirica* fir-needles (abisib) – chitabis was studied. Chitabis (5 ml/kg) was administered per os immediately after X-irradiation of experimental rats and then within 10 days. Control animals received distilled water at the same dose. Administration of chitabis increases survival and life expectancy of experimental rats X-irradiated at a dose of $LD_{90/30}$. The radioprotective activity of chitabis was studied by irradiating rats at a dose of 5.5 Gy for two critical systems of the body: hematopoietic and gastrointestinal. The experiment demonstrated a weakening of the degree of leukopenia and a greater degree of preservation of bone marrow cellularity in irradiated animals taking chitabis compared to irradiated rats. On the part of the gastrointestinal tract, the normalizing effect of chitabis on the epithelial mucous layer of the small intestine of irradiated animals is noted, which contributes to the formation of a more resistant to destruction of the mucous layer of the small intestine. We think that the radioprotective activity of the complex chitabis is the result of the synergism of its components – chitosan and abisib.

# MOSAICISM IN CELL OF ATAXIA-TELANGIECTASIA PATIENTS

**Mirya Kuranova[1], Aleksandra Nozdracheva[2], Roman Ushakov[2], Nadezhda Pleskach[1], Irina Spivak[1], Viktor Mikhelson[1]**

1 Insitute of Cytology RAS, Saint Petersburg, Russia
2 Peter the Great St. Petersburg Polytechnic University, Saint Petersburg, Russia

In biological systems mosaicism is not particularly rare, but rather understudied phenomenon, often underestimated by clinicians and biologists. ATM kinase is a key element of a cell response to DNA damage and initiates a repair process in the most severe case of such damage – double-strand DNA break. Ataxia-telangiectasia (AT) or Louis Bar syndrome (OMIM: 208900) is a severe autosomal recessive progeroid disease associated with a high risk of cancerogenesis. It is caused by homozygous or compound heterozygous mutations in ATM gene (607585) (Jaspers et al., 1988). Currently, more than 100 mutations in ATM gene are described (Sandoval et al., 1999; Lee et al., 2013), which consists of 66 exons of approximately 150 thousands bp and encodes ATM kinase (Savitsky et al., 1995; Lavin, Khanna, 1999; Pulvere et al., 2003).

Earlier we have described for the first time a mosaicism in two cell lines of dermal fibroblasts from patients with AT (Kuranova et al., 2014). After 30 minutes of X-ray irradiation with a dose of 2 Gy 24.8% and 31.8% of cells in respective lines showed no ATM kinase activity (an absence of phospho-ATM/Ser1981), while in a control line of a healthy donor 100% of cells showed a presence of phospho-ATM/Ser1981. Recently we have found a third mosaic AT form: after 30 minutes of exposure in 50 and 100 µg/ml of radiomimetic bleomycin there was almost a half of cells without phospho-ATM/Ser1981. After an hour of exposure a percent of cells without phospho-ATM/Ser1981 slightly increased which suggests a severe DNA reparation defect. Protein p53BP1 foci were detected in a majority of cells after 30 minutes and after 1 hour of exposure. Also, distribution of intensity of SIRT6 deacetylase fluorescence showed 2 peaks which may suggest an association between ATM and SIRT6.

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# THE MOBILITY OF 53BP1 DNA DAMAGE FOCI INDUCED BY X-RAYS, ALPHA AND MIXED BEAM RADIATION

**Maciej Gałecki[1], Beata Brzozowska[1], Alice Sollazzo[2], Lei Cheng[2], Lovisa Lundholm[2], Harry Schertan[3], Adrianna Tartas[1], Andrzej Wojcik[2]**

1 Faculty of Physics, University of Warsaw, Warsaw, Poland
2 Department of Molecular Biosciences, Centre for Radiation Protection Research, The Wenner-Gren Institute, Stockholm University, Stockholm, Sweden
3 Bundeswehr Institute of Radiobiology, D-80937 Munich, Germany

Ionising radiation is a unique DNA damaging agent which induces lesions in a strictly controlled manner, both with respect to the duration of damage induction and the transmitted energy. DNA double strand breaks (DSBs) are critical DNA lesions which may lead to gross chromosomal rearrangements, mutations and cell death. During DNA repair histone alterations, nucleosome repositioning and changes in higher-order folding of the chromatin fibre cause significant accumulation of proteins in the lesions areas. These protein clusters form nuclear foci which may be visible by light microscopy.

In this experiment 53BP1 foci were tracked during the live-cell observation to study their mobility which affects the probability of the successful lesion repair. U2OS osteosarcoma cells were irradiated with 1 Gy of alpha particles, 1 Gy of X-rays and a combination of these two: 0.5 Gy of alpha particles and 0.5 Gy of X-rays and were analysed along with control sample. Random walk behaviour of the foci was observed. In order to describe experimentally measured focus mobility several sub-diffusion models were applied and used for a comparison. Additionally, data analysis included two measuring methods. Firstly, the mean square displacement (MSD) was calculated for all foci. Secondly, calculations of the standard deviation of the relative focus distance changes were performed. Using the distance between neighbouring 53BP1 foci allowed to reduce the impact of the cell nucleus movement.

The results of the presented project indicate that the diffusion coefficient changes together with linear energy transfer of the radiation, clearly observed for densely ionising alpha particles and sparsely ionising X-rays. Fitted parameters, which describe focus diffusive motion, are different for different treatments: exposure of X-rays, alpha particles and mixed beams. The mobility of the foci induced by mixed beams seems to be the most limited, since the damage in this case is more complex than for X-ray and alpha particle irradiations given separately.

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# DETERMINATION OF MUTAGENIC EFFECTS AFTER THE EXPOSURE TO RADON IN DWELLINGS ON THE EXAMPLE OF KOWARY (POLAND)

**Katarzyna Walczak, Jerzy Olszewski, Piotr Politański, Marek Zmyślony, Maciej Stępnik**

Nofer Institute of Occupational Medicine, Łódź, Poland

**Introduction:** Breathing the air with radon content can cause damage at the DNA level. The aim of the project was to investigate the induction of mutagenic effects in the human body as a result of long-term exposure to elevated concentrations of radon in dwellings.

**Method:** The blood were collected from inhabitants of Kowary (Poland, Sudety) and the level of damage to genetic material in the peripheral blood lymphocytes was determined using selected biomarkers, such as scoring micronucleus (micronucleus test), single strand breaks (SSB) and double strand breaks (DSB) of DNA (comet test also with analysis of oxidative DNA damage after using the enzyme formamidopyrimidine glycosylase), the detection of DSB of DNA based on the level of H2AX histone phosphorylation, and the concentration of autoantibodies against the P53 protein. All examined people (93 person) were divided into 3 groups according to the radon concentration value in their apartment, respectively <100 Bq/m3 (1st group), 100-300 Bq/m3 (2nd group), and> 300 Bq/m3 (3rd group). Results: Significant dependencies (p<0,05) were found between 1st and 3rd group of radon exposure according to the occurrence of SSB and DSB of DNA measured by comet test, as well as for DSB of DNA based on the level of H2AX histone phosphorylation. When taking values of the biomarkers levels below 1st quartile and above 3rd quartile it turn out that almost all of them are positively significantly correlated (p<0,05) with radon exposure.

**Conclusions:** The findings of this preliminary study indicate that there may be a correlation between long term exposure to domestic radon and mutagenic effects in the human body, represented by various biomarkers level. Because the group of subjects was relatively small, the research should be repeated on a larger number of people.

# THE CHLOROPHYLL PIGMENT MEASUREMENT IN DIFFERENT GENERATIONS AT *PHASEOLUS VULGARIS* MUTANT LINES


**Arjana Ylli[1], Laura Binxhija (Qeska)[1], Erion Ylli[2]**

1 Biotechnology Department, Faculty of Natural Sciences, University of Tirana, Tirana, Albania
2 Biotechnologies – Ingénierie de la Santé et du Médicament UFR de Pharmacie, Université Grenoble Alpes, Grenoble, France



For a long time inducted mutagenesis is considered a precious direction of agriculture to create high quality and sustainable to environmental conditions plant crop. In this study bean seeds of *Phaseolus Vulgaris* were irradiated with gamma rays of Co-60 with three doses 50 Gy, 100 Gy and 150 Gy, and were treated with chemical mutagen EMS also in three different doses 0.5, 0.75 and 1%. The irradiated and chemically treated seeds, based in IAEA protocols, were planted in green house and experimental field. After plant growing, we evaluated that the chlorophyll mutations, according to Gustaffson, have higher frequency in green house plants. In these biological materials the chlorophyll mutations are due to physical and chemical mutagens. The material irradiated at absorbed dose 50 Gy and 100 Gy demonstrated Albine mutations. The most visible forms of mutation in our plants were: Chlorina – some light-colored spots appeared on the leaves as a result of the mutagenic action, and Maculate – which occurs with the destruction of chlorophyll or carotenoids. We observed pigment destruction and therefore the leaf became white in some parts. Xantha – the leaves had become yellow as a result of mutagenic action. At the same time we recorded incidence of mutations in plants treated with EMS in M1. In M2 generation different mutations become visible, transforming the flours color from white to light yellow. Chlorophyll content is an important indicator of plant health condition. The origin of chlorophyll mutations is mainly due to mutations in two genes, which are responsible for the synthesis of photosynthetic pigments. Every week, using a chlorophyll content meter CCM-200 was measured the quantity of the chlorophyll in all treated plants and control.



**Key word:** *Phaseolus Vulgaris*, mutation, gamma radiation, chlorophyll pigment

# DOSE-RATE EFFECT IN RADIATION BIOLOGY: DNA DOUBLE-STRAND BREAKS REPAIR EFFICIENCY

**Andreyan Osipov[1], Dmitry Klokov[2]**

1 State Research Center – Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency (SRC-FMBC), Moscow, Russia
2 Canadian Nuclear Laboratories, Chalk River, Canada

Understanding cellular responses to DNA double-strand breaks formation and repair after a particular radiation exposure mode is an important step towards understanding the potential biological consequences of such exposure. Although repair of radiation-induced DNA double-strand breaks is well studied for acute irradiation, responses to DNA double-strand breaks produced by continuous or chronic exposures to ionizing radiation are not well characterized. Yet, most real-life scenarios of human exposures to low and intermediate doses of radiation include prolonged exposures, lasting from hours to days or even years most of the time, and possible health consequences of such exposures are of great concern. The challenges for such continuous irradiation studies include both technical ones related to irradiation facilities and difficulties in interpreting results. For example, one would need to account for i) two opposite but concurrent processes of accumulation and elimination of DNA damage during exposure, ii) cell cycle redistribution, and iii) cell proliferation during exposure, i.e. a dose is split between mother and daughter cells, etc. Our finding indicate that continuous irradiation of normal human cells (fibroblasts, stem cells) triggers DNA repair responses that are different from those elicited after acute irradiation. During continuous irradiation, accumulation of cells in S/G2 phases and associated activation of homologous recombination DNA DSB repair pathway are observed. The observed activation of the error-free DNA DSB repair pathway suggests compensatory adaptive mechanisms that may help alleviate long-term biological consequences and could potentially be utilized both in radiation protection and medical practices.

# INFLUENCE OF ELECTROMAGNETIC RADIATION FROM A MOBILE PHONE (1745 MHz) ON THE STATE OF THE REPRODUCTIVE SYSTEM OF MALE RATS OF TWO GENERATIONS

**Natalya Chueshova, Grigory Goroch, Igor Cheshik**

Institute of Radiobiology of National Academy of Sciences of Belarus, Gomel, Belarus

**Introduction.** The growing frequency of male sterility assumes significant influence of negative factors of the environment on a condition of reproductive system. Particular attention should be paid to electromagnetic radiation created by means of communications in the decimeter range, including widespread standards of cellular communication.

**Aim.** Research of effects in the reproductive system of male rats and in the resulting offspring when exposed to electromagnetic radiation from a cellular phone.

**Objective.** White rats from the age of 52-54 days were exposed to electromagnetic radiation from mobile phone (EMR MP, 1745 MHz, 8 hours/day by fractions of 30 minutes with an interval of 5 minutes, power density 0.2-20 μW/cm$^2$, = 7.5±0.34 μW/cm$^2$) for 90 days. The irradiated males and females were then mated in a 1:2 ratios. Females throughout the entire period of pregnancy (20-21 days) and the posterity ($F_1$) received from them continued to be irradiated at the above-stated mode before achievement of age of 6 months.

**Methods.** The number of born animals was recorded and their general biological indicators (weight, sex) were evaluated at the age of 1 month. The condition of the reproductive system of male parents ($F_0$) was evaluated on the 1$^{st}$ day after the irradiation stopped, and in $F_1$ – at the age of 2, 4 and 6 months. Absolute and relative masses of testes, epididymis and seminal vesicles were determined, and the number of spermatogenic cells of different stages of differentiation was evaluated. The number was counted and the viability of epididymal spermatozoa was determined. The concentration of testosterone in blood serum was measured. When comparing groups, the Mann-Whitney test was used. Differences were considered significant at $p < 0.05$.

**Results.** The effect of EMR MP on the body of male rats $F_0$ for 90 days did not cause significant changes in the weight of the organs of the reproductive system and the composition of spermatogenic cells, but resulted in a decrease in the number and viability of spermatozoa, as well as a slight (by 12.5%) drop in concentration of testosterone in blood serum.

Exposure of animals $F_0$ in the field EMR from MP was reflected in the size of the litter, which was 53.6% compared to the control. At the same time, in the group of irradiated animals, the 2 females did not give posterity.

Male $F_1$ rats showed significant abnormalities in the reproductive system. This was expressed in a decrease in the weight of seminal vesicles in animals at 2 months of age, in violation of individual stages in the process of spermatogenesis, more pronounced for animals of 4 and 6 months of age, in reducing the number of spermatozoa in 2 and 6 months and their viability at 2 and 4 months of age. A significant decrease in concentration of testosterone in blood serum in F1 animals at the age of 2 and 4 months (25.9 and 44.9% of control) indicates about violation of the work of Leydig cells.

**Conclusion.** The obtained data make it possible to consider that EMR MP should be considered as a significant negative factor for the male reproductive system in the period of its formation

# Radiochemistry 02

# EFFECT OF IONIZING RADIATION FIELD ON CSI AEROSOLS FORMED BY CONDENSATION OF SUPERSATURATED VAPOR

**Sergey Kulyukhin[1], Igor Melikhov[2], Viktor Lavrikov[2], Vladimir Kulemin[2], Vladimir Krapukhin[2]**

1 Frumkin Institute of Physical Chemistry and Electrochemistry RAS, Moscow, Russia
2 IPCE RAS, Moscow, Russia

During a hypothetic severe accident involving the coolant loss, heating of fuel elements and subsequent destruction of their cladding at temperatures exceeding 1100°C the formation and subsequent growth of Cs aerosols occur in a water vapor–air medium in a strong ionizing radiation field. Despite urgency and importance of this problem, published data on this subject are extremely scarce. In this study we examined the properties of CsI radioaerosols formed by condensation of unsaturated vapor in an ionizing radiation field.

The effect of the ionizing radiation field on the behavior of CsI aerosols formed by condensation of supersaturated vapor was examined. Supersaturated CsI vapor was formed by evaporation from a metal surface ohmically heated to high temperatures. The CsI sublimation time at a heater temperature of (800 ± 50)°C at the minimal current passed through the heater was about 15 min at a current of 10–20 A. The radiation field in the chamber was made with a GUG-120 γ-ray installation consisting of 80 $^{60}$Co ionizing radiation sources of type GIK-7-4 with a total activity of 0.065 MCi. In the ionizing radiation field produced by the GUG-120 γ-ray installation, the flux of γ-quanta per aerosol particle was $(5–8)\cdot10^{14}$ s$^{-1}$. Similar experiments were performed on a stationary electron beam from U-12F (mean current 1000 μA, electron energy $E$ = 4.0 MeV) and U-003 (mean current 150 μA, electron energy $E$ = 4.5 MeV) accelerators. In both cases, the absorbed dose was 9 kGy. In the 4–4.5-MeV electron field produced by U-12F and U-003 electron accelerators, the electron flux per aerosol particle was $2\cdot10^{13}–10^{14}$ s$^{-1}$.

A study of the size distribution function of CsI particles showed that, both in the field of $^{60}$Co γ-radiation and in a stationary electron beam, three modes of particle size are observed with the mean sizes of 0.13, 0.57, and 0.76 μm. The amount of particles of size 0.13 μm is larger by a factor of ~10–20 than the amount of particles of sizes 0.57 and 0.76 μm. Comparison of the distribution functions of CsI aerosol particles formed by supersaturated vapor condensation in an ionizing radiation field and without it showed that the ionizing radiation affected not only the size but also the amount of particles. The mean size of the particles of the first mode increased from 0.006 to 0.13 μm (by a factor of more than 20), but their number decreased. At the same time, for the second and third modes, the particle size decreased with a simultaneous increase in their relative amount. The particle size decreased from 2.5 to 0.57 μm for the second mode and from 125 to 0.76 μm for the third mode. It should be noted that, in the ionizing radiation field, the particle size practically does not exceed 1.0 μm. That is, under the action of the ionizing radiation, not only the CsI particle sizes become closer, but also the particles of size in the range 0.1–1.0 μm are stabilized.

# APPLICATION OF MICROWAVE RADIATION FOR THE DECOMPOSITION OF URANYL NITRATE IN THE SILICA GEL MATRIX

**Sergey Kulyukhin[1], Vladimir Kulemin[2], Vladimir Krapukhin[2], Elena Krasavina[2], Margarita Gorbacheva[2], Igor Rumer[2]**

1 Frumkin Institute of Physical Chemistry and Electrochemistry RAS, Moscow, Russia
2 IPCE RAS, Moscow, Russia

Decomposition of aqueous solutions of uranyl nitrate in a matrix of granulated silica gel (KSKG grade) under the action of microwave radiation (MWR) was studied. Microwave irradiation leads not only to formation of solid decomposition products $UO_3$, $UO_2(OH)NO_3$, and their hydrates in pores of KSKG granules, but also to accumulation of gaseous $NO_x$ and $H_2O$. The presence of $NO_x$ in KSKG pores leads to $HNO_3$ formation in the course of washing of sorbent granules with water. This prevents hydrolysis of uranyl nitrate and formation of $UO_2(OH)_2{\cdot}H_2O$ in KSKG pores. Washout of uranium with water and $HClO_4$ solutions from the KSKG fraction containing products of decomposition of 2 and 10 g of the initial $UO_2(NO_3)_2{\cdot}6H_2O$ under the action of MWR (hereinafter denoted as KSKG-P-I) was studied. Upon about 7-day contact of the solid and liquid phases at the total ratio S : L = 1 : 20, from 5 to 14% of U passes into the aqueous phase from KSKG-P-I samples obtained in experiments with 10 and 2 g of $UO_2(NO_3)_2{\cdot}6H_2O$, respectively. In the course of repeated treatments of KSKG-P-I with water, pH of the wash water increased from 3 to 6, owing to removal of $NO_x$ from KSKG pores. Then an insoluble phase of uranyl hydroxide $UO_2(OH)_2{\cdot}H_2O$, which can also be presented as hydroxylated uranium trioxide $UO_3{\cdot}2H_2O$, is gradually formed from the solution obtained by treatment of KSKG-P-I with water. On treatment of KSKG-P-I with $HClO_4$ solutions (pH 1–2), virtually all uranium species formed by MWR treatment of aqueous uranyl nitrate solutions in KSKG matrix dissolve (at a contact time of the solid and liquid phases of about 21 days, the amount of U that passed into $HClO_4$ solutions is about 90%). The amount of the U form that is not extracted with $HClO_4$ solutions and remains in KSKG granules is about 12% of its initial amount. X-ray phase analysis suggests that the uranium species remaining in KSKG are silicate compounds formed by sorbent saturation with a uranyl nitrate solution and subsequent MWR treatment.

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# CORRELATION BETWEEN INCREASED $^{226}Ra$ AND $^{228}Ra$ ACTIVITY CONCENTRATION AND CHEMICAL COMPOSITION AND CHEMICAL TYPE OF GROUNDWATERS

**Agata Kowalska**

Wroclaw University of Science and Technology, Wroclaw, Poland

So far, there is no comprehensive research on the relationship between the physical and chemical properties and the increased activity concentrations of radium isotopes in groundwaters. The author has done a number of analysis to observe the behaviour of radium isotopes in the groundwater environment.

The purpose of the research was to study the relationship between the chemical composition, physical and chemical properties of groundwater and the content of dissolved two major radium isotopes: $^{226}Ra$ and $^{228}Ra$.

To achieve the intended aim 72 groundwaters samples were investigated: mineral waters, reservoir waters or potentially therapeutic waters. Comprehensive analysis of chemical composition and also physical and chemical properties of groundwaters allowed to determine their chemical types. To measure $^{226}Ra$ and $^{228}Ra$ activity concentration author used the method based on precipitation of radium-barium sulphate and using liquid scintillation counting (LSC).

The study has shown the behaviour of radium isotopes in the groundwater environment. The concentration of $^{226}Ra$ and $^{228}Ra$ increases with the increase of the total dissolved solids (TDS). Increased TDS values correspond to different chemical components. Most strongly correlated with the content of $^{226}Ra$ and $^{228}Ra$ were such components: $Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $NH_4^{+}$, $Sr^{2+}$, $Cl^{-}$, $F^{-}$, Br-, metaboric acid and also $Na^{+}$, $Mn^{2+}$ and $Li^{+}$. Due to the precipitation of radium-barium sulphate on the flow of groundwater, no correlation between the $Ba^{2+}$ and $SO_4^{2-}$and radium isotopes activity was found.

The highest values of $^{226}Ra$ and $^{228}Ra$ activity concentrations were recorded in the following chemical water types: Cl-Mg-Na, Cl-Na-Ca, Cl-Na and also in fluoride, iodine and ferric waters, and those containing more than one of these specific component.

In most waters with increased activity concentrations of $^{226}Ra$ and $^{228}Ra$, negative redox potential values were measured (reducing conditions) and such waters could be deep circulation waters. No correlation between $^{226}Ra$ and $^{228}Ra$ and the radon ($^{222}Rn$) activity concentration in shallow circulation waters was found.

All the relationships between concentrations of $^{226}Ra$ and $^{228}Ra$ and the concentration of individual chemical components or values of physical and chemical parameters found during this study are universal.

Most of the studied groundwaters are mineral or reservoir waters, some of them also could be potentially therapeutic. The determination of $^{226}Ra$ and $^{228}Ra$ activity concentration is important investigation due to its strong radioactive properties because the use of these waters could be limited. The knowledge about the values of radium isotopes activity concentrations and its behaviour in the environment could also be useful in planning the use of these waters.

# DETERMINATION OF CARBON-14 AND TRITIUM IN IRRADIATED REACTOR GRAPHITE

**Iurii Simirskii, Alexey Stepanov, Ilia Semin, Anatoly Volkovich**

NRC “Kurchatov Institute”, Moscow, Russia

The irradiated reactor graphite is significant part of solid radioactive waste of the nuclear industry. Activation of impurities and formation of radionuclides with various half-lives take place in the reactor graphite during continuous irradiation by neutrons. Special attention is paid to long-lived β-emitting radionuclide $^{14}C$ ($T_{1/2}$ = 5730 years) and biologically active beta-emitting radionuclide tritium ($T_{1/2}$ =12.3 years).

The method based on oxidation of graphite in oxygen flow was used for the determination of $^{14}C$ in irradiated graphite. The sample of graphite 0.2-1.0 g was burned in oxygen flow at temperature of 850 -900 $^{0}C$. Formed $^{14}CO_2$ and HTO were collected into two consecutive trap flasks filled by 10% NaOH solution. It was found 90-95% $^{14}CO_2$ and 100% HTO were accumulated in the first trap flask. The concentrations of $^{14}C$ and $^{3}H$ were determined by liquid scintillation spectrometry. Simultaneous determination of $^{14}C$ and $^{3}H$ was possible when their concentrations were closed. In other cases concentration of $^{3}H$ was determined after its separation by distillation. Visual control of the process finish and separation of $^{14}C$ from $^{137}Cs$ and $^{90}Sr$ which interferes its determination was possible using this method. The good convergence of the results was obtained.

The method was used to analyze the irradiated graphite samples from research reactor RFT (NRC “Kurchatov Institute”) and RBMK Leningrad nuclear power plant. The concentrations of $^{14}C$ and $^{3}H$ in the irradiated graphite of reactor RFT were insignificant excepting the active zone. In the active zone the concentrations of $^{14}C$ and $^{3}H$ were increased by more than 2 orders of magnitude up to $10^{7}$Bq/kg confirmed their activation nature. The radionuclide $^{14}C$ was the main pollutant of the irradiated graphite at the RBMK Leningrad NPP. At the same time the fission products $^{137}Cs$ and $^{90}Sr$ made significant contribution to the irradiated graphite pollution.

# PHOTOCHEMISTRY OF HEXACHLOROPLATINATE (IV) IN ORGANIC SOLVENTS

**Svetlana Matveeva[1], Evgeni Glebov[1], Ivan Pozdnyakov[1], Alexey Melnikov[2]**

1 Voevodsky Institute of Chemical Kinetics and Combustion, Novosibirsk, Russia
2 Institute of Spectroscopy, Moscow, Russia

Nowadays, photochemical studies of platinum metal complexes are due to a numbers of practical tasks.

For example, their use in photocatalysis is widely known to expand the semiconductor absorbance spectrum into the visible spectral range by modifying surfaces with metallic platinum through the photoreduction of hexachloroplatinate. In addition, to obtain platinum nanoparticles is a promising four-electron photoreduction of Pt(IV).

It should be noted that the photochemistry of platinum metal complexes has not been fully investigated. Questions of fundamental photochemistry in many cases remain undeveloped, even at the level of integrated characteristics of processes (determination of the final products of photolysis and quantum yields of their formation). Meanwhile, even in the presence of this information, it is insufficient to determine the mechanisms of photochemical reactions. It is necessary to look inside the photochemical process, allowing to register the intermediate products of photolysis and to determine the constants of elementary reactions with their participation. Only such information allows us to get a complete picture of the processes. Ideally, a complete description of the photochemistry of the process should include the entire time range, from absorption of the light quantum to the formation of the final products of photolysis. The present work is devoted to detail study of the complete mechanism of photoconversion of hexachloroplatinate(IV) in acetonitrile, methanol and chloroform by ultrafast kinetic spectroscopy (with a 100 fs time resolution), nanosecond laser flash photolysis and stationary photolysis.

It was found that the photosolvation of $PtCl_6^{2-}$ in acetonitrile is a chain photochemical process. As a result of intraspheric electron transfer an intermediate with a lifetime of about 200 ps is formed, interpreted as the primary Adamson radical pair [$Pt^{III}Cl_5^{2-}(C_{4v})$... $Cl^{\bullet}$], which in turn transfers the electron from the solvent. As a result, two successive intermediates, $Pt^{III}Cl_5^{2-}(C_{4V})$ and $Pt^{III}Cl_4^{-}$ are formed. Complex $Pt^{III}Cl_4^{-}$ is the carrier of the chain in the process of photosolvation.

For the $PtCl_6^{2-}$ complex in methanol, the quantum yields of parallel photosolvation and photo-reduction reactions were measured and the absence of chain processes assumed in the literature was shown.

In the case of chloroform complicated mechanism was proposed. Within the framework of this mechanism, photosolvation occurs by the formation of $(n\text{-}Bu_4N)Pt^{IV}Cl_5(CHCl_3)$ and photo-reduction with the formation of $(n\text{-}Bu_4N)Pt^{II}Cl_3$.

The results obtained apparently exhaust the experimental stage of the study of the photochemistry of these systems. The question of proving the structures of the proposed short-lived intermediates comes to the fore.

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# APIGENIN AND APIGETRIN STABILITY TO UV-IRRADIATION TREATMENT IN METHANOL SOLUTIONS

**Aleksandar Lazarević, Sanja Petrović, Jelena Stanojević, Dragan Cvetković, Ljiljana Stanojević, Jelena Zvezdanović**

University of Nis, Faculty of Technology Leskovac, Leskovac, Serbia

Flavonoids are a family of polyphenolic compounds synthesized by plants with a similar structure. They are benzo-*γ*-pyrane derivatives consisting of pyrane and phenolic rings. Some of the most abundant and most studied flavonoids are 4',5,7-trihydroxyflavones, such as apigenin and its derivate apigenin-7-*O*-glucoside, also known as apigetrin. Apigenin and apigetrin are mainly found in a variety of vegetables and fruits. Several beneficial properties attributed to apigenin and its derivate were antioxidant, anti-inflammatory, anti-carcinogenic effects and potential radioprotective effects. On the other hand, plants generally respond to the increase of UV-radiation part in natural sunlight through different mechanisms, including the synthesis of UV-absorbing protective pigments – flavonoids. Flavonoids are believed to be responsible for prevention of extended UV radiation-induced damage to a variety of plants. The aim of this work was to examine UV-irradiation effects to two chosen flavonoids, apigenin and apigetrin, keeping in mind their high absorption ability in where used UV-irradiation ranges and possibilities of their application as UV-protecting pigments.

The stability of apigenin and apigetrin during UV-A and UV-B irradiation treatments in the methanol solutions, have been studied by HPLC-chromatography and absorption UV-VIS spectroscopy. Continuous irradiation of apigenin and apigetrin solutions was performed in cylindrical photochemical reactor "Rayonnet" equipped by 10 symmetrically placed Hg-lamps, with emission maxima in two different UV sub-ranges, UV-A (350 nm) and UV-B (300 nm) and total measured energy flux 12.9 W $m^{-2}$ and 15 W $m^{-2}$, respectively. The samples were irradiated in quartz cells placed on a circular rotating holder at 10 cm distance. Absorption UV-VIS and HPLC analyses were done on a Varian Cary-100 spectrophotometer and Agilent 1100 Series system, before and after irradiation treatments.

According to obtained results, apigenin and apigetrin are shown high stability to continual UV-A and -B irradiation in methanol: it is very difficult to degrade them. Even after 2 h of irradiation with UV-A or UV-B lamps, the absorption spectra, as well the corresponding peak areas (in the chromatograms) of apigenin and apigetrin were not significantly changed. However apigetrin was more stable in comparasion to apigenin at both UV irradiation treatments, probably due to only one structural difference at C-7 atom (7-*O*-glucoside mojety in the apigetrin structure). In addition, the influence of UV-photon energy input was clearly detected: both compounds were more stable against UV-A irradiation in comparison to more energetic UV-B. Apigenin and apigetrin high stability can be related to their absorption properties: both of them absorb UV light in examined ranges, UV-A and -B; it is also known one of their safe dissipation pathways through the heat. Finally, the results implicated great possibility of apigenin and apigetrin application as UV-protective compounds in the skin-care formulations.

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# SORPTION REMOVAL OF $Sr^{2+}$ AND $Y^{3+}$ IONS FROM AQUEOUS SOLUTIONS BY A $TiO_2$-BASED SORBENTS

**Hanna Vasylyeva[1], Ivan Myroniuk[2]**

1 Uzhgorod National University, Uzhgorod, Ukraine
2 Vasyl Stefanyk Precarpatian National University, Ivano-Frankivs'k, Ukraine

Sorption extraction of 90-Sr is widely research. Much less researches are devoted to 90-Y (daughter radionuclide of 90-Sr). In present work the sorption removal of $Sr^{2+}$ and $Y^{3+}$ ions from aqueous solutions by $TiO_2$ – based sorbents were investigate. The dependence of sorption process on the time interval of interaction between solution and sorbent was measured. Four simplified kinetic models: Lagergren pseudo-first, pseudo-second order; diffusion and Elovich models were tested to describe the adsorption process. The adsorption of these elements has been investigate as a function of pH and initial concentrations of Sr and Y. Equilibrium isoterms data were analysed using Langmuir and Freundlich isoterm models. It was sown, that this sorbent can be used for sorption removal of both Sr and Y, more over, the rate of Yttrium's sorption is bigger.

# $Cu(OTf)_2$ AND $Cu(OTf)_2(Py)_4$ PROMOTED RADIOFLUORINATION OF BENZOYL AND PHTHALOYL GLYCINATES

**David Blevins, Dustin Osborne, George Kabalka, Murthy Akula**

The University of Tennessee, Knoxville, United States

Positron Emission Tomography is a non-invasive imaging modality that provides in vivo physicochemical and pharmacokinetic information. PET provides the biodistribution of molecular probes that are labeled with positron emitting nuclides. Also, PET is currently used to detect cancers, cadiovascular diseases and neurological disorders. Of various short-lived positron emitting isotopes, the most favourable is fluorine-18 as it has low energy, longer half-life (109.6 min) and its easy availability in "no-carrier-added" form. During the past decade, various transition-metal-mediated (Ag, Pd, Ni, Cu) fluorination methods have been transformed to radiochemistry. Among these Cu-promoted fluorination is very versatile (Cu is less toxic compared to Pd, Ni) to prepare F-18 fluorinated aromatics and hetero-aromatics. It is reported that aromatic boronate esters are readily radiofluorinated with $K_{222}/K_2CO_3/[^{18}F]$fluoride using 10 mol % $Cu(OTf)_2(Py)_4$. Attempted fluorination of phenylpiracetam boronate ester did not provide the rquisite fluorinated phenylpiracetam. Piracetam has glycinate [>$NCH_2COOEt$] like motif and it is known in the literature that both benzoyl and phthaloyl glycinates form complexes with transition metals such as (Fe, Co, Ni, and Cu). Aryl boronate esters of these two glycinates also did not yield the corresponding fluorides. However, the addition of $Cu(OTf)_2$ to the reaction mixture resulted in the fluorinated products. Aryl boronates of benzoyl and phthaloyl glycinates were prepared from the corresponding chlorides by using pinacalatodiboron, $Pd(OAc)_2$ and Gorlos-Phos-HBF4. These boronate esters were successfully radiofluorinated by varying amounts of copper triflate and 10 mol % of $Cu(OTf)_2(Py)_4$. The highest yields of the fluorinated products were observed using 1 mol equivalent of copper triflate. The influence of copper triflate on radiofluorination of boronate esters of glycinates will be presented in detail.

# ASSESSMENT OF RADIONUCLIDE RATIOS IN SOIL SAMPLES

**Krystle Bartholomew, Claudia Landstetter, Viktoria Damberger, Bernd Hiegesberger, Martin Korner**

AGES – Austrian Agency for Health and Food Safety Ltd., Vienna, Austria

In case of radioactive release nuclides are found in a certain ratio. The determination of this ratio, the so called nuclide vector, provides information for nuclear forensics to find e.g. the origin of the nuclear material. Furthermore, the nuclide vector can be applied for decommissioning projects. For example, an easily detectable nuclide will be measured. Then the nuclide vector is used to estimate activity of the radioactive elements, which would otherwise be determined by expensive and time consuming radiochemical separation. Therefore, analytic costs decrease and the classification of the material is quicker.

The presentation will provide a method for investigation of soil samples. The method includes gamma-spectrometry of Am-241 and the determination of Pu-238, Pu-239, Pu-240, and Pu-241 in the same sample. Measuring all plutonium isotopes requires alpha-/beta-counting as well as ICP-MS measurement. Therefore, samples had to be chemically digested. To optimize yield of decomposition, different acid systems and sequential digestion were used. For yield estimation the residue was analyzed by gamma-spectrometry for remaining Am-241. Chemical separation was performed by Dowex®1X8 resin and DGA®resin, since Am-241 was additionally measured via alpha-spectrometry for estimation of decomposition yield. Alpha-spectrometry source preparation was performed by micro-precipitation as $NdF_3$. Pu-239 was detected by ICP-MS measurement, Pu-241 was detected by beta-counting liquid scintillation measurement from the alpha-spec. source. The presentation will also show the challenges and issues of sampling, sample preparation as well as loss of yield. On the basis of the achieved values by different methods and their chemical yield, an optimized method has been developed.

# ISOLPHARM: NEW ISOL-PRODUCTION METHOD OF HIGH SPECIFIC ACTIVITY BETA-EMITTING RADIONUCLIDES AS RADIOPHARMACEUTICAL PRECURSORS

**Stefano Corradetti[1], Matteo Ferrari[2], Francesca Borgna[1], Michele Ballan[1], Alberto Monetti[1], Massimo Rossignoli[1], Mattia Manzolaro[1], Daniele Scarpa[1], Gianfranco Prete[1], Alberto Andrighetto[1]**

1 INFN-LNL, Legnaro, Italy

2 Department of Mechanical and Industrial Engineering, University of Brescia, Brescia, Italy

At INFN-LNL (Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Legnaro) a new facility for the production of radioactive ion beams is implemented, SPES (Selective Production of Exotic Species). Radioactive ion beams of neutron-rich nuclei with high purity, in the range of mass between 80 and 160 amu, will be produced.

The radioactive isotopes will be obtained by 40 MeV protons, accelerated by a cyclotron, that will collide on a target of uranium carbide (238U), producing nuclides of elements having an atomic number between 28 and 57.

The core of the ISOL method, adopted in the ISOLPHARM project, is the possibility to obtain pure isobaric beams for radiopharmaceuticals applications. In this way, no isotopic contaminations will be present in the beam and in a properly designed ion collector. Only potential isobaric contaminations can affect radiochemical and radionuclide purity, but proper methods can be developed to separate chemically different elements.

The goal of the ISOLPHARM project is to provide a feasibility study for an innovative technology for the production of extremely very high specific activity beta emitting radionuclides as radiopharmaceutical precursors. This new technique will allow to obtain radiopharmaceuticals, impossible in most cases to obtain in the standard production facilities, with lower costs with respect to traditional techniques and reduced environmental impact. The ground-breaking idea of the ISOLPHARM method was granted an International patent (INFN).

# ADSORPTION OF Cs-137 ON ALKALI-ACTIVATED SLAG AND FLY ASH BASED SORBENTS

**Andrzej Gasiorowski, Piotr Szajerski**

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

Cs-137 and Cs-134 are fission products generated in light water nuclear reactors in highest amounts and of highest importance. Radiological hazard from caesium isotopes comes mainly from Cs-137 radionuclide due to its relatively long half-life of 30.17 years and efficient gamma emission rate. Thus it is important to elaborate new efficient methods which allow for effective separation of caesium ions from radioactive effluents and for further stabilization of these species in solid state forms.

The main objective of this study was the verification of adsorption properties of alkali-modified slag and fly ash towards caesium ions.

Preparation steps of slag and fly ash based sorbents were carried out by drying solid materials in 105°C for 24 h followed by grinding in rotary ball mill. Grinded materials were placed in round bottom flask equipped with condenser and modified with concentrated NaOH during 1 – 20 h.

Absorption process was carried out by contact method, with constant ratio of solid state to liquid 1/10 (w/v) and at various ionic strength conditions mimic real effluents processing conditions. Adsorption kinetics studies were performed during 24 h. Equilibrium activity of Cs-137 tracer was detected using gamma spectrometry detection system equipped with 3” NaI(Tl) detector (Flir Scintispec).

Our results clearly indicate that alkaline modification significantly improves caesium adsorption efficiency, both in case of fly ash, as well as slag based sorbents. Even samples modified only during 1 h, exhibits much better performance than raw, unmodified materials. For modified slags, modification time has moderate influence on adsorption properties of the final material.

In order to examine adsorption properties of alkali-modified sorbents in various ionic strength conditions Cs-137 tracer was contacted with sorbents in solutions of varying concentration of $NaNO_3$ from $10^{-3}$ to 1 M. For the modified slag Cs-137 distribution coefficient was as high as 160 (unmodified material up to 1.4), whereas for fly ash up to 144 (unmodified material up to 0.8). Results indicate that even in high ionic strength conditions adsorption efficiency of alkali-modified materials allow for practical application of these sorbents for technical purposes towards Cs-137 and its adsorption from technological effluents generated in nuclear industry.

# SEQUENTIAL DETERMINATION OF $^{90}$Sr AND $^{210}$Pb IN BONE SAMPLES USING MOLECULAR RECOGNITION TECHNOLOGY PRODUCT AnaLig® Sr-01

**Silvia Dulanská[1], Michaela Štofaníková[1], Ľubomír Mátel[1], Marijana Nodilo[2], Ivana Coha[2], Željko Grahek[2]**

1 Comenius University, Bratislava, Slovakia
2 Ruđer Bošković Institute, Zagreb, Croatia

A new sequential method employing molecular recognition technology product AnaLig®Sr-01 gel which is commercially available from IBC's Technologies Inc. for determination of $^{90}$Sr and $^{210}$Pb in samples of bones. 10 g of bone ash was used for $^{210}$Pb and $^{90}$Sr analysis. The use and effectiveness of AnaLig®Sr-01 gel was successfully checked by analysing of certified reference animal bone material, supplied by *International Atomic Energy Agency* (IAEA A-12) and $^{210}$Pb reference sample and reliable results have been obtained. The activity concentrations of $^{90}$Sr and $^{210}$Pb were determined in bones of wild boars and goats from different regions of Slovakia and Croatia.

# PRODUCTION OF MEDICAL RADIONUCLIDE $^{131}$I ON PRESSURE-TUBE POWER REACTOR

**Oleg Yu. Kochnov, Natalia V. Zorina**

Karpov Institute of Physical Chemistry, Obninsk, Russia

**Introduction.** Nowadays radiopharmaceuticals based on $^{131}$I are widespread in cancer theranostics. This radionuclide is usually produced by irradiating $^{130}$Te with thermal neutrons in irradiation facilities of research reactors.

**Objectives.** To increase the production of medical radioisotope $^{131}$I it is proposed to use pressure-tube power reactors. A reactor of RBMK-1000 type besides power channels also has other technological channels. The irradiation device was developed to be placed in a reserve channel of the reactor control and protection system outside the reactor core. At Karpov Institute of Physical Chemistry, we have developed a target with $^{130}$Te to be used with this irradiation device.

In 2017, successful tests were performed on RBMK-1000 reactor of the Leningrad Nuclear Power Plant (Sosnovy bor town, Russia) in accordance with the developed scheme. The test batches of $^{131}$I confirmed high quality of the product. At the present time, the concept of medical radionuclides production on RBMK-1000 reactor of Smolensk Nuclear Power Plant (Desnogorsk, Russia) is being worked out.

**Conclusion.** Reactors of RBMK-1000 type can be successfully used for manufacturing of medical radionuclides as a by-product during electric power generation. At the present time the construction which allows increasing radionuclide activity by several times is in works.

RAD2018

# Radiation Chemistry

03

# IRRADIATION OF CYTOSINE ADSORBED IN A CLAY MINERAL

**Alejandro Paredes-Arriaga[1,2], Adriana Melendez-Lopez[1,3], Sergio Ramos-Bernal[1], Alejandro Heredia[1], Alicia Negron-Mendoza[1]**

1 Instituto de CienciasNucleares, Universidad Nacional Autonoma de Mexico (UNAM), Mexico CDMX, Mexico
2 Facultad de Ciencias, UNAM, Mexico CDMX, Mexico
3 Posgrado en Ciencias Quimicas, UNAM, Mexico CDMX, Mexico

Chemical evolution is the process through which simple compounds generate organic compounds that are essential for the development of life. The study of chemical evolution provides insights into the steps that preceded the appearance of life. A critical factor in chemical evolution is related to the chemical stability of the compounds formed by abiotic processes. In this context, the study of the stability of cytosine in an aqueous solution exposed to a high radiation field while it is adsorbed onto clay mineral was studied. Cytosine is an important compound in chemical evolution studies due to its participation in biological systems as the nucleic acids. Several mechanisms should have been present both to form molecules and to endure them in the environment. Mineral surfaces may have been one of those protective mechanisms. The results showed that clay protects from the radiation to the cytosine molecules and that this protection was extended to molecules in the surrounding environment. In this regard, it is proposed that the participation of clays in preserving important molecules was crucial to the formation of more complex molecules.

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# THE GAMMA RADIOLYSIS OF ALDEHYDES OF BIOLOGICAL IMPORTANCE IN AQUEOUS SOLUTIONS

**Anayelly Lopez-Islas[1,2], Claudio Fuentes-Carreon[1,3], Jorge Cruz-Castañeda[1,4], Alejandro Heredia[1], Sergio Ramos-Bernal[1], Alicia Negron-Mendoza[1]**

1 Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, UNAM, Mexico CDMX, Mexico
2 Posgrado en Ciencias Biológicas, UNAM, Mexico CDMX, Mexico
3 Facultad de Ciencias, UNAM, Mexico CDMX, Mexico
4 Posgrado en Ciencias Químicas, UNAM, Mexico CDMX, Mexico

The steady-state γ-radiolysis of aqueous solutions containing aldehydes of biological importance has been studied at a 25°C and an initial pH of 6. Experiments were conducted in Ar-purged aqueous solutions, or in $N_2O$-purged. The decomposition and radiolytic products were analyzed as a function of irradiation dose and temperature.

The analysis of these systems was performed by UV spectroscopy and liquid chromatography (HPLC), HPLC-coupled to a mass spectroscopy, gas chromatography (GC) and GC coupled to a mass detector.

The initial step for the radiolytic decomposition of formaldehyde, glycolaldehyde, and glyceraldehyde are abstraction reactions of the target compound by OH, from the radical formed by the γ-radiolysis of water. The formed radical decomposes in a series of smaller oxidation products. The formation of organic acids, and eventually $CO_2$, reduce the pH of the solution in some of the studied compounds. Many compounds are formed as result of the irradiation, although in low yields.

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# Radiation Physics

# 04

# MONTE-CARLO SIMULATION OF BACKGROUND COMPONENTS FOR SHIELDED HPGe DETECTOR

**Dusan Mrdja, Kristina Bikit-Šreder, Istvan Bikit, Jaroslav Slivka, Sofija Forkapic**

Department of Physics, Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

The events contributing to the background spectrum of high-purity germanium detectors have various origin: cosmic-ray induced processes (interaction of muons with passive shield of detector, as well as interactions of cosmic neutrons with detector active volume), radioactive decay of terrestrial radionuclides in detector shield surroundings (natural radioactivity of laboratory walls) and radioimpurities within material of shield itself. In this work we simulated first the background spectrum of unshielded HPGe detector positioned inside a room with concrete walls of 15 cm thickness. In simulations realistic energy and angular distribution of cosmic-ray muons were generated, as well as emission of gamma rays from concrete laboratory walls, due to presence of Ra-226, Th-232 and K-40 radionuclides. The obtained spectrum was compared to the experimentally acquired background spectrum of unshielded HPGe detector. In addition, the background spectrum of shielded HPGe detector was also simulated. In simulation, the detector inside the room was surrounded by 15 cm thick lead shield. Besides interactions of cosmic-ray muons and external gamma rays with lead shield and detector, the contribution of neutrons of cosmic origin to the background spectrum was also analyzed in simulations. The bremmstrahlung emission due to presence of Pb-210/Bi-210 within lead shield and its influence on the low-energy continuous part of background spectrum is taken into account by simulation too. Finally, the separate contributions of all simulated components to the background spectral intensity were compared with the experimental background spectrum of lead shielded HPGe detector.

# DETERMINATIONS OF TRANSITION ENERGIES AND HALF-LIVES FOR PHOTO-NUCLEAR REACTION PRODUCTS OF SOME RARE EARTH NUCLEI

**Tuncay Bayram[1], Serkan Akkoyun[2]**

1 Department of Physics, Karadeniz Technical University, Trabzon, Turkey
2 Department of Physics, Cumhuriyet University, Sivas, Turkey

Photon induced reactions are used in many research field of nuclear science and nuclear physics such as radiation shielding and protection, radiation transport analyses, reactor core design, activation analysis and nuclear waste transmutation. Photo-nuclear reaction can be used for determination of transition energy and half-life of nuclei. There is still a lack of existing experimental photo-nuclear reaction data. In the present study, we have performed photonuclear reactions on Ga and Er target by using a modified clinical linear accelerator (cLINAC). By using measured residual activity of photonuclear reaction products of Ga and Er nuclei, we have determined the half-life and transition energies of product isotopes. Also, new measurements on gamma-ray energies of the products have been determined accurately. Furthermore, neutron capture process of Er target have been observed in our experiment because of neutrons naturally occurred in experimental area. Based on this observation transition energies and half-life of $^{171}$Tm have been determined. Also, this study shows that repurposed cLINAC with limited budget can contributes to the nuclear science knowledge.

# INVESTIGATIONS OF ISOMERIC CROSS SECTION RATIOS FOR THE REACTIONS ON $^{187}$RE AND $^{194}$PT TARGETS

**Tatiana Chuvilskaya**

Nuclear Physics Institute of Moscow State University, Moscow, Russia

Investigations of isomeric cross-section ratios (ICSR) of the reactions $^{187}$Re(α,n)$^{190mg}$Ir and $^{194}$Pt(α,n)$^{197mg}$Hg in the energy range 18 – 32 MeV were carried out using off-beam measurements of induced activity of members of the isomeric pair. Calculations of ICSR for the indicated reactions are performed using the codes EMPIRE-3 and TALYS. These codes are based mainly on widely used Hauser-Feshbach model (HFM), grounded on the statistical theory of nuclear reactions. Other mechanisms play a more limited role. The field of application of the HFM lies in the range of 10 – 50 MeV compound nucleus excitation energy, where the widths of resonances are greater than the distances between them. For the reaction $^{187}$Re(α,n)$^{190mg}$Ir experimental values of ICSR up to energy $E_{pr}$ = 23 MeV are in agreement with calculated by EMPIRE-3 ones with an accuracy of 20 – 30 %. At higher energy of α-particles calculated isomeric ratios exceed experimental ones, this behaviour is an evidence indicating that mechanisms of α-reactions other than statistical ones (pre-equilibrium, direct) become dominant. As for the data calculated by TALYS a good agreement with experimental results takes place. For the reaction $^{194}$Pt(α,n)$^{197mg}$Hg a good agreement of the experimental and calculated values of ICSR is seen in the α-particle energy range $E_{pr}$ = 14 – 18 MeV for both EMPIRE-3 and TALYS codes. At higher energies of α-particles calculated isomeric ratios exceed experimental ones and this difference turns out to be more significant for EMPIRE-3 code than for TALYS.

# DEFECT CENTER PARAMETERS IN β-IRRADIATED MgO NANOPARTICLES

**N.M. Hasanli[1,2], M. Isik[3]**

1 Department of Physics, Middle East Technical University, Ankara, Turkey
2 Virtual International Scientific Research Centre, Baku State University, Baku, Azerbaijan
3 Department of Electrical and Electronics Engineering, Atilim University, Ankara, Turkey

Shallow defect centers were investigated in MgO nanoparticles in the low temperature region of 10-300 K using photo-transferred thermoluminescence (PTTL) experiments. MgO is a wide band gap insulator with gap energy of 7.8 eV. The sample was subjected to $^{90}Sr/^{90}Y$ beta source at room temperature to fill deep centers and then illuminated at 10 K using a blue LED emitting at ~ 470 nm (2.6 eV) to excite charges from deep centers to shallow centers.

PTTL spectrum obtained at heating rate of 1 K/s exhibits one peak around 150 K. The analyses of the observed peak were achieved using curve fitting, initial rise and peak shape methods. Attempt to fit the theoretical curve to experimental data with only single peak was not successful. This fact forced us to fit the data considering that observed peak is composed of two individual peaks responsible for two different trapping centers in MgO nanoparticles. As a result, we have obtained successful overlapping of experimental and fitted curves. Curve fitting treatment resulted in activation energy values of 0.70 and 0.91 eV. Moreover, successful fitting was accomplished when second order of kinetics case was used in the fitting process.

Experimental PTTL curve was also analyzed using initial rise and peak shape techniques. The initial rise method, which is suitable for all order of kinetics, is based on the theoretical deduction of that PTTL is proportional to exp $(-E_t/kT)$ when the trap centers begin to empty as temperature is increases. This implies that the slope of ln $(I_{TL})$ vs. $1/T$ yields $(-E_t/kT)$. The activation energies of revealed centers were found as 0.69 and 0.92 eV utilizing this method. The activation energies of trapping centers were also calculated using peak shape method. The average values of activation energies were calculated as 0.67 and 0.88 eV. The $\mu_g$ parameter for these peaks were calculated and found closer to 0.52 which indicates the presence of dominant mechanism of fast retrapping. All obtained activation energy values of peaks by curve fitting, initial rise and peak shape methods are in good agreement with each other.

# THE SPES FACILITY AT LEGNARO NATIONAL LABORATORIES

**Matteo Ferrari, Mattia Manzolaro, Alberto Andrighetto, Stefano Corradetti, Daniele Scarpa, Alberto Monetti, Massimo Rossignoli, Michele Ballan, Francesca Borgna, Aldo Zenoni, Antonietta Donzella**

INFN-LNL, Padova, Italy

The selective production of exotic species (SPES) project aims to construct at Legnaro National Laboratories (LNL) a new facility for the production of radioactive ion beams (RIBs) according to the isotope separation on line (ISOL) technique. In the specific case of the SPES facility, a multi-foil uranium carbide target is impinged by a 40 MeV, 200 μA proton beam generated by a cyclotron proton driver. In these conditions, a fission rate of approximately $10^{13}$ fissions per second is expected in the target. The $^{238}U$ fission fragments produced in this way are delivered to the ion source making use of a tubular transfer line. Here they can be ionized (at charge state 1+) and subsequently accelerated toward the experimental areas. In ISOL facilities the target system can be combined with different types of ion sources in order to optimize the production of specific radioactive ion beams. The SPES target system is composed of 7 coaxial uranium carbide disks closed inside a graphite box. It is closed under vacuum inside a water-cooled chamber, and has to maintain high working temperatures, close to 2000°C. During operation the proton beam provides the heating power required to keep the target at the desired temperature level. As a consequence, its characteristics have to be strictly controlled in order to avoid an undesired overheating of the system.

# RADIOCARBON DATING APPLICATIONS OF ACCELERATOR MASS SPECTROMETRY

**Maria-Valentina Ilie[1,2], Tiberiu Bogdan Sava[1]**

1 "Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania
2 Faculty of Applied Sciences, University Politehnica of Bucharest, Bucharest, Romania

This paper gives an overview of the radiocarbon dating method, the origin of $^{14}C$, the global carbon cycle and the Accelerator Mass Spectrometry at the 1 MV Tandetron.

Accelerator Mass Spectrometry (AMS) is today the most sensitive isotopic analysis method known.

The AMS sensitivity can reach $10^{-15}$ scarce isotope ($^{14}C$)/ abundant isotope ($^{12}C$), in other words, AMS allows determination of the existence of a single atom in a torrent of one million billion other foreign atoms. So, AMS is an analytical technique for measuring low levels of long-lived radionuclides.

Due to its exceptional sensitivity, this method has opened a very wide range of applications in various fields: medicine, archaeology, geology, atmospheric physics, paleoclimatology, astrophysics, nuclear physics, nuclear pollution tracking, etc.

The isotope with mass 14 known as radiocarbon is one of the unstable isotopes of carbon with widespread applications in the scientific world. The use of $^{14}C$ as a „clock" for estimating the age of various historical and pre-historical samples is one of its most important applications.

Towards the development of a National Dating Program in Romania, the $^{14}C$ dating laboratory was commissioned in 2012 at IFIN-HH Bucharest. The particle accelerator in conjunction with ion sources, large magnets, and detectors was commissioned to measure C, Be, I and Al isotopic ratios with an accuracy of $10^{-15}$.

Performing analysis with such accuracy opens the possibility for applications in various domains such as: carbon dating of artefacts, material research, geology, determination of erosion rates, detection of existing nuclear pollution, forensic science and nuclear activity surveillance, diagnose of fusion experiments, astrophysics and oceanography, biomedical, pharmacological applications and others.

Sampling, sample preparation and measurement of the $^{14}C$ content are important steps in obtaining reliable radiocarbon ages. In the $^{14}C$ AMS technique, the element of interest (sample carbon) is chemically separated from the original sample, converted to graphite, pressed into a cathode (sample target holder) where it forms a solid graphite plug or layer and is then placed into a sputter ion source of an accelerator. Calibration of radiocarbon ages is the final step in establishing chronologies.

In conclusion, any material which is composed of carbon may be dated. The advantage of the radiocarbon dating method consists in the capability to be uniformly applied throughout the world on any material that contains residual carbon.

# THE ESTIMATION OF THE COSMIC RAY COMPONENT AND THE TOTAL γ-BACKGROUND OF ATMOSPHERE, COMPARISON WITH THE EXPERIMENT

**Maxim Cherepnev[1], Valentina Yakovleva[2], Aleksey Zelinskiy[2]**

1 Tomsk Polytechnic University, Tomsk State University, Tomsk, Russia
2 Tomsk Polytechnic University, Tomsk, Russia

Simulation results of characteristics of atmospheric γ- and β -radiation fields, which are produced by primary cosmic rays when overcoming an Earth's atmospheres, with using Geant4 are presented.

The form and character of the experimental range will well be coordinated with data, received in calculation.

Estimates of γ-radiation flux density with energies of 50 keV–3 MeV formed in ground atmosphere by cosmic radiation is 33 $m^{-2}s^{-1}$, what, according to the experimental data, can make about 5 – 10% of all natural radiation.

The barometric effect within various ranges of energies of photons and electrons was also investigated in the work.

# ESTIMATIONS OF ATTENUATION COEFFICIENTS FOR GAMMA RAY ANGULAR DISTRIBUTION

**Serkan Akkoyun[1], Tuncay Bayram[2]**

1 Cumhuriyet University, Sivas, Turkey
2 KATU, Trabzon, Turkey

Angular distribution of gamma rays from aligned nuclei is an important tool for the determination of nuclear spin and multipolarity of the gamma ray transition. The degree of alignment of the nuclear states is calculated by statistical tensors with population parameters. In the interpretation of the experimental data of gamma ray angular distributions, attenuation parameters are important for the explication correctly. In this study we have performed artificial neural network method in order to predict these parameters. Our results are consistent with the existing literature values. Therefore, one can confidently us the method for the estimation of the attenuation parameters for gamma ray angular distribution.

# HEAVY-ION FUSION CROSS SECTIONS FOR $^{20}$NE+$^{90,92,94,96}$ZR

**Burcu Erol[1], A. Hakan Yilmaz[2]**

1 Faculty of Science, Department of Physics, Recep Tayyip Erdogan University, Rize, Turkey
2 Faculty of Science, Department of Physics, Karadeniz Technical University, Trabzon, Oman

Heavy-ion fusion near the Coulomb barrier attracts experimental and theoretical interest. The collisions are typically characterized by the presence of many open reaction channels. In the energies around the Coulomb barrier, the processes are elastic scattering, inelastic excitations and fusion operations of one or two nuclei. The fusion process is defined as the effect of one-dimensional barrier penetration model, taking scattering potential as the sum of Coulomb and proximity potential. We have performed heay-ion fusion reactions with coupled-channel (CC) calculations. CC formalism is carried out under barrier energy in heavy- ion fusion reactions. In this work fusion cross sections have been calculated and analyzed in detail for the four systems $^{20}$Ne+$^{90,92,94,96}$Zr in a wide range of bombarding energies around the Coulomb barrier. Calculations with computer codes explains the fusion reactions of heavy-ions very well, while using the scattering potential as WOODS- SAXON volume potential with Akyuz-Winther parameters. It was observed that AW potential parameters are able to produce fusion cross sections reasonably well for these systems. There is a good agreement between the calculated results.

**Key words:** Heavy-ion reactions, coupled-channel calculations, sub-barrier fusion

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# Radiation in Medicine

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# ABSOLUTE DOSE DETERMINATION IN FLATTENING FILTER-FREE BEAMS: AAPM TG 51 AND IPEM RECOMMENDATIONS

**Silvia Vargas Castrillon, Francisco Cutanda Henriquez**

Edinburgh Cancer Centre, Edinburgh, United Kingdom

**Introduction.** Flattening Filter Free beams are current practice in radiotherapy; an assessment of different dosimetric approaches is therefore recommended. The British Institute of Physics and Engineering in Medicine (IPEM) Topical Report 1 (2016) recommendations include a FFF spectral correction, to be utilized with the current British code of practice, IPSM 1990. This type of correction cannot be found in AAPM TG-51 or its Addendum.

**Materials and Methods.** Two Varian Truebeam linacs were used, both with 6FFF and 10FFF beams. A PTW Semiflex thimble chamber and an IBA CCU electrometer were used for PDD measurements for IPSM 1990, a PTW Roos and an IBA CCU electrometer were used for AAPM TG-51 PDD measurements. A parallel-plate ion chamber was chosen given its effective point of measurement is more accurately defined. For absolute dose measurements, a Farmer chamber (NE 2571) and a PTW Unidos E electrometer were used. Absolute dose was measured following both protocols recommendations: 5cm (IPSM 1990) and 10cm (AAPM) deep. Polarity and recombination factors were measured at the two recommended depths. Our secondary standard chamber (NE 2561) and electrometer (NE 2670A) were calibrated at the National Physical Laboratory (UK), and all our measurements are subsequently traceable to NPL standards. Ion chamber intercomparisons, using the replacement method recommended for FFF beams by IPEM Topical Report 1, were performed with our secondary standard and NE 2571 at each of the recommended depths and for both beam qualities.

**Results.** NPL $N_{D,w}$ calibration factors were used for each beam quality for IPSM 1990; whereas for AAPM TG-51, the recommended option of using $N_{D,w}$ for Co-60 along with its tabulated $k_q$ factors was utilized. AAPM TG-51 and IPSM 1990/IPEM Topical Report 1 absolute dose measurements are within 0.4% for 6FFF and 0.3% for 10FFF, well within uncertainty estimates.

**Discussion.** A detailed and thorough absolute dose study was carried out according to the two above mentioned codes of practice: correction factors, ion chamber intercomparisons and absolute dose measurements at recommended depths. All experimental results were accompanied by a rigorous uncertainty analysis, according to ISO GUM. Our results for 6 FFF and 10 FFF show that, within uncertainty, agreement is found between absorbed dose to water determination for both beam qualities according to these codes of practice.

# $^{230}$Pa ISOLATION FROM IRRADIATED Th-TARGET AND DEVELOPMENT OF A $^{230}$U/$^{226}$Th GENERATOR

**Elena Lapshina[1], Stanislav Ermolaev[1], Boris Zhuikov[1], Valentina Ostapenko[2], Aleksandr Vasiliev[1]**

1 Institute for Nuclear Research of Russian Academy of Sciences, Moscow, Russia
2 Lomonosov Moscow State University, Moscow, Russia

Among alpha-emitting radionuclides prospective for targeted alpha-therapy, $^{230}$U ($T_{1/2}$=20.8 d) has strong potential due to appropriate nuclear properties. It can be utilized directly or as a parent of $^{226}$Th ($T_{1/2}$=31 min) in a generator system. $^{230}$U is accumulated via decay of $^{230}$Pa ($T_{1/2}$=17.4 d), Ci-amounts of which may be produced in natural thorium under proton irradiation in the energy range 200-60 MeV together with other useful alpha-emitters $^{225}$Ac ($T_{1/2}$=9.9 d) and $^{223}$Ra ($T_{1/2}$=11.4 d).

Radiochemical procedures were developed for $^{225}$Ac, $^{223}$Ra and $^{230}$Pa recovery from natural thorium irradiated with medium-energy protons. Irradiated thorium was dissolved in 6M nitric acid with the addition of catalytic amounts of HF and passed through a column filled with extraction chromatographic sorbent Octanol Resin (TrisKem Int. Company, 1-octanol as an extracting agent). The most part of radionuclides (mono- and bivalent cations, Th, Ac, Ra, lanthanides and others) were passed through the column. The eluate may be further used for isolation of $^{225}$Ac and $^{223}$Ra according the method, proposed in (*Solvent Extraction and Ion Exchange*, 2014, v. 32, p. 468-477). Pa and partially Nb were sorbed on the column and eluted by 1M nitric acid. Finally, purification of Pa was performed on silica gel using different oxalic acid solutions. The total chemical yield of $^{230}$Pa was about 80% and radionuclidic purity >99%.

The capacity factor k' values for U and Th were determined in static experiments (batch technique) for a wide concentration range of nitric and hydrochloric acid solutions on extraction chromatographic resins of TrisKem Int. Company, namely, tri-octylamine on different carriers: C2-caped silica, PS-DVB and Amberchrom CG71. The obtained data are used as starting conditions for column separation and development of a $^{230}$U/$^{226}$Th generator.

# A NEW METHOD DEVELOPMENT FOR MEDICAL RADIONUCLIDE $^{223,224}$Ra AND $^{225}$Ac PRODUCTION

**Vladimir Panteleev, Anatoly Barzakh, Leonid Batist, Dmitry Fedorov, Victor Ivanov, Sergey Krotov, Pavel Molkanov, Stanislav Orlov, Maxim Seliverstov, Yuri Volkov**

NRC "Kurchatov Institute" PNPI, Gatchina, Russia

The cyclotron C-80 capable of producing 40–80 MeV proton beams with a current of 100–200 μA has been constructed and put into operation at PNPI NRC KI (Petersburg Nuclear Physics Institute of National Research Center "Kurchatov Institute"). Presently the system has been worked out on the simultaneous beam transportation to the target stations for radioisotope production and to the medical box for the treatment of ophthalmologic diseases. One of the main goals of the C-80 is the production of a wide spectrum of medical radionuclides for diagnostics and therapy. For this purpose the project of the radioisotope complex RIC-80 (RadioIsotopes at the cyclotron C-80) has been developed. The mass-separator utilization at one of three target stations of RIC-80 will allow on-line or semi on-line production of a high purity separated radioisotopes. Among them are radionuclides $^{223,224}$Ra and $^{225}$Ac which decay by the alpha particle emission and are used for therapy of malignant tumors at the early stage of their appearance. The results of target and ion source tests for the production of radioisotopes $^{223,224}$Ra and $^{225}$Ac by different methods, including one with the mass-separator use, have been presented.

# DOSE COEFFICIENTS FOR MONOCLONAL ANTIBODIES AND ANTIBODY FRAGMENTS LABELED BY ZIRCONIUM-89

**Michael Zhukovsky[1], Hesham M. H. Zakaly[2]**

1 Institute of Industrial Ecology UB RAS, Ekaterinburg, Russia
2 Ural Federal University, Ekaterinburg, Russia

In nuclear medicine, a trend has developed for the visualization of tumors based on the target radionuclide delivery. Monoclonal Antibodies (MAB) and antibody fragments $F(ab)'_2$ and F(ab)' have been used to transport drugs into the body due to their specificity and affinity. During the last two decades, considerable efforts have been made to obtain a visualization technique using antibodies labeled with various radionuclides. From the very beginning of their use, the question of the strict correspondence of the physical half-life of the radionuclide and the biological accumulation and half-life of antibodies is relevant. The physical half-life of Zr-89 is well suited for the production of PET imaging based on antibodies. These characteristics stimulated an increase in interest in Zr-89 from a relatively little known positron-emitting radioactive isotope less than ten years ago to an "ideal" isotope for preclinical and clinical imaging in immuno-PET.

Based on the literature data, a biokinetic model of the behavior of monoclonal antibodies and antibody fragments labeled with Zr-89 was developed. It was taken into account that Zr-89 is incorporated into monoclonal antibodies and antibody fragments in the form of chelate complexes. Therefore, the biokinetic model of the behavior of Zr-89 after the destruction of antibodies or antibody fragments corresponded to the model of elimination of chelate complexes. It is shown that when using Zr-89, associated with intact MAB, the most exposed organs are: spleen, liver, heart wall, kidneys, red bone marrow and lungs. With the introduction of Zr-89, associated with $F(ab)'_2$, the largest doses of radiation are created in the spleen, kidneys, lungs and liver, and when using Zr-89, associated with fragments of antibodies F(ab)', the most irradiated organ is the kidney. It was demonstrated that a change in the half-life of the removal of monoclonal antibodies from the bloodstream from 25 to 100 h had little effect on radiation doses in organs and tissues, as well as on the effective dose. The effective doses at administrating of intact MAB and antibody fragments $F(ab)'_2$ and F(ab)', labelled by Zr-89 are 0.61, 0.25 and 0.15 mSv/MBq correspondently. The injected activity for imaging the tumor using the Zr-89 radionuclide varies from 37 to 75 MBq, which corresponds to the effective doses of 25-45 mSv.

# USE OF TOTAL REFLECTION ENERGY DISPERSIVE X-RAY FLUORESCENCE SPECTROMETRY IN NANOMEDICINE

**Ana Pejovic-Milic, Gabriella Mankovskii**

Ryerson University, Toronto, Canada

Due to their unique and customizable optical and physical properties, nanoparticles are being investigated for the wide variety of applications. Amongst these nanoparticles, gold nanoparticles are being used in nanomedicine as dose enhancers and drug carriers in cancer therapy. In addition, the biocompatible nature of gold nanoparticle has allowed for early phase clinical trials. Further advancement of nanomedicine requires understanding and investigating factors that affect cellular uptake and transport of nanoparticles.

We have developed and validated a Total Reflection X-ray Fluorescence (TXRF) based method for quantification of trace-level gold nanoparticles accumulated in cancer cells. The spectrometer used employs a molybdenum target X-ray tube, SDD detection system and quartz sample carriers (S2 PicoFox, Bruker-AXS, USA). Gold was investigated, in the form of a standard solution, solid nanoparticle and accumulated in breast and prostate cancer cells.

The use of bench-top, low power total reflection X-ray fluorescence (TXRF) spectrometry for the quantification of elements in biological tissues is presently limited in nanomedicine, although, the *ex vivo* TXRF measurements of any tissue provides multi-elemental analysis, which could help diagnose or monitor a medical condition or environmental exposure to many trace and toxic elements. Besides of only recent availability of these low power spectrometers, the particular challenges presented by the complex biological samples, such as human cells and tissues, could be influencing their limited use. In this presentation we will discuss constraints imposed by the use of TXRF, together with a brief description indicating the range of elements for which such analyses have been or could be established.

# Radiation Measurements

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# MEASUREMENTS OF HALF-VALUE LAYER USING DIFFERENT DETECTORS AND CALCULATIONS OF EFFECTIVE ENERGIES FOR LOW ENERGY X-RAY EXPERIMENTAL SETUP

**Joanna Czub[1], Janusz Braziewicz[1], Marcin Brodecki[2], Adam Wasilewski[3], Pawel Wolowiec[4], Andrzej Wojcik[5], Anna Wysocka-Rabin[3]**

1 Jan Kochanowski University, Kielce, Poland
2 Nofer Institute of Occupational Medicine, Lodz, Poland
3 National Centre for Nuclear Research, Otwock-Swierk, Poland
4 Holy Cross Cancer Center, Kielce, Poland
5 Stocholm University, Stockholm, Sweden

The half value layers (HVL) were determined using four types of detectors i.e. Mult-O-Meter, Farmer 30013, Markus 34045, Gafchromic EBT2 film for low energy X-ray experimental setup localized at Institute of Physics of Jan Kochanowski University in Kielce, Poland. HVL values and effective energies showed different values for various detectors and increased with raising voltage in the range of 30 kV to 60 kV. The effective energies showed identical values when the V, Zr, Fe filters of PANalytical company were installed on X-ray tube (X-ray Diffraction type no. 9430 922 00291, PANalytical company) at 60 kV of voltage.

# ABSORBED DOSE READINGS USING GAFCHROMIC FILMS EBT2 AND XR-RV3 IN AN EXPERIMENTAL SYSTEM WITH LOW RADIATION X-RAYS

**Joanna Czub[1], Janusz Braziewicz[1], Marcin Brodecki[2], Adam Wasilewski[3], Pawel Wolowiec[4], Andrzej Wojcik[5], Anna Wysocka-Rabin[3]**

1 Jan Kochanowski University, Kielce, Poland
2 Nofer Institute of Occupational Medicine, Lodz, Poland
3 National Centre for Nuclear Research, Otwock-Swierk, Poland
4 Holy Cross Cancer Center, Kielce, Poland
5 Stocholm University, Stockholm, Sweden

The dose rate (Gy/min) in experimental setup with low X-ray energy dedicated for radiobiological studies was measured using two radiographic films i.e. Gafchromic EBT2 and XR-RV3. Both films were calibrated at the Secondary Standards Dosimetry Laboratory (SSDL), Łódź, Poland. The dose rate was measured in place, where the biological cells situated in Petri dish were irradiated. Two films showed various values and the difference was 0.2 Gy/min.

# IN-SITU $CeBr_3$ GAMMA-RAY SPECTROMETRY FOR THE ANALYSIS OF RADIOISOTOPES IN THE SOIL

**Jun-Ho Lee[1], Jong-In Byun[2], Dong-Myung Lee[2]**

1 UST (University of Science and Technology), Daejeon, South Korea
2 Korea Institute of Nuclear Safety, KINS, Daejeon, South Korea

A portable HPGe (High Purity Germanium) has been using for in-situ gamma-ray spectrometry for environmental monitoring because of relatively high efficiency and good resolution. However, an HPGe detector has the major drawback that it must be cooled to the cryogenic temperature for appropriate data acquisition. Therefore, solid type of scintillation detector to operate at room temperature has also been used for gamma-ray measurements on site. In the presentation, the applicability of $CeBr_3$ scintillation detector is discussed as an in-situ gamma-ray detector for radioactivity analysis of radionuclides in the soil. For the study, 2"X2" $CeBr_3$scintillation detector was used. This detector was calibrated by using the conventional method (Beck, 1972). The relatively flat field was selected as a reference site for validation of the calibration, and gamma-ray measurement was carried out at a height of 1 m above the ground. Radioactivity of $^{40}K$ and gamma-ray emitting isotopes of U- and Th-series were analyzed from gamma-ray energy spectra obtained by $CeBr_3$ detector. Self-measurement was also performed in the ultra-low background lead shield with the thickness of 150 mm, in order to subtract the intrinsic radioactivity, $^{227}Ac$, inside the $CeBr_3$ detector from the measured count in the peak of interest, such as $^{40}K$ at 1460 keV and $^{214}Bi$ at 1765 keV. For the radioactive characterization in the field, soil samples were collected and pretreated through drying and grinding. Then, the samples were sealed in cylindrical containers and measured by using an HPGe detector with 30% relative efficiency after radioactive equilibrium between Rn and its daughters. The analysis results of gamma-ray emitting natural radionuclides by using the $CeBr_3$ detector in the field were compared with those obtained in the laboratory. As the result, radioactivity by in-situ gamma-ray spectrometry agreed well with those obtained by laboratory analysis for each of the radionuclides.

# DETERMINATION OF $^{226}$Ra AND $^{228}$Ra IN WATER USING LabSOCS EFFICIENCY CALIBRATION SOFTWARE FOR GAMMA SPECTROMETRIC ANALYSIS

**Manjola Shyti[1], Miha Trdin[2]**

1 University of Tirana, Institute of Applied Nuclear Physics, Tirana, Albania
2 Jožef Stefan Institute, Ljubljana, Slovenia

Radium (Ra) isotopes are important from the viewpoints of radiation protection and environmental protection. Radium is routinely analyzed in drinking water. Radium isotopes can be analyzed by different analytical methods based on gamma spectrometric measurements or alpha spectrometry. Modern gamma spectrometry systems are typically operated via computer software applications. In this study the LabSOCS (Laboratory Sourceless Calibration Software) mathematical efficiency calibration software is used. An improved method was developed to determine radium isotopes from water using gamma spectrometry after micro-coprecipitation as lead (radium) sulfate method for radiochemical separation ($Pb(Ra)(Ba)SO_4$). This method was successfully modified to allow direct determination of $^{226}$Ra and $^{228}$Ra by gamma spectrometry. However, large volumes of samples and/or long waiting time (20 days), before radioactive equilibrium is established, are required for accurate $^{226}$Ra activity concentration determination. The amounts of $^{226}$Ra and $^{228}$Ra on the sample were quantified by using gamma spectrometric analysis for its 186 keV gamma emission, 351.9 ($^{214}$Pb), 295.2 ($^{214}$Pb), and 609.3 ($^{214}$Bi), 1764.5 ($^{214}$Bi) and for $^{228}$Ra can be nonetheless achieved via its daughter nuclide $^{228}$Ac in 911.2 and 969 keV gamma emission. The radiochemical recovery was 93% and 100% for $^{226}$Ra and $^{228}$Ra, respectively. The Minimum Detectable Activities (MDAs) for 8 L of sample and a measuring time of 200 000 seconds for $^{226}$Ra and $^{228}$Ra were calculated. The best results were obtained when the herein described method was combined with LabSOCS calculations.

# THE ROMANIAN SYSTEM OF ACTIVITY STANDARDS FOR THE RADIOPHARMACEUTICALS USED IN POSITRON EMISSION TOMOGRAPHY; INFLUENCE OF THE DECAY SCHEME ON THE STANDARDIZATION METHOD

**Maria Sahagia, Aurelian Luca, Andrei Antohe, Mihail-Razvan Ioan**

Horia Hulubei National Institute for Physics and Nuclear Engineering, IFIN-HH, Bucharest, Magurele, Romania

The Romanian system of activity standards for PET radiopharmaceuticals consists from the primary standardized radionuclides: $^{18}$F, $^{64}$Cu, $^{68}$Ga, $^{89}$Zr, $^{124}$I. These radionuclides are either of normal use in clinics, known as "standard radionuclides" like $^{18}$F and $^{68}$Ga, [$^{68}$(Ge+Ga) generator], or in advanced studies, known as "emergent PET radionuclides" like $^{64}$Cu, $^{89}$Zr, $^{124}$I. Our system was developed in tight connection with the studies performed at the TR-19 cyclotron of the Centre for Radiopharmaceutical Research (CRR) from IFIN-HH for their obtaining and use.

Two main problems, in direct connection with our available standardization installations and further use of standards in practice were solved. (i) Use of the coincidence system, consisting from a 4π proportional counter working at normal pressure and a NaI(Tl)detector, the 4πPC-γ, which was used for standardization in all cases. A common feature of all radionuclides is the occurrence of the 511 keV positron annihilation quanta, which allows for the counting of coincidence between positrons and annihilation, method simply applicable in the case of $^{18}$F. All the others decay by positron emission and significant electron capture processes and emit other high energy γ-rays. Auger electrons, x-rays and γ- rays strongly influence the counting rates and this influence must be determined experimentally, or calculated. A special, difficult radionuclide is $^{89}$Zr, which emphasize a high energy (909 keV), high intensity (99.8%), isomer transition. Specific coincidence relations and corrections to be applied for each radionuclide will be presented in the paper. (ii) Another problem is to find the method for the precise calculation of the response of the ionization chamber, secondary standard, to each radionuclide, which can be validated only by using primary standardized solutions. Some calculated response values and their agreement with the experimental ones are also presented.

# REFERENCE MATERIALS (RM) AND PERFORMANCE TESTING (PT) SAMPLES IN RADIOACTIVITY ANALYSIS: PRACTICE, CAPABILITIES, ALTERNATIVES

**Evgeny Taskaev**

Eckert & Ziegler Analytics, Inc, Atlanta, United States

Current regulatory environment requires Radianalytical Laboratories to use Reference Materials (RM) and perform analysis of Performance Testing (PT) Samples. Developing a Reference Material is a long and expensive process. Homogeneity of the RM is one of the most critical parameters that is hard to achieve and maintain through the overall shelf life of the material. It is especially difficult to achieve homogeneity for materials used in radiochemical analysis, with sample size of 0.5-5 g.

Major National Metrology Institutes (NMI) cannot produce enough Reference Materials (RM) to satisfy industry needs. They have even less capabilities to provide PT samples. Laboratories on the other hand have to use RM and PT samples on a daily basis to satisfy regulatory requirements.

Options are discussed about what laboratories can do to sufficiently satisfy regulatory requirements using existing capabilities. There are efforts in the industry to address shortage of RM and develop reasonable approach by introducing “working reference materials” (WRM) and “reference samples” (RS). The meaning and importance of the commutability of RM and PT is discussed.

Using the RS as a whole (no subsampling) is especially valuable option, providing flexibility and development cost reduction. If the assumption can be made that the Reference Material (RM) can actually be the Reference Sample (RS) with similar weight as the regular sample and be treated the same way as the regular sample (e.g. totally dissolved), it will be much easier for the analytical laboratory (or RS provider) to design an RS that will address the specific analytical need. RS can be used for calibration or as PT sample.

There are some advantages to use RS vs RM:

- Homogeneity requirements can be less restrictive if any at all,
- Flexibility in matrix choice, including perishable materials,
- Flexibility in spike choice (including refractory Pu and U, specific complexes etc.),
- Overall lower uncertainty for the activity of isotopes used for spiking in RS vs RM,
- Manufacturing of RS can be done within regulatory requirements (ISO 17025, ISO 17043 etc.)

Disadvantages of using RS:

- User (or provider of RS) has to ensure that spiked nuclides are not absorbed by container material and transferred from the container quantitatively for further analysis
- With a few exceptions it will be not possible to provide organically bound nuclides.

# AN IMPROVED METHOD FOR THE MEASUREMENT OF $^{210}$Pb IN ENVIRONMENTAL SAMPLES BY LIQUID SCINTILLATION COUNTER

**Jung-Seok Chae, Eunhwa Kwon, Yong-Jae Kim**

Korea Institute of Nuclear Safety, Daejeon, South Korea

Lead-210 is naturally occurring radionuclide of the $^{238}$U decay series with half-life of 22.3 y. $^{210}$Pb is used as a useful tracer for geochronological studies, food chain research, and atmospheric science because of the wide distribution in soil, atmosphere and water due to the characteristic of naturally occurring radionuclide. In addition, $^{210}$Pb can affect humans and the environment due to radiation exposure.

Several $^{210}$Pb analysis methods such as measurements of $^{210}$Po by alpha spectrometry and $^{210}$Bi by a proportional counter, and direct measurement of $^{210}$Pb using gamma spectrometry in environmental samples have been used for various fields of study. Compared with these methods, the measurement of $^{210}$Pb by liquid scintillation counter has advantages such as short analysis time and relatively high detection efficiency.

In this study, an improved method for the measurement of $^{210}$Pb in environmental samples using liquid scintillation counter (LSC) is devised.

After the acid digestion of sample, Pb is purified through the extraction chromatography with Sr resin and precipitated as lead oxalate. Following re-dissolved, it is mixed with scintillation cocktail and measured by LSC.

Unlike a previous study which divided three regions by energy level and selected only $^{210}$Pb region, all the spectra regions of in which signals of $^{210}$Pb, $^{210}$Bi, and $^{210}$Po are used for the calculation of the activity of $^{210}$Pb. This method involves a procedure for a correction of the blank value due to $^{210}$Pb activity in the $Pb^{2+}$ carrier.

This measurement technique has twice the detection efficiency as previous study; therefore, it is expected to be useful for the analysis of environmental samples with low radioactivity concentration.

# USING OF THE REMOTE METHODS FOR RADIATION SURVEY DURING REACTOR MR DISMANTLING

**Alexey Stepanov, Oleg Ivanov, Alexey Danilovich, Ilia Semin, Sergey Smirnov, Victor Potapov, Vyacheslav Stepanov**

NRC "Kurchatov Institute", Moscow, Russia

The projects for decommissioning of MR and RFT reactors have been carried out in the National Research Centre "Kurchatov Institute" from 2011. The character of it radioactive contamination requires individual strategies for the decontamination work. This requires information about the character of the distribution of radioactive contamination of equipment in the premises. A detailed radiation survey of these premises using standard dosimetric equipment is almost impossible, due to of high levels of radiation and high-density of the equipment. The problem can be solved by using the set of remote measurement systems: gamma-pioneer, gamma-locator, gamma-camera "Gammavizor" and underwater spectrometer system.

Gamma-pioneer is a radiometric system for application with robot Brokk-90. System includes two scintillation detectors (collimated detector and detector without shielding), video camera and has WiFi or LAN connection with control unit. The measuring range: 0.4 mSv/h to 8.5 Sv/h. The system was used in survey of elements from temporal near reactor radwaste storage, preliminary scanning of activity distribution along elements, video and dose rate characterization of SNF elements and arrangements. Gamma-locator is a remotely operated spectrometric system. The system consists of a spectrometric collimated gamma-ray detector (the CdZnTe crystal of 1500 $cm^3$), a color video camera and a control unit, mounted on a rotator, which are mounted on a tripod with the host computer. The gamma locator was used to estimate the contribution of various radiation sources to the dose rate produced at the point the measurements, and to build a picture of the distribution of dose rate for the surveyed premises.

The remote-controlled gamma camera "Gammavizor" was used for gamma imaging of radioactively contaminated components of equipment and rooms when preparing such equipment for dismantling. The angular resolution of gamma-ray imaging with camera is from 1 to 2 degrees. The field of view is about 30 degrees. As the results of work "Gammavizor" a gamma-ray maps in pseudo colors superimposed on video image of the premises was obtained.

The underwater spectrometer system with collimated detector based on CdZnTe crystal of volume 60 and 20 $mm^3$ was used for detection of irradiated nuclear fuel on the pool bottom of the MR reactor. The principle of detection of uranium-containing materials is based on the identification of the characteristic peaks in the spectra of uranium radiation measurements in the energy range 95 ÷ 115 keV. The angle of view of the collimator (full aperture angle) is about 12 degrees. The underwater spectrometer system was used in a high radiation fields.

Presented equipment for remote measurements can be used widely in the projects for decommissioning of shutdown reactors and reactor facilities and can significantly reduce radiation doses for personnel.

# STUDY OF COSMIC-RAY MUON-INDUCED PROCESSES IN VARIOUS MATERIALS

**Kristina Bikit-Šreder, Dusan Mrdja, Sofija Forkapic, Istvan Bikit**

Department of Physics, Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia

The most penetrating component of secondary cosmic radiation are cosmic muons, which interact with detector active volume and shielding as well as detector surroundings, thus contributing to the background spectrum of HPGe detectors used in gamma spectrometry. The main contribution of cosmic-ray muons is through the electromagnetic cascade production, i.e. electron-photon shower along their path in massive detectors shielding. Such contributions are also of importance in ultra-sensitive experiments regarding detection of rare nuclear events, including dark matter particles detection.

In order to reduce the detection of muon induced events resulting from interactions with detector shielding materials and enable direct measurements of cross section for processes induced by muons in investigated materials, the construction of spectrometer system with adequate geometry and performance was necessary. Spectrometer system MIREDO (*Muon Induced Rare Events Dynamic Observatory*) is dedicated to muon-induced processes investigation, based on triple coincidences between HPGe detector and two plastic scintillation detectors. In coincidence regime, this system provides the possibility to register specific muon-induced processes in various materials, placed around HPGe detector endcap, and study them in detail, by selecting adequate coincidence interval. Also, if mechanisms of muon interactions with different materials are known, together with cross section dependency for these interactions on material atomic number, better theoretical basis for low-level measurements analysis results can be established, leading to easier detection of WIMPs (*Weakly Interacting Massive Particles*).

By MIREDO system, the first results of muon-induced low-energy continuum production in CaO, NaCl and SiC materials, with distribution maximum around 100 keV, were obtained. Experimental intensity ratios of produced continuum originating from different materials are in good agreement with corresponding ratios obtained by Monte-Carlo simulations with GEANT4 software. Cross sections for low-energy continuum production are derived for several energies as well as its dependency on atomic number of target material.

# CALIBRATION OF IONIZATION WELL CHAMBERS AT THE POLISH SSDL

**Wojciech Bulski, Piotr Ulkowski, Adam Kowalczyk, Ewelina Gruszczyńska, Krzysztof Chełmiński**

Department of Medical Physics, The Maria Skłodowska-Curie Memorial Cancer Centre and Institute of Oncology, Warsaw, Poland

In Poland, there are 32 centres performing brachytherapy. In 2017, these centres treated about 11000 patients. All these centres use about 50 HDR machines with Ir-192 sources. Each source has to be replaced every three month, and the new sources have to be calibrated. In every centre the calibration is performed with a well ionization chamber. Each centre has at least one such chamber which has to be calibrated against the secondary standard.

Since 2012 the Polish Secondary Standard Dosimetry Laboratory (SSDL) in Warsaw has been performing calibrations of well type ionization chambers used for the measurement of the dose rate of radiation sources used in brachytherapy. The SSDL in Warsaw is the only laboratory in Poland and in central and eastern Europe performing calibration of such type of chambers. Since 2014, Polish SSDL is an accredited laboratory according the ISO/IEC 17025 norm (accreditation no.: AP 155 by the Polish Centre for Accreditation). Until November 2017 the SSDL in Warsaw calibrated well type ionization chambers for 30 Polish radiotherapy centres performing brachytherapy with Ir-192 HDR sources. Each such centre has to calibrate new HDR sources replaced every three months, and they are using well chambers to do so. According to the national recommendation the calibration certificates for ionization chambers are valid for 2 years. The calibration procedure for well chambers was established at the SSDL in 2012. As a secondary standard, a PTW well chamber type TW33004 has been used. The standard chamber was calibrated at the Primary Standard Laboratory PTB-Braunschweig, Germany. The extended uncertainty of the calibration coefficient for user's chambers is 2.8% (k=2). The detailed uncertainty budget is presented. The calibrations take place at the Brachytherapy Department of the Centre of Oncology in Warsaw, using the Ir-192 source of the MicroSelectron HDR unit. Until November 2017, the SSDL performed 66 calibrations of well chambers from the following manufacturers: Standard Imaging, Nucletron Holland and PTW Freiberg. The analysis of the results is presented.

Mean values and SD of calibration coefficients for each chamber type were calculated. For Standard Imaging HDR1000 Plus well chambers the mean calibration coefficient was 0.4668±0.0026. For Nucletron Holland well chambers (type 77091, 77092 and 77094) the mean calibration coefficient was 0.9472±0.0142 and for PTW33004 well chambers the mean calibration coefficient was 0.9655±0.01863. Twenty two chambers were calibrated two or more times which allowed for the evaluation of their stability which was of the order of 0.3%.

# CALCULATION OF THE CONCENTRATIONS OF ELEMENTS IN ENVIRONMENTAL SAMPLES USING XRF PORTABLE SYSTEMS AND THE FUNDAMENTAL PARAMETERS METHOD

**Alketa Sinanaj, Blerina Papajani**

Aleksander Xhuvani, Elbasan, Albania

X-ray fluorescence method is known as a laboratory method, one of the few atomic spectroscopy methods used in many fields. The process of emission of the characteristic X-ray is called "X- ray fluorescence" (XRF). The analysis that uses XRF is called "XRF Spectrometry". The objectives of this research study are optimization of the XRF portable system geometry and the use of the fundamental parameters method to calculate the concentrations of the elements in environmental samples using portable systems. Since this method is quick in getting results and does not destroy the sample, it is widely used both in research and in the analysis of industrial products for materials check in the field of mineralogy, geology, environmental analysis of water, air, etc. Various experiments have led to the optimization of the geometry system, as the distances' minimization, angles optimization and the assessment of the beam spot in the position of the sample. Most of the data collected are used as initial data in ADMCA program that uses fundamental parameters (FP-XRF) for calculating the concentrations of elements in environmental samples. Errors in calculating the concentrations of the sediment and soil samples when we introduce the approximate content light elements can be eligible for geochemical studies. During the research, several areas that can be used in the future to improve the results are identified.

# RECENT RESULTS FOR SPACE RADIATION QUANTITIES ABOARD THE EXOMARS TRACE GAS ORBITER TO MARS

**Jordanka Semkova[1], Rositza Koleva[1], Victor Benghin[2], Krasimir Krastev[1], Tsvetan Dachev[1], Yuri Matviichuk[1], Borislav Tomov[1], Stephan Maltchev[1], Plamen Dimitrov[1], Igor Mitrofanov[3], Alexey Malahov[3], Dmitry Golovin[3], Maxim Mokrousov[3], Anton Sanin[3], Vyacheslav Shurshakov[2], Sergey Drobyshev2**

1 Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria
2 Institute of Biomedical Problems of the Russian Academy of Sciences, Moscow, Russia
3 Space Research Institute, Russian Academy of Sciences, Moscow, Russia

ExoMars is a joint ESA-Roscosmos program for investigating Mars. Two missions are foreseen within this program: one consisting of the Trace Gas Orbiter (TGO) launched on March 14, 2016 and the other, featuring a rover and a surface platform, with a launch date in 2020. On October 19, 2016 TGO was inserted into high elliptic Mars' orbit. The dosimetric telescope Liulin-MO for measuring the radiation environment onboard ExoMars 2016 TGO is a module of the neutron detector FREND. Here we present recent results from measurement of the charged partcles dose rates, fluxes, linear energy transfer spectra and estimation of the dose equivalent rates in the interplanetary space during the cruise of TGO to Mars and in Mars' orbit. The obtained data show that during the cruise to Mars and back (6 months in each direction), taken during the declining of Solar activity, the crewmembers of future manned flights to Mars will accumulate at least 60% of the total dose limit for the cosmonaut's/astronaut's carrier in case their shielding conditions are close to the average shielding of Liulin-MO detectors- about 10g/cm-2.

# DETERMINATION OF COINCIDENCE SUMMING CORRECTION FACTORS FOR $^{22}$Na POINT SOURCE

**Aleksandar Jevremović[1], Aleksandar Kandić[1], Mirjana Đurašević[1], Ivana Vukanac[1], Igor Čeliković[1], Zoran Milošević[1], Jovan Puzović[2]**

1 "Vinča" Institute of Nuclear Sciences, Laboratory for Nuclear and Plasma Physics, Belgrade, Serbia
2 Faculty of Physics, University of Belgrade, Belgrade, Serbia

Coincidence summing effect play an important role in HPGe spectrometry at low source-detector distances, due to a large solid angle and therefore calculation of correction factors is necessary. The aim of research described in this paper was to compare values of correction factors for point source $^{22}$Na obtained using the software package GESPECOR (Monte-Carlo method) and experimentally obtained values.

Radionuclide $^{22}$Na has a simple decay scheme. The radionuclide $^{22}$Na disintegrates predominantly to the 1274.537 keV level of $^{22}$Ne (90.3 % $\beta^+$ and 9.64% EC) and a very small fraction (0.055 %) disintegrates to the ground state of $^{22}$Ne. If the gamma rays on 511 keV ($p_{511}$=180.7 %) and 1274.537 keV ($p_{1275}$=99.94 %) are detected in true coincidence, this will lead to the creation of sumpeak on 1785.537 keV.

Measurements were performed using a semiconductor HPGe spectrometer, GEM30-70, (relative efficiency 35.5 %, resolution 1.66 keV). The $^{22}$Na radioactive point standard produced at the Czech Metrology Institute was measured at the central detector axis at nine different distances from the detector end-cap. Processing of recorded spectra was made using the Genie2000, Cannbera software. The measurement time ranged from 65000 s to 250000 s, depending on the location of the source.

For the purpose of calculating correction factors, a system of 4 count rates equations was formed for: full energy peaks at 511 keV and at 1274.537 keV, count rate in the sum peak at 1785.537 keV, and total count rate in the entire spectrum. The equation for the sum peak is proved to be unstable because of a large statistical uncertainty of net count. Thus, the system is formed using other 3 equations with four unknowns. Solving the system of equations was done by introducing an approximation that the ratio of total and full energy efficiency is a linear function of energy. To solve this system of equations the program package Mathematica 5.0 (Wolfram Research) was used, whereby corrected values for efficiency were obtained. The correction factors for coincidence summing effects were determined by comparing corrected values for efficiencies with uncorrected ones, obtained from spectrum.

In order to calculate the correction factors by using GESPECOR, the parameters of the detector system and the radioactive source $^{22}$Na were defined. They were related to their geometry, the type of detector (HPGe) and the material from which they were made. The input number of the photons was set to $10^6$.

By comparing the obtained values for the point source $^{22}$Na, it was found that the correction factors obtained by these two methods have discrepancies less than 3 % in contact geometry, while increasing the distance between source and end-cap leads to reduction of discrepancies.

# BAYESIAN STATISTICS AS A MODERN TOOL IN RETROSPECTIVE DOSIMETRY OF MIXED IONIZING RADIATION

**Iwona Słonecka[1,2], Zuzanna Baranowska[1], Krzysztof Łukasik[2], Krzysztof Fornalski[3,4]**

1 Central Laboratory for Radiological Protection, Warsaw, Poland
2 Warsaw University of Technology, Faculty of Physics, Warsaw, Poland
3 PGE EJ 1 Sp. z o. o., Warsaw, Poland
4 Ex-Polon Laboratory, Warsaw, Poland

More and more often, new statistical methods and tools are used in dosimetry of ionizing radiation and radiological protection. One of the most popular in recent times is Bayesian statistics. Authors present three applications of Bayesian reasoning in dosimetry.

The first concerns Bayesian statistics in biological dosimetry of mixed, neutron and gamma radiation from nuclear reactors. These two types of ionizing radiation have completely a different nature and biological effectiveness. Therefore, in a case of overexposures of people to neutron and gamma radiation, it is very important to assess not only the total absorbed dose, but its separate neutron and gamma components. To determine the absorbed dose in an accidentally exposed person in case of absence of a personal dosimeter and the physical measurements, the most commonly used method is cytogenetic biological dosimetry. It uses the dicentric chromosomes in peripheral blood lymphocytes of an irradiated person, which reflect the average total-body dose. The classical, iterative method generally works well, but it doesn't work in case of the lack of detailed information about the percentage contribution of both radiation types. In these cases, Bayesian statistics, which assume the probability distribution of the ratio of dose components, have proved to be useful.

The second application pertains to Bayesian statistics in TLD dosimetry of mixed beta and gamma ($\beta + \gamma$) radiation. Limitations associated with mixed beta and gamma dose estimation based on thermoluminescent dosimetry in many cases make it impossible to properly assess workers' exposure. The calibration coefficients for Hp(10) and H*(10) obtained in Central Laboratory for Radiological Protection allow the assessment of doses in mixed $\beta + \gamma$ fields for the following sources: Kr-85, Sr-90, Cs-137 and Co-60. In the case of personal, Hp(10), and environmental, H*(10), dose assessment, dosimeters give the possibility of recognizing the separate contribution from beta and gamma, which is related to the construction of the detector. There are four pellet positions available, with/or without the aluminum. However, there is a problem with the ring dosimeters because there is only one pellet inside the dosimeter. Significant problems occur also in the case of sources with energies beyond the calibration range. In such examples, Bayesian statistics allow assigning a prior probability function to parameter $\theta = D\beta/D\gamma$, which is not precisely known from the experiment, and finally estimate doses components.

The third application concerns the curve fitting method, what authors have used to create dose-response curves for the purposes of biological dosimetry of mixed radiation $n + \gamma$. Generally, in data analysis the most common used curve fitting methods are the least squares method and maximum likelihood estimation. But in the case of data with outliers or scattered points, these methods do not reflect the actual trend. In such situations, Bayesian analysis, which is resistant to the significantly different points, proved to be a much better pick. The Bayesian method assists in determining the curve which reflects the actual trend of the experimental data points, omitting the outliers by assigning them insignificant weights. In situations with the lack of outliers, the Bayesian method is comparable to popular used methods.

# THERMAL STABILITY OF THE MERCK QUARTZ CW-OSL AND EPR SIGNALS

**Ş. Kaya Keleş, G. Polymeris, N. Meriç**

Ankara University, Institute of Nuclear Sciences, Çankaya, Turkey

Quartz is the most common mineral in luminescence dating and retrospective dosimetry studies for reconstruction of either radiation dose in an accident or equivalent dose of archaeological materials. For dose assessment, luminescence intensity of irradiated sample is compared with the intensity of the sample irradiated with known dose in the laboratory. The intensity can be obtained by the method based on optically stimulating called Optically Stimulated Luminescence (OSL). Also Electron Paramagnetic Resonance (EPR) is a technique based on the detection of paramagnetic defects that are proportional to the absorbed radiation dose within the material. Thermal stability is one of the essential properties for a material to be useful in dosimetry studies. Trap centers must be enough stable to accumulate the radiation dose until the time of measurement. For irradiation, heating and monitoring the CW-OSL signals, Risø TLDA 20 reader which has an internal $^{90}Sr/^{90}Y$ beta source was used. Luminescence emission was detected through U-340 filter. Merck quartz samples were irradiated with 300 Gy for both CW-OSL and EPR measurements. For thermal stability, samples were heated from room temperature (~20°C) up to 425°C by the steps of 25°C with a heating rate of 1°C/s, after monitoring the blue stimulated OSL signals, EPR measurements were done. EPR measurements were carried out using X-band (~10 GHz) using a Bruker EMX spectrometer In this study, thermal stability of Merck quartz CW-OSL and EPR signals were investigated and we tried to see whether there is a correlation between these two signals. As a result, CW-OSL and EPR signal intensities are similar with heating between room temperature and 425°C. Both signals were stable up to 250 °C and started to decrease after this temperature. Above 375°C the signals are totally depleted. By considering the thermal stability behaviour of CW-OSL and EPR signals, we may talk about a possible correlation between them.

# JET COUNTER NANODOSIMETER AS A TOOL FOR INVESTIGATING PARTICLE TRACK STRUCTURE

**Aliaksandr Bantsar[1], Marcin Pietrzak[2], Stanisław Pszona[1]**

1 National Centre for Nuclear Research, Otwock-Swierk, Poland
2 University of Warsaw, Warsaw, Poland

Nanodosimetry is a field of dosimetry to investigate and quantify track structure of ionizing radiation in nanometer scale (at unit density), which dates back to 70's. Main aim of experimental nanodosimetry is to establish a new concept of of radiation quality that builds on measurable characteristics of the particle track structure at nanometer scale.

Experimental nanodosimetry operates with following parameters: simulated nanometer site SNS (a few nm), cluster size as a number of ionizations produced by ionizing particle in SNS and ionization cluster size distributions ICSD. Using ICSD additional parameters may be derived like mean cluster size $M_1$ and cumulative distributions $F_k$. All these parameters are used as descriptors of particle track structure at nanometer scale.

At present work, detailed descriptions Jet Counter nanodosimeter as well as techniques used to investigate the track structure of ionizing particles will be presented. Jet Counter nanodosimeter is a unique device as it may investigate particle track structure for single electrons (100 – 1000 eV), alpha particles (e.g. 3.8 MeV, $^{241}$Am source) and Carbon Ions (23 – 76 MeV, U-200 cyclotron at HIL).

The capability and the performance of Jet Counter will be discussed with respect to:

– range of the size of the simulated nanometric volume (up to 20 nm)

– geometry and number of sensitive volumes

– measurement of ICSD

– measurements of spatial correlations of ionization events

– position of the sensitive volume with respect to the primary particle beam

– efficiency of single ion counting (up to 80%)

– measured type of primary particle (alpha particles, carbon ions and electrons)

– event counting rate

The description of Jet Counter modifications including new acquisition system will be presented as well as results of performance tests. Ionisation Cluster-Size Distributions obtained with modified interaction chamber adapted for radial measurements will be shown and discussed.

# REVIEW OF RECENT JET COUNTER EXPERIMENTS

**Mateusz Filipek[1,2], Aliaksandr Bantsar[3], Marcin Pietrzak[1,3], Stanisław Pszona[3], Zygmunt Szefliński[2]**

1 Biomedical Physics Division, Faculty of Physics, Warsaw University, Warsaw, Poland
2 Heavy Ion Laboratory, Warsaw University, Warsaw, Poland
3 National Centre for Nuclear Research, Otwock, Poland

In the last thirty years the number of diagnosed cancer cases has doubled. Medicine, trying to catch up with this trend, introduces new methods of therapy dedicated to specific types of cancer. As a result, the interest in methods using non-photon sources of ionizing radiation increases. Depending on the type and energy of radiation, different biological effects are observed at the cellular level. To investigate those effects, the procedure of characterization of radiation damage at the nanoscale (approx. the width of DNA strand) is being developed.

One of the three devices available in the world that makes study the biological effect included by radiation on sub-cellular structures is the Jet Counter nanodosimeter in NCBJ. In order to accurately reproduce the processes occurring in the nanometre scale, measurements are taken in areas of millimetre size at low pressure gas (e.g. nitrogen), but with the same amount of matter as in those structures in human tissue. Experiments with carbon ions of energies 23 – 76 MeV and alpha particle (241Am) took place in Heavy Ion Laboratory and National Centre of Nuclear Research. To extract real ionization cluster size distribution, the efficiency of ion transport has to be known. It is necessary to determine the real amount of ionization acts that occurred in the experiment, so-called ion detection efficiency.

The efficiency of ion detection is the basic parameter that distorts the measured shape of the distribution and must be known with relatively good precision. The efficiency of ion detection is a product of 3 components:

- efficiency of ion extraction from the interaction chamber,

- efficiency of ion guiding to ion detector by electrostatic field,

- efficiency of ion detector (electron multiplier).

The first two components were studied with SIMION 3D version 8.1, which is a program for simulation of electrostatic lens analysis with the possibility of observing the travelling path of ions in a simulated electrostatic field. In the simulations, the real geometry of the Jet Counter was taken into account with a voltage applied on the extracting grids. The starting points of ions were placed within the interaction chamber. The interaction of ions with the nitrogen was taken into account.

The detailed analysis of recent Jet Counter experiments considering ion transport efficiency will be presented.

# QUALITY CONTROL OF LIQUID SCINTILLATION COUNTER QUANTULUS 1220

**Gordana Pantelic, Marija Jankovic,**
**Natasa Sarap, Jelena Krneta Nikolic**

Vinca Institute of Nuclear Sciences, Belgrade, Serbia

The paper presents quality control measurement for Ultra Low Level Liquid Scintillation Spectrometer Quantulus 1220. The accuracy and reproducibility of results of a LSC are verified on a periodic basis, before each set of measurements, in order to confirm the stability of LSC. QA/QC procedure includes determination of efficiency and background. Two type of efficiency are determined. First efficiency is determined for 3H unquenched liquid scintillation counting (LSC) standard in order to confirm that obtained measured value is higher than minimum efficiency for LSC predicted in Rulebook on ionizing radiation detector. The second efficiency is determined with 3H standard used for instrument calibration for low activity measurements of tritium in natural water samples. We observe that the stability of our LSC is very good during the time.

# MEASUREMENT OF AMBIENT DOSE EQUIVALENT H*(10) IN THE SURROUNDING OF NUCLEAR FACILITIES IN SERBIA

**Aleksandra Sokić, Luka Perazić, Ivan Knežević**

Public Company “Nuclear Facilities of Serbia”, Belgrade, Serbia

In the Public company Nuclear facilities of Serbia, measurement of the operational dosimetric quantity- ambient dose equivalent-H*(10), is continuously carried out at measurement points in the surrounding of the radioactive waste storage facilities (hangars H1, H2 and H3) and old reactor buildings (RA and RB), located at Viča site in Belgrade. For that purpose, two different types of passive dosimeters are used: Thermoluminescent (TL) high sensitivity dosimeters (LiF:Mg,Cu,P) and optically stimulated luminescence dosimeters, OSL dosimeters ($Al_2O_3$). The principle of radiation interaction with both types of material is very similar, and the main difference is reflected in the method of reading the accumulated dose in the dosimeter. Measurement of the ambient dose equivalent is performed at 34 measuring points in order to monitor the level of radiation exposure in the vicinity of mentioned facilities. The paper shows the results of measurements in the period from January to December of 2016. TL and OSL dosimeters were used and read at the same time, under the same measurement conditions, once a month. The aim of this paper is to present comparative results of the ambient dose equivalent measurements using TL and OSL dosimeters and compare it with the measurement results using reference instrument for measuring dose rate (Atomtex AT6101C spectrometer) at the same measuring points. It was found that differences among measurement results using different dosimeter types are satisfactory, with a maximum deviation of 15%. The results also show that there is no significant increase in the level of radiation exposure, which is of particular importance to the environment and the population around nuclear facilities in Serbia.

## READMON: A PORTABLE RADIATION MONITORING SYSTEM BASED ON THE CERN PH-RADMON DOSIMETERS

**Isidre Mateu, Maurice Glaser, Georgi Gorine, Michael Moll, Giuseppe Pezzullo, Federico Ravotti**

CERN, Geneva, Switzerland

The ReadMon system, currently under development at CERN, is an instrument aiming at the measurement of Total Ionizing Dose (TID) and 1 MeV neutron equivalent fluence ($\phi_{eq}$) for radiation damage in semiconductor components. It is based on the readout of the PH-RADMON sensors, which are widely used for radiation monitoring at the CERN Large Hadron Collider (LHC) accelerator and its experiments. The sensor can be equipped with different devices: RadFETs for the TID measurement (from 0.1 Gy to $10^5$ Gy) and silicon p-i-n diodes to monitor $\Phi_{eq}$ (from $10^{10}$ to $10^{15}$ $n_{eq}/cm^2$). The purpose of the ReadMon system is to widen the range of application of these sensors outside the CERN LHC. Together with this new readout electronics, the PH-RADMON sensors could be used as reference system for dosimetry in irradiation test facilities, but also in several other fields such as medical therapy, nuclear, industry or material testing. A single ReadMon unit can readout up to 8 PH-RADMON sensors over cables up to several hundred meters, thus allowing to monitor radiation in different locations inside the radiation field, while keeping the electronics far from the potentially harsh radiation environment. The instrument is equipped with an Arduino microcontroller running a web server to which the user can connect and parametrize the data acquisition, thus working as a stand-alone system. Optionally, it can also be interfaced with other systems using simple HTTP requests. Both Ethernet and Wi-Fi connectivity are supported.

In this paper, we describe the principle of operation, including the full description of the readout circuit, the calibration procedure and a detailed analysis of the system performance. Results of characterization tests at different temperatures are also reported.

Moreover, the results of two different irradiation tests, performed at the CERN proton irradiation facility (IRRAD), are presented. In the first test, lasting a few months, a PH-RADMON sensor was placed in the bunker area outside the path of the proton beam, thus monitoring the secondary radiation field generated by the high-energy 23 GeV protons interacting with the samples undergoing irradiation and the surrounding air volume. The ReadMon unit was installed in the control room of IRRAD, and connected to the sensor in the bunker through the cabling infrastructure of the facility. A detailed data analysis, comparing the results with other passive dosimeters installed together with the PH-RADMON sensor, is performed. For the second test, lasting a few days and carried out during a run with high-energy Xe ions in IRRAD (6-7 GeV/n), the PH-RADMON sensor was installed directly inside the beam. Even with a low intensity ion flux, the different dosimeters showed evidence of both very high ionizing and non-ionizing energy loss. In view of these results, the effects of heavy ion irradiation on both the PH-RADMON RadFETs and the p-i-n diodes will be discussed.

# CALCULATION OF EFFECTIVE ANGULAR CORRELATION CORRECTIONS IN THE SUM-PEAK METHOD

**Tomas Nemes[1], Dusan Mrdja[2]**

1 Faculty of Technical Sciences, Novi Sad, Serbia
2 Faculty of Sciences, Novi Sad, Serbia

To achieve higher accuracies in the absolute source activity measurement with a single detector, angular correlation corrections have to be taken into account. There are two ways to calculate these corrections: Monte Carlo method and exponential attenuation law. Both approaches are applied and compared for different gamma cascade emitting radionuclides.

# MEASUREMENT OF THE INTERNAL PAIR-PRODUCTION BRANCHING RATIO IN THE $0^+ \rightarrow 0^+$ TRANSITION OF $^{90}$Zr: APPLICATION IN MEDICAL IMAGING

**Giuseppe Lorusso[1,3], Alberto Boso[1], Rhiann Canavan[1], Sean Collins[1], Frederic Juget[2], Robert Shearman[1]**

1 NPL, Teddington, United Kingdom
2 CHUV, Lausanne, Switzerland
3 University of Surrey, Guilford, United Kingdom

Yttrium-90 ($^{90}$Y) has many properties that make it an ideal radionuclide for targeted internal therapy and is one of the widest used. It is one of a handful of radionuclides that is considered a pure beta-emitter, but a very small decay branch (~$10^{-5}$) to the first ($0^+$) excited state of $^{90}$Zr at 1.76 MeV results in emission of positron-electron pairs that have been successfully used for PET/CT system to image $^{90}$Y in both patients and phantom studies. This may open the possibility to use this isotope for quantitative image dosimetry with major consequence for health care and the possibility of tailoring therapy to an individual patient's response. For this application, however, the accurate knowledge of the pair-production emission probability is fundamental. The three existing measurements reporting values of $3.6 \pm 0.9 \times 10^{-5}$, $3.4 \pm 0.4 \times 10^{-5}$, and $3.186 \pm 0.047 \times 10^{-5}$, respectively, do not fully agree with each other, and the most recent measurement suffered from large background.

This motivates our new measurement using two different approaches. The first employs the magnetic spectrometer of the Ecole Polythecnique Federal de Lausanne (Switzerland) to detect positrons and filter out the much larger amount of beta radiation emitted in the ground-state-to-ground-state transition. The spectrometer consists of a semi-circular vacuum chamber containing a pair of poles and coils. The poles are shaped to produce a magnetic field that focusses electrons in both the horizontal and vertical planes. The radius of the central trajectory is 180 mm. A silicon detector in the focal plane provides the trigger signal and additional background rejection.

A second and complementary approach employs an array of 12 $LaBr_3$ detectors setup at the National Physical Laboratory (UK) to detect the 511-keV radiation following electron-positron annihilation. In this case, the large amount of bremsstrahlung background radiation is very efficiently rejected by identifying gamma-rays emitted back-to-back and within a small (~100 ps) time window. Detector signals are processed using a timestamped digital data acquisition system and pulse shape analysis techniques.

In this contribution we will present the experimental setups, their accurate characterization, and the preliminary result of the pair-production branching ratio measurements. We will also briefly discuss the future plans to test $^{90}$Y quantitative dosimetry using phantoms at NPL.

# DOSE VERIFICATION AND MODELLING OF A RADIOCHROMIC FILM IN THE MONTE CARLO CODE

**Adrianna Tartas[1], Maciej Gałecki[1], Beata Brzozowska[1], Paolo Pellicioli[2], Mattia Donzelli[2], Elke Bräuer-Krisch[2]**

1 Biomedical Physics Division, Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
2 European Synchrotron Radiation Facility, Grenoble, France

The precision of dose delivery is crucial for radiotherapy purpose and accurate dosimetric measurements are needed. A radiochromic film is a dosimeter which is typically used for the dose distribution verification in radiotherapy. It is based on a polymerization reaction of a chemical active layer upon irradiation causing colour changes of the film.

The purpose of the study was to model a radiochromic film using Monte Carlo methods. Simulations were performed with the radiation transport simulation toolkit Geant4 (GEometry ANd Tracking) and compared with the experimental data. As a radiosensitive film, Gafchromic HD-V2 Dosimetry Film (Ashland Global Specialty Chemicals Inc., the USA) was used. It has a resolution of a few micrometers which makes its suitable for an application to Microbeam Radiation Therapy (MRT). The MRT uses extremely high doses which are delivered in spatially X-ray fractionated microbeams. The technique is characterized by difficulties of dose measurements, because of required spatial accuracy and dose pattern including high differences in dosage. In the presented project the radiochromic film model was implemented and tested. The dose pattern was simulated and compared with the experimental data collected in European Synchrotron Radiation Facility, Grenoble.

# THE UNCERTAINTIES OF PERSONAL NEUTRON DOSIMETERS AT VARIOUS OPERATIONAL NEUTRON FIELDS

**Maria Pyshkina, Michael Zhukovsky, Aleksey Ekidin**

Institute of Industrial Ecology UB RAS, Ekaterinburg, Russia

The effective dose is generally considered to be an adequate indicator of the health detriment from radiation exposure at the levels experienced in normal operations. The operational quantity for the effective dose assessment in personal monitoring is the personal dose equivalent $H_p(d)$ at the depth of 10 mm.

Uncertainties of $H_p(10)$ and effective dose measurements obtained by thermoluminescent (TL) albedo and electronic personal (EP) dosimeters were studied in this paper.

The method of albedo assumes that neutrons undergoing backscattering events within a moderator (human body), lose energy until they thermalize and then are detected by personal dosimeter $^{6}$LiF. Taking into account the influence of gamma radiation, accompanying neutron fluxes, is taken into account using the second $^{7}$LiF dosimeter not sensitive to neutrons. Semiconductors behave like solid state ionization chambers with an advantage of a lower energy for the creation of an electron-hole pair in Si detector.

The possibility of using of personal neutron dosimeters, calibrated in different reference spectra, in the operational fields was analyzed. The published data on calibration spectra, response functions of TL albedo and EP dosimeters and operational fields at working places were used during analysis. The spectra of $^{238}$Pu-Be, $^{252}$Cf and $^{252}$Cf with iron and polyethylene moderator were considered as calibrating spectra. Operational neutron spectra at working places were chosen in way to cover as wide range of neutron energies as possible. The response functions of TL albedo and EP dosimeters from different sources also were used in this work.

As the first step, calibrating factors for dosimeters was determined for different calibration spectra. At the second step, the assessment of $H_p(10)$ based on different calibration conditions was calculated for operational fields at working places.

It was obtained, that TL albedo dosimeter, calibrated in high-energy fields such as 238Pu-Be and 252Cf, overestimates the $H_p(10)$ and uncertainty varies from 58% up to 10500%. On the other hand, dosimeter, calibrated in moderated fields such as 252Cf with iron and polyethylene moderator, underestimates $H_p(10)$ in high-energy operational fields with uncertainty from 40 % up to 80 %. At the same time it overestimates $H_p(10)$ in “soft” fields and uncertainty is from 92% up to 580%. The EP dosimeter has the same tendency as TL albedo dosimeter, calibrated in moderated fields. It underestimates the effective dose of high-energy operational fields and overestimates it in “soft” fields for any calibration spectrum. For high energy fields uncertainties are in the satisfactory range from 13% up to 47%. For “soft” fields range of uncertainty for EP dosimeters is from 20% up to 580%,

It is concluded that for correct personal neutron dosimetry it is necessary either to know the neutron spectra on working place or calibrate personal dosimeters in real operational neutron fields

# EBT3 RADIOCHROMIC FILM RESPONSE TO DIFFERENT RADIATION FIELDS

**Francesco Di Capua, Luigi Campajola, Pierluigi Casolaro**

Università Federico II and INFN, Napoli, Italy

In many applications, the dosimetry plays a fundamental role to assure the delivery of demanded dose, as in Radiation Hardness Assurance test or in High Energy Experiment to monitor critical parts of the detector. Radiochromic films are dosimeters massively used in such applications and in medical physics for therapy with particle beams, X and gamma radiations. Moreover, the exposed film retains memory of dosimetric information, making it a suitable instrument for certificate the dose.

EBT3 type is widely used, giving response from cGy to tens of Gy. It consists of a thin film made of a single layer of radiation-sensitive material sandwiched between two polyester foils. The active layer, due to its chemical properties, exhibits an increased darkness with the increase of the absorbed dose. The EBT3 response and the comparison of exposures to different fields have been partially reported in many papers in a limited range of dose, as for example for photons and electrons or for photons and protons.

In this work, for first time, is presented the characterization of the response for a set of EBT3 Gafchromic films to photons, electrons and protons radiation fields for a wide dynamic range, from fraction of Gy up to 150 Gy. Many different radiation sources has been used in this study: 250 kV SIEMENS X-ray tube, $^{60}$Co gamma source, $^{90}$Sr/$^{90}$Y beta source, 1 MeV electrons from ILU6-LINAC accelerator of Institute of Nuclear Chemistry and Technology in Warsaw, 23 MeV protons from tandem accelerator of Laboratori Nazionali del Sud of INFN, 50 and 200 MeV protons from cyclotron of Paul Scherrer Institute.

The response of the films to a single radiation type was characterized with respect to the surface dose. The dose of X and gamma radiation fields have been evaluated by referring to certified sources. Moreover, during the irradiations, the dose was controlled by means of independent measurements performed with ionization chambers and Fricke dosimeters.

The dose response was found to be absolute, that is independent of the incident radiation type. The film response was also found independent of dose rate used in the test. The grey Pixel Value versus the surface Dose shows a characteristic trend well represented by the Green-Saunders equation. The best fit parameters of the fitted equation are in excellent agreement with each other by changing radiation type. The dynamic range of the films was seen to be wider respect to what declared by the manufacturer. A resolution in the dose determination well below 5% is achieved in the present work.

These important features make EBT3 radiochromic films a valuable tool for dosimetric applications in mixed field radiation, in radiotherapy and adrontherapy applications and for monitoring of dose in High Energy Experiments and Radiation Hardness applications as well. The same study will be performed also on HDV2 type of radiochromic films that have a different dose range response shifted toward higher values.

# CHARACTERISATION OF THE TRIGA MARK II REACTOR RADIATION FIELD WITH THERMOLUMINESCENCE DETECTORS

**Klaudia Malik[1], Barbara Obryk[1], Klemen Ambrožič[2], Luka Snoj[2]**

1 Institute of Nuclear Physics Polish Academy of Sciences (IFJ), Kraków, Poland
2 Jožef Stefan Institute (JSI), Ljubljana, Slovenia

Thermoluminescence detectors based on LiF are widely used for dosimetry, also at mixed radiation fields (*Radiat. Meas.* 43, 315-318, 2008, *Radiat. Meas.* 46, 1882-1885, 2011). Based on the high-temperature behaviour of LiF:Mg,Cu,P detectors at high and ultra-high doses, a new method of TL measurement of radiation doses ranging from micrograys up to a megagrey, has been developed at the IFJ (*Radiat. Meas.* 46, 1882-1885, 2011).

Highly sensitive $^{nat}$LiF:Mg,Cu,P (MCP-N) and $^{7}$LiF:Mg,Cu,P (MCP-7) TLDs detectors were manufactured at IFJ PAN in Kraków, Poland. Due to a large difference in the Li-6 and Li-7 isotopes' neutron capture cross sections, the combination of $^{nat}$LiF /$^{7}$LiF detectors allows to distinguish between neutron/photon components of radiation field. Fifty dosimeters were prepared – every dosimeter consisted of three detectors of each type.

The TRIGA Mark II reactor at the Jožef Stefan Institute (JSI) is light-water research reactor suitable for irradiation of various samples and due to a number of irradiation channels of different fluxes, spectra, and dimensions also very adaptable (*App. Rad. Iso.* 70, 483–488, 2012). The reactor core, placed at the bottom of the open aluminium tank, has an annular configuration. Part of the experimental samples have been placed in the reactor core i.e. Central Channel, F26 and fast pneumatic transfer system. In the graphite reflector surrounding the reactor core, TLD samples have been placed in one representative irradiation channel – IC40. The reactor power during the experiment was altered from 0 W up to 2.5 MW.

The purpose of this experiment was to characterise the radiation field in terms of dose rate during operation and after reactor shutdown. The experiment confirmed the effectiveness of the TL detectors in the mixed radiation field measurements and their usefulness in measuring high doses. Comprehensive results of these studies will be presented during the Conference.

# DEVELOPMENT AND CHARACTERIZATION OF GRAPHITE IONIZATION CHAMBER AT IONIZING RADIATION LABORATORY AT GUM

**Piotr Tulik[1], Adrian Bożydar Knyziak[2], Michał Derlaciński[2]**

1 Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, Warsaw University of Technology, Warsaw, Poland
2 The Central Office of Measures, Laboratory of Ionizing Radiation, Warsaw, Poland

A graphite ionization chamber with sensitive volume of 0.5 $cm^3$ was developed at Ionizing Radiation Laboratory at GUM (Central Office of Measure), Poland with cooperation of Group for Biomedical Engineering from Institute of Metrology and Biomedical Engineering of Warsaw Technology University to be used as primary standard for air kerma of Co-60 and Cs-137 at GUM (Central Office of Measure) which is Poland's NMI (National Metrology Institute). The cylindrical ionization chamber with walls and collecting electrode made of high purity graphite with density of 1.81 $g/cm^3$ with heat-shrink tubing of 4kV used as isolator, all parts were glued with epoxy resin. The chamber was tested and correction factors were determined with experimental methods (polarity effect, ion collection, saturation, steam effect, short- and medium term stabilities, leakage current) and Monte Carlo evaluations using EGSnrc (wall effects, nonaxial uniformity, stopping powers, energy absorption). The air kerma rate obtained with chamber was compared with results from current primary standard (chamber ND-1005) and showed good agreement. Dimensions of chamber were determined using CT and radiography methods. Radiography method was developed at Ionizing Radiation Laboratory. After key comparison at BIPM (International Bureau of Weights and Measures), Ionizing Radiation Laboratory will decide if chamber may be used as primary standard for air kerma of Co-60 and Cs-137 at GUM (Central Office of Measure).

# LabSOCS VS ANGLE FOR HPGe EFFICIENCY CALCULATIONS

**Ivana Tucaković[1], Jovana Nikolov[2], Željko Grahek[1], Nataša Todorović[2], Ivana Coha[1], Dušan Mrđa[2], Goran Stanić[2]**

1 Ruđer Bošković Institute, Zagreb, Croatia
2 University of Novi Sad, Faculty of Sciences, Novi Sad, Serbia

High resolution gamma-ray spectrometry is a nuclear analytical technique widely used for a determination of radionuclides in various kinds of samples. The quantitative determination requires a high accuracy of a detection efficiency determination. It can be done by using the standard calibration materials with known activities or in a mathematical way by detector and sample setup modeling. The aim of this work is to compare different methods and softwares used for the efficiency calibration modeling and analyses. For that purpose, the same samples of vegetation and soil of known activities were measured using HPGe detectors in two laboratories which are using different software for the mathematical efficiency calibrations and analyses. The Laboratory for Testing Radioactivity of Samples and Doses of Ionizing and Non-Ionizing Radiation at University of Novi Sad uses semi-empirical approach to derive the efficiency for different containers, sample materials, and sample positions done by Angle software (Ortec). In Laboratory for radioecology of the Ruđer Bošković Institute in Zagreb the analyses are done using Canberra's Genie 2000 software and the efficiency calibrations by LabSOCS tool from the same producer. All the obtained spectra are analysed by both laboratories. The results are compared and confronted with the referenced values in order to check the accuracy and precision of the methods used. The main advantages and disadvantages of both softwares are compared.

# DOSIMETRY IN NEUTRON FIELDS OF BINP ACCELERATORS WITH INTENSE LOW ENERGY PART OF SPECTRUM USING TLDs WITH LiF

**Mikhail Petrichenkov, Vladimir Chudaev, Anatoliy Repkov, Vladimir Eksta, Nataliya Shamakina, Sergey Melnik**

BINP, Novosibirsk, Russia

There are electron-positron colliders and accelerator based neutron source for boron neutron capture therapy (BNCT) being in operation at Budker Institute of Nuclear Physics (BINP). Personal dosimetry and monitoring of controlled areas require the use of certified means. Thermoluminescent dosimeters (TLDs) DVGN-01 (AKIDK-301 measuring complex) with Lithium Fluoride (LiF) are of this kind in Russia, but they have too high response to low energy neutrons. Average energy of “ideal” neutron spectrum for BNCT is 10-13 keV, for example. Fortunately there is “dosimeter of effective dose” method developed at Institute of High Energy Physics (IHEP, Russia), allowing correction of TLD response to neutrons. We have determined in experiments these correction coeffcients for neuron field behind shielding of VEPP-2000 collider and got preliminary results for BNCT facility. For H*(10) they are 1/16 and 1/21 correspondingly.

# STUDIES ON THE CHARACTERISTICS OF ALANINE DOSIMETERS IN STEREOTACTIC RADIOSURGERY

**Elena Iliescu[1], Sorin Bercea[1], Catalin Tuta[1], Aurelia Celarel[1], Stela Patrascu[1], Constantin Cenusa[1], Fery Stoica[2], Rodica Stempurski[2]**

1 “Horia Hulubei” National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania
2 “Bagdasar-Arseni” Emergency Hospital, Bucharest, Romania

The reference dosimetry in stereotactic radiosurgery (SRS) for ionizing radiation treatments using the linear accelerator (LINAC) is achieved by measuring the absorbed dose in water (Dw) in a large field of reference radiation (10x10 $cm^2$) and using an output factor, which is the difference between the conventional reference radiation field and the small field of interest in SRS. Unlike LINAC, for other types of specific equipment, such as the Leksell Gamma Knife (LGK), the large 10x10 $cm^2$ reference field required by existing protocols, does not exist. In these cases, the determination of the absolute dose in water for SRS treatment is frequently done by calculating the product of the water absorbed dose (Dw), measured in the largest available radiation field (generally having a diameter of 16 mm or 18 mm) using a small volume ionization chamber according to conventional protocols and the output parameter provided by the manufacturer (or user) for each treatment area.

After many years of research, major concerns for reference dosimetry in the radiation fields used in SRS remain. This is due to the difficulty of making accurate dose measurements, difficulties caused by various factors such as:

- partial closure of the photon beam in the measuring point;
- the absence of the charged particle balance;
- the gradient of the absorbed dose rate;
- the effect of the average volume on the detector response;
- fluctuation of photon fluctuations in the lateral direction of the beam

Because of these difficulties, ideal dosimeters for use in these fields of application of ionizing radiation should be water equivalent and also should be small in size and provide a sub millimetric resolution.

The ionization chambers, which are commonly used in clinical dosimetry, are not suitable for small and non-standard fields of radiation because of lack of spatial resolution on the one hand and lack of precision in measuring the absorbed dose, caused by the photon fluctuation disturbance.

Data from the literature presents the analysis of the use of passive dosimeters for reference dosimetry in small fields (subject to acceptable measurement accuracy). Various types of passive dosimeters (radiochrome films, TLD, alanine) have been used for measurements in radiation fields with a diameter of between 4 mm and 35 mm in a LGK equipment. Dosimeters were calibrated in terms of the absolute dose in water (Dw), using a calibrated ionization chamber calibrated in a calibration laboratory.

The alanine dosimeter can provide high precision, but not for fields with a diameter of less than 20 mm, whereas TLDs are not suitable for fields smaller than 10 mm in diameter; a suitable method in these cases remains radiochromic film dosimetry (Gafchromic).

# EFFECTS OF STORAGE ON THE LUMINESCENCE RESPONSE OF CERTAIN SPICES

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

Faculty of Electrical Engineering and Information Technologies, Ss Cyril and Methodius University in Skopje, Skopje, Macedonia

Application of ionizing radiation is a well known method for preservation of food by reducing the number of harmful microorganisms and toxins, delaying ripening and preventing sprouting. European and national legislation specifies the special requirements for irradiated food, including its proper detection. Different kinds of detection methods are now developed, all of them based on detection of changes in food caused by the irradiation treatment. Photostimulated luminescence (PSL) is one of the first applied methods for detection of irradiated food. The physical explanation of this method lies in the structure of minerals found in certain foodstuffs. When minerals are exposed to ionizing radiation, they accumulate energy by which some electrons move to higher energy states. When returning to ground state, they may remain trapped in some imperfections of the crystal lattice. When these minerals are exposed to light trapped electrons are released and recombination with holes occurs, resulting in emission of photons, i.e. a luminescence signal is obtained. The intensity of this signal identifies the sample as irradiated or unirradiated. PSL measurements are performed according to the standard EN 13751 Foodstuffs – Detection of irradiated food using photostimulated luminescence.

When heat is used instead of light as stimulation, the method is called thermoluminescence (TL). In order to verify and confirm PSL results, TL should be applied after the initial PSL measurements. Because of the variety of food samples, a control sample cannot be used, so TL analysis is done twice for each sample. The first measurement is done after the isolation of minerals and detection of the TL signal. The second measurement is done after exposing the sample to a certain dose of ionizing radiation and detecting the TL signal. 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. Magnitude of TL glow ratio and shape of TL glow curves can identify the sample as irradiated or unirradiated. Minerals are isolated according to the standard EN 1788 Foodstuffs – Thermoluminescence detection of irradiated food from which silicate minerals can be isolated.

PSL measurements for this study are done on certified samples, including unirradiated paprika standard and irradiated paprika standard. Tested samples are then stored for a long time in laboratory conditions, after which PSL measurements are repeated. In order to confirm the results, TL measurements are performed. All samples are correctly identified as irradiated or unirradiated by repeating the PSL measurement, even though a reduction of the PSL signal is observed after storage. Results are confirmed by TL measurements. This shows that PSL and TL may be used as proper methods for detection of irradiated food even after storage of food for long periods of time.

# PREPARATION OF THE RECOMBINATION CHAMBER USE IN ENVIRONMENTAL MEASUREMENTS

**Łukasz Murawski, Michał Kuć**

National Centre for Nuclear Research, Otwock, Poland

REM recombination chambers are one of the most sensitive radiation detectors one can actually use. Its radiation sensitivity depends on its volume, pressure and type of gas filling the chamber. The value of sensitivity factor is about hundreds pA/mGy/h. One of the biggest advantages to use this chamber is its sensitivity on different types of particles. Additionally, as a phantom detector, it can be used to determinate biological effects within its volume. Recently, the use of this type of detector in environmental measurements has been considered. That kind of measurement will be particularly desirable in solar flares and cosmic radiation detection. In order to guarantee proper measurement outside the laboratory it is needed to estimate how temperature changes affect the detector. Although temperature calibration of the REM chambers was done before, it was performed only for static or semi-static temperatures. This paper presents influence of the environmental temperature fluctuation on the detector. It is shown that dynamic changes of temperature have significant impact and leads into slightly incorrect measurements. In order to achieve better measurements quality for the natural radiation background level measurements, this correction for temperature changes must be investigated and considered. Also the stabilization time of the detector is influenced by the temperature changes. This research was carried out in a climatic chamber. The measurements were done in several configurations (e.g. only detector in climatic chamber, only cables in climatic chamber and detector with the cables in climatic chamber) and with several different rates of temperature changes. This investigation is the first step towards proper use of the REM recombination chambers in environmental measurements, especially for, mentioned earlier, solar flares and cosmic radiation detection. There was conducted an experimental measurement outside laboratory – on top of the High Mountain Meteorological Observatory on Kasprowy Wierch (Poland). It was placed on about 2000 m.a.s.l. height with very dynamic weather changes there. The results of the measurements will be also shown with conclusions regarding future experiments. There are the plans to use REM type recombination chambers as a part of the solar flare detection system in different measurement points in the country or in Europe.

# THE STUDY ON A LOW RADIOACTIVE BACKGROUND HPGe SPECTROMETER AT A SURFACE LABORATORY

**Tao Hu**

Institute of High Energy Physics, CAS, Beijing, China

Due to their high energy resolution and efficiency, HPGe detectors are widely used to analyze the radioactivity of materials which is very important for low background experimental research, such as neutrino experiments and dark matter search. To achieve the ultra low radioactive background, the HPGe detector is often setup in the deep underground which is inconvenient. It's very helpful to study a low background HPGe spectrometer at a surface laboratory.

In order to reduce the environmental background for an ultra-low background HPGe spectrometer, low-activity lead and oxygen free copper are installed outside the probe to shield from gamma radiation, with an outer plastic scintillator to veto cosmic rays, and an anti-Compton detector to improve the peak-to-Compton ratio. The HPGe spectrometer include the geometry of each detectors are optimized by simulation tool GEANT4 before construction. The simulation results and the final performance of spectrometer include the background rate, peak-to-Compton ratio and sensitivity will be presented.

# DETERMINATION OF Cs-137 INVENTORY IN A DISTURBED AREA USING IN-SITU AND LABORATORY GAMMA-RAY SPECTROMETERS

**Jong In Byun[1], Don Sik Ham[1], Tae Woo Gang[2]**

1 Korea Institute of Nuclear Safety, Daejeon, South Korea
2 National Institute of Environmental Research, Gwangju, South Korea

In order to determine the Cs-137 inventory in the disturbed soil after deposition on the ground due to global fallout, in-situ and laboratory gamma-ray measurements were carried out using portable and fixed HPGe (High Purity Germanium) detectors with relative efficiency of 30%. The vertical and horizontal distributions of the Cs-137 were estimated through core sample analysis and in-situ measurements, respectively. Nine core samples (50 mm in diameter by 270 mm long) were collected, and they were separated into 50 mm depth intervals. The Cs-137 concentrations and inventory were performed at one meter height above the ground, in order to directly estimate the Cs-137 inventory. The portable HPGe detector was calibrated using point-like disk sources considering angular correlation, and the gamma-ray fluxes at one meter above soil were calculated using mathematical modeling with the concentration depth-profiles. The Cs-137 inventories by sampling and in-situ methods were compared with each other, and the MDCs of other anthropogenic radionuclides were estimated.

# COMPARISON OF ALGORITHM FOR NEUTRON AND GAMMA SEPARATION

**Zdenek Matej[1], Ales Jancar[2], Zdenek Kopecky[2], Herman Ondrej[1]**

1 Masaryk University, Brno, Czech Republic
2 VF, a.s., Cerna Hora, Czech Republic

Many different methods for separating neutron events from photon events based on the pulse waveform have been developed and their implementation is available. To improve the separation of gamma and neutron events using pulse shape analysis, data about the types of particles obtained using the time-of-flight method could be exploited to identify a metamethod based on the output of the available separation methods, combining their strengths.

When colliding with the mass of a scintillator, both photons and neutrons cause molecules of the scintillating material to move into an excited state. The deposited energy is later released as light, which can be detected and converted to electric current in a photomultiplier tube for further processing (S. Pošta, Digitální zpracování výstupních dat ze spektrometrického detektoru neutronů a záření gama, 2011).

The mechanisms by which these scintillations are created differs for photons and neutrons, and this fact can be exploited to determine the type of the incident particle. Photons deposit energy in the target material by the Compton effect – interacting with electrons in the atomic shell. This causes the molecules of the scintillator to move into singlet excited states. The molecules then quickly release the energy as light by the prompt fluorescence mechanism (G.F. Knoll. Radiation Detection and Measurement, 2nd ed. Wiley, 2000).

In case the incident particle is a neutron, it exchanges its energy with an atomic nucleus by the inelastic scattering effect, ejecting acharged particle – alpha or proton, which have the ability to excite the molecules into the slower-decaying triplet excited states (G.F. Knoll. Radiation Detection and Measurement, 2nd ed. Wiley, 2000).

Many different PSD (pulse shape discrimination) methods for determining the type of the incident particle based on shape of the pulses generated by scintillation detectors have been developed. For a review of the methods, see Moslem Amiri. (Neutron/gamma-ray measurement and discrimination, Mas. uni., Brno, 2014) and (Z. Matej, Digitalization of spectometric system for mixed field of fast neutrons and gamma radiation, Dis. work. Mas. uni., Brno, 2014).

The discrimination parameter of a separation method is stored, along with the energy information for every detected particle, in the so-called PSD matrix. The convention used in this work is such that the vertical axis represents the energy deposited by the particle and the horizontal axis gives the value of the separation parameter, which varies depending on the type of the particle. The color at every point represents the amount of the events that occurred with the given energy and discrimination parameter. The implementations of the different separation methods used in this work have been developed in (L. Bacinska et al. Implementace diskriminacnich metod pro dvouparametricky gama/neutronový spektrometr, Mas. uni., 2014).

The methods used are: Integration method, Amplitude difference, Amplitude difference improved, Angle, Integral, Length, Length v2, Risetime amplitude difference, Risetime improved, Risetime, Rising edge, Mean vs standard deviation, Partial integration, Polynomial interpolation, Least squares method, Simpson's rule, Simpson38, WBO, Lebreton, Frequency Gradient Analysis, Votes, Simpson composite delta, Exact point – relative.

# CHARACTERIZATION OF THERMOLUMINESCENT RESPONSE OF LiF: Mg, Ti DOSIMETER AT DIFFERENT DOSES OF BETA RAYS WITH RISØ TL/OSL DA-20 READER AT LOW AND UPPER DOSE LIMIT

**Aleksandar Krleski[1], Margarita Ginovska[1], Hristina Spasevska[1], Sonja Petkovska[2]**

1 Faculty of Electrical Engineering and Information Technologies (FEEIT), "Ss. Cyril and Methodius" Univerzity in Skopje, Skopje, Macedonia
2 Radiotherapy and Oncology Department, Clinical Center Acibadem Sistina, Skopje, Macedonia

The Risø TL/OSL DA-20 reader is originally designed for usage in the geo and archetypal dating. It is later used in the examination of foods treated with ionizing radiation and retrospective dosimetry. This paper aims to characterize thermoluminescent dosimeters through its use by examining parameters such as stability, reproducibility, abilities to measure the low and its behavior at the upper limit doses. In the paper is performed an analysis of thermoluminescent curves obtained for different groups of dosimeters, LiF: Mg, Ti (MTS-100, MTS-600 and MTS-700). Also, a comparison was made regarding the differences in the temperature profiles, the spectral sensitivity, and the intensity of the thermoluminescent response. Linearity and the supralinearity are transmitted within the different range for each individual type of this group of dosimeters. It has been found that the use of filters with different optical characteristics can significantly extend the measurement range. All examined dosimeters have reproducibility that fits the prescribed standards.

**Key words:** Thermoluminescent reader, low doses, upper limit doses, MTS, Risø TL/OSL DA-20.

# METHODOLOGY OF PERSONAL DOSE ESTIMATION IN MIXED BETA AND GAMMA RADIATION FIELD USING THERMOLUMINESCENT DOSIMETERS

**Zuzanna Baranowska[1], Iwona Słonecka[1,2], Katarzyna Wołoszczuk[1]**

1 Central Laboratory for Radiological Protection, Warsaw, Poland
2 University of Technology Faculty of Physics, Warsaw, Poland

Ionizing radiation is widely used in both industry and medicine. Frequently, people working with radiation are exposed to more than one type of it. Because of its low penetration, beta radiation is often neglected compared to gamma radiation during exposure estimation. However, it is important to remember that although it is not very penetrating, its biological effectiveness is equal to gamma radiation and is important for estimating doses equivalent to skin, limbs and eyes. This work presents a methodology for estimating the percentage of beta and gamma irradiation in an individual dose equivalent of the whole body with the use of thermoluminescent detectors (TLD).

In this work were used thermoluminescent detectors type MCP-N made of LiF:Mg,Cu,P. These are popular detectors used to routinely control workers exposure to ionizing radiation. The study was conducted on tablets placed in a base case containing four pellets, three of which are covered by an aluminum filter, and the fourth is exposed in two types of additionally used dosimeter protection cover – Plexiglass cover with uncovered pill in the fourth position and Plexi cover with additional black foil covering the fourth tablet.

Irradiation was performed at the Central Laboratory for Radiological Protection using of accredited beta and gamma radiation sources. The detectors were irradiated with various doses of beta or gamma radiation and in a mixed beta-gamma field. All radiations were made using slab phantom. To achieve mixed field detectors were exposed to beta radiation and then was made another exposure – to gamma radiation. As the source of beta radiation we used Beta Secondary Standard (BSS2, Beta Secondary Standard) for Sr-90/Y-90 and Kr-85 radionuclides. As a source of gamma radiation we used the source of Cs-137 at the gamma calibration station.

Based on research the calibration factor for all used radiation sources was calculated. The dependence of readout and type of used cover was also defined. It allowed developing a methodology for determining the percentage of beta and gamma radiation in the mixed field and to calculate the individual dose equivalent of Hp(10) from gamma radiation and Hp(0.07) from beta radiation.

# BACKGROUND MEASUREMENT AND MODELLING

**Kremena Ivanova[1], Bistra Kunovska[1], Konstantinos Potiriadis[2]**

1 National Centre of Radiobiology and Radiation Protection, Sofia, Bulgaria
2 Greek Atomic Energy Commission, Athens, Greece

The investigations of radioactive contamination take a lot of systematic activities for understanding, interpreting and analysing the data. The phases which were taken for assessment of environmental data have been presented in this paper. The first step is the background measurements, which were carried out to obtain a detailed understanding of radionuclides present in area. The gamma dose rates were determined with field detector and soil samples from the background areas were taken to define the natural radioactivity on the site and distribution on depth. In addition the background spectrum was collected with field gamma spectrometry. The Monte Carlo simulation to achieve the spectral data from a Cs-137 source in order to compare with real measurement has been used.

# SPECTRAL PROPERTIES OF IRRADIATED POTASSIUM CHLORIDE CRYSTALS

**Ewa Mandowska, Renata Majgier, Arkadiusz Mandowski**

Institute of Physics, Jan Dlugosz University, Częstochowa, Poland

Alkali halides are well-known wide band gap (Eg = 8–12 eV) materials, which are very important for luminescence dosimetry. Many of them exhibit pronounced thermoluminescence (TL) and optically stimulated luminescence (OSL) after irradiation by high-energy photons or particles. Sodium chloride (table salt) exhibits very strong defect-related luminescence. For this reason NaCl was considered for its potential use for retrospective and accidental dosimetry. It was shown also, that the natural mineral (halite) allows determination of the age of sediment formation and thus tracing climate changes and geomorphology processes. KCl luminescence properties are much less known. The material was investigated mainly in its doped form, primarily with europium. KCl:Eu was considered as two-dimensional X-ray and UV imaging sensor as well as dosimeter in radiotherapy. Typical TL measurements of pure KCl were investigated from the sixties mostly at low temperatures after X-ray, gamma and alpha irradiation.

Spectrally resolved thermoluminescence (SR-TL) measurements were performed for nominally pure KCl single crystals and pellets. Before the measurements KCl samples were annealed for 1h in 650 C in the air, then immediately cooled and irradiated by a beta source with various doses. Non-annealed samples exhibited much lower luminescence. All irradiations were done at room temperature by $^{90}Sr/^{90}Y$ beta source with activity of 2.9 GBq. After irradiation any exposure to ambient light was avoided. The SR-TL was carried out in vacuum using optical chamber with quartz windows using heating rate of 0.7 K/s at the temperature range 300–550 K. During SR-TL investigations each sample was used only once.

In general, the TL-3D spectra showed a compact region of luminescence emission in the temperature range of 300-550 K and the wavelength range of 350-650 nm. The emission was found with a maximum at ca. 420 nm for crystals and pellets. Deconvolution in energy domain allowed to identify four broad Gaussian peaks in both types of samples, with maxima ranging from 403 nm to 520 nm.

It was shown by calculating 'partial' TL glow curves for various spectral bands found in the material, that the kinetics has much more complex character than expected. In most cases the curves are considerably different indicating no direct relation between charge transfer from a specific trap to particular recombination center. It rather suggests a mixture of localized and delocalized processes occurring simultaneously. The conclusion is in agreement with the recent observation of anomalous regeneration phenomenon that was measured in KCl. Theoretical analysis of this phenomenon excludes a simple one carrier kinetics with purely delocalized recombination.

# NEW METHODS OF OPTICAL STIMULATION FOR THE PROTOTYPE OF OSL HELIOS READER

**Krzysztof Maternicki, Renata Majgier, Magdalena Biernacka, Arkadiusz Mandowski**

Jan Dlugosz University, Czestochowa, Poland

Optically stimulated luminescence (OSL) is a method which can be used in radiation dosimetry, archeological and geological dating. The most common methods of optical stimulation is the continuous wave CW-OSL with constant intensity and energy of stimulation light, linearly modulated stimulation LM-OSL and pulse stimulation POSL.

In addition to standard readout techniques, the recently developed OSL reader Helios provides several new methods of stimulation. The reader allows for determination of very long-lived characteristics of OSL detectors. One of the new functions of the reader is the OSL-Probe readout. This mode of measurement consists of the stimulation in the form of short pulses and subsequent detection of the resulting OSL signal (afterglow). It is partly similar to the Pulsed OSL method, but it differs in functionality. The advantage of using short stimulation times is the gradual sampling of the studied detector by light pulses. The OSL sampling gives the possibility of indirect observation of long-lived recombination processes in the material, such as regeneration and dark signal loss. These effects manifest in the shape of the obtained OSL-Probe decay in the form of a peak curve. Depending on the choice of measurement parameters such as the intensity of lighting with the LED pulse, as well as the time interval between pulses, a differentiated view of the OSL-Probe characteristics can be obtained.

The other method is the variable decay OSL method (VD-OSL). It allows to measure subsequent CW-OSL response following various delay times. The method gives similar information as the OSL-Probe measurement. Therefore the results obtained by these two methods could be compared. This paper presents some measurements done by these methods to show its compatibility. Other stimulation and detection features of the Helios reader, also in short-time domain are also presented. Especially it relates to various modes of stimulated light modulation. The shape of the illumination intensity may have various forms. These special modes of stimulation could provide specific information relating the properties of the studied material.

# Radiation Protection

# 07

# MEDICAL EXPOSURE IN 2016 IN ROMANIAN RADIOLOGICAL DEPARTMENTS

**Olga Girjoaba, Alexandra Cucu**

National Institute of Public Health, Bucharest, Romania

**Purpose:** A survey of medical exposure of the Romanian population is performed annually, in accordance with Romanian regulations and European Directive 2013/59 Euratom. The aim of the evaluation is to reduce the risk associated with X-ray diagnostic medical exposure and to optimize the quality of the radiological act.

**Method:** The study is applied to the reported data by the radiological departments from Romanian hospitals during 2016 and centralized at country level by the National Institute of Public Health. For each type of examination, the total number of exams and their distribution per age and gender groups were analyzed. Average values for DAP (dose-area product), DLP (dose-length product) in case of CT exams and MGD (mean glandular dose) in case of mammography were estimated. In the same time, mean effective dose were calculated using the conversion coefficients from NRPB R262 for each type of examination. The annual collective dose was determined from the mean effective dose and the frequency for each type of radiological examination, in conformity with the national regulations.

**Results:** The radiological examinations were grouped in five categories: radiography (including dental), fluoroscopy, computed tomography, cardiology and non-cardiology interventional radiology. A total of 5.938.451 radiological procedures were reported: 5.007.458 exams for radiography (including 864.390 dental), 383.536 exams for fluoroscopy, 503.337 CT exams, 28.252 cardiology interventional radiology procedures and 15.868 non-cardiology interventional radiology procedures. The reporting rate is 75% for radiography (40% for dental), but only 25% for CT exams and 30% for interventional radiology, which involve that the actual number of annual radiological consumption is much higher than the result from report. The estimated values of mean effective dose for radiography and fluoroscopy are less than the typical effective dose in European countries (RP 180), but the estimated values of mean effective dose for CT exams are much higher than the typical effective dose in European countries. The CT contribution to annual collective dose is 1.198 mSv/capita, total annual collective dose for all radiological examinations being 1.298 mSv/capita.

**Conclusions:** The most important contributions to the collective effective dose are from CT exams (abdomen, pelvis, thorax, abdomen-pelvis, head- thorax-abdomen-pelvis, etc), followed at a distance by the cardiac angiography and angioplasty, and very far by the radiography of pelvis, lumbar spine, thorax and the fluoroscopy of thorax and gastrointestinal tract. Based on these results, an important conclusion is linked by the justification process of each CT examinations. CT exams, with their very high contribution to the collective dose, must be perfectly justified for each individual patient and CT protocols must be optimized (low dose protocols), especially for paediatric patients.

# RADIATION AND VIDEO SURVEY OF THE WATER CLEANUP AND VENTILATION SYSTEM OF RFT REACTOR

**Vyacheslav Stepanov, Alexey Stepanov, Sergey Smirnov, Iurii Simirskii, Alexey Safronov, Ilia Semin, Anatoly Volkovich**

NRC "Kurchatov Institute", Moscow, Russia

The specialists of NRC "Kurchatov Institute" carry out the dismantling of the MR multiloop research reactor and RFT reactor. Technical start-up of the 20 MW capacity experimental graphite water cooling reactor (RFT) was started up in 1952. After 10 years working period the reactor was shut down. The fuel was removed and the reactor was partially dismantled. The ventilation system and water cleanup system of the RFT reactor were located in a separate building. The upper part of the reactor vent stack was dismantled in the early 60's. The water cleanup system, which consists of 6 stainless steel tanks (4 – ⌀ 1.5 m, h= 5m; 2 – ⌀ 3 m, h = 5m) located around the base reactor vent stack, was mothballed.

To plan the dismantling work, a radiation and video survey of the water cleanup system and the reactor vent stack was carried out. For this purpose, holes were drilled in the upper ceiling of premises with water cleanup system and at the top of vent stack. Through these holes were carried out video recording and measurement of the exposure dose rate distribution. The measurement of the exposure dose rate distribution along height of vent stack also was carried out. Based on the result of these surveys, the measurements of distribution of activity from radioactive waste along the height of the tank were carried out. The collimated spectrometric system on the basis of a semiconductor detector CdZnTe (volume of a crystal of 60 $mm^3$) was used. The measurements showed that the distribution of activity from radioactive waste along the height of the tank non uniform. To measure distribution of contamination of the inner surface vent stack we used the spectrometric system with semiconductor detector CdZnTe (volume of a crystal of 500 $mm^3$) with circular collimator.

The results of measurements are presented and discussed. The results of the survey will be used for planning the dismantling work.

# HANDHELD X-RAY UNIT IN DIAGNOSTIC RADIOLOGY PROCEDURES – RISKS AND RECOMMENDATIONS

**Zoran Mirkov, Jelena Pajić**

Serbian Institute of Occupational Health, Belgrade, Serbia

This paper presents the ambient dose equivalent values for manual intraoral x-ray machine of an unknown producer used in diagnostic radiology procedures, which is ordered and purchased online. Named x-ray device was used for a 20 days' period with an average frequency of twenty exposures per day. Measurement of the ambient dose rate equivalent showed significantly higher values compared to average measured values for the same procedures. In accordance with the Rulebook on conditions for obtaining a license for performing the radiological activity, the dental office was immediately informed of the necessity of medical examination of the persons handling the mentioned radiation source. The person responded to the review within the defined time limit. Since initial cytogenetic screening did not show an increased incidence of radiation biomarkers, there was no indication for carrying out biodosimetry tests in order to estimate the absorbed dose. Cytogenetic findings were expected since the exposure was below the detection threshold of the accredited laboratory (0.1 Gy). However, since the estimated effective dose at that measurement of the ambient dose equivalent is significantly higher than the usual for this workplace, frequent health examinations were recommended because of an increased risk of delayed health effects due to chronic exposure in such conditions.

# COMPARATIVE MEASUREMENT OF DENTAL X-RAY DEVICES IN ORDER TO IMPROVE THE QUALITY CONTROL IN THE COUNTRY

**Zoran Mirkov[1], Nataša Todorović[2], Kristina Bikit[2], Jovana Nikolov[2]**

1 Serbian Institute of Occupational Health, Belgrade, Serbia
2 University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia

Quality control testing was carried out on intraoral, panoramic and CBCT dental X-ray units in use in one private dental practice by two different laboratories from Serbia. The main aim of this study was: performance testing of the dental X-ray units and dosimetry inspection of the radiation protection facilities for patients, personnel and population in general. From the other point of view, intercomparison measurements between different laboratories that use same or similar equipment are very important in order to have reliable and precise measuring results. The obtained results showed good agreement between the two laboratories that participated in this study. This intercomparison study will lead also to the improvement of quality control in this field of radiology.

# JOINT RESEARCH FOR THE PURPOSE OF DETERMINING LOCAL DIAGNOSTIC REFERENCE LEVELS IN A PART OF THE REPUBLIC OF SERBIA, THE REPUBLIC OF CROATIA AND THE REPUBLIC OF MONTENEGRO

**Zoran Mirkov[1], Doris Segota[2], Aleksandra Milatović[3]**

1 Serbian Institute of Occupational Health, Belgrade, Serbia
2 University Hospital Rijeka, Rijeka, Croatia, Croatia
3 Centre for Eco-toxicological Investigations, Podgorica, Montenegro

Numerous research on patient doses in intraoral dental radiology in the last ten years, as well as recommendations of international institutions in the field of radiological protection, consider the introduction of diagnostic reference levels (DRL) as an integral part of the patient protection system.

The goal of this research is to determine the doses for patients on the territory of the Republic of Serbia, the Republic of Croatia and the Republic of Montenegro in the field of intraoral dental diagnostic radiology. For this purpose, the values of kerma area product (KAP) products for the various types of dental X-ray units were tested for the purpose of optimizing doses for patients, which will help in establishing national diagnostic reference levels (in this area).

# DOSE COEFFICIENTS TO CONVERT AIR KERMA INTO ORGAN DOSE RATE VALUES FOR PEOPLE OF DIFFERENT AGES EXTERNALLY EXPOSED TO $^{137}$CS IN SOIL

**Aleksandra Volchkova[1], Elena Shishkina[1], Marina Degteva[1], Bruce Napier[2]**

1 URCRM, Chelyabinsk, Russia
2 PNNL, Richland, Washington, United States

Dose coefficients converting air kerma into the dose rates in organs and tissues of people of different ages were calculated and analyzed for external exposure to $^{137}$Cs in soil. The range of the obtained dose coefficients was from 0.6 to 1 Gy Gy$^{-1}$. The minimum values of dose coefficients were typical for esophagus, thymus, pancreas and adrenal glands. The maximum dose factors were typical for tooth enamel, skin, endosteum and testes. It is shown that the results obtained are practically independent of the depth of radionuclide in the soil. The data for different sexes also differ insignificantly. A significant decrease in dose rates with age (up to 25%) was found. Uncertainties of dose coefficients under the approximation of a flat uniform source of different depths calculated for different organs of people of different ages do not exceed 15%.

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# OCCUPATIONAL EYE LENS DOSE TO CLINICAL STAFF IN INTERVENTIONAL RADIOLOGY: PRELIMINARY RESULTS

**Federica Savino[1], Tiziana Capussela[2], Maria Antonella Di Pasquale[2], Maria Quarto[1], Giuseppe Roberti[1]**

1 Dipartimento di Scienze Biomediche Avanzate – Università degli Studi di Napoli, Napoli, Italy
2 A.O.R.N., Napoli, Italia

In 2011, the International Commission on Radiological Protection (ICRP) recommended for the lens dose a new limit of 20 mSv in a year, averaged over 5 years, and a single year dose not exceeding 50 mSv. Since the dose for the lens cannot be measured directly on the eyes, this new lower limit imposes a precise determination of the dose to the lens of the workers, particularly the clinical staff exposed to relatively high dose in x-ray angiography and interventional radiology.

For the assessment of the equivalent dose to the lens, it is recommended to wear on the forehead or laterally (depending on the position of the operator-centre diffuser) a thermo-luminescent dosimeter (TLD) for the measurement of Hp (3) equivalent dose. However, due to the difficulty of calibrating these dosimeters for X-ray exposure of the quality used in interventional radiology, a calibration in Hp (0.07) or Hp (10) is currently considered also acceptable. Therefore, several alternative methods have been proposed for the assessment of the occupational eye lens dose in clinical practice, using dosimeters positioned on the neck, or on the chest, or at the level of the glasses (in particular positioned on the eyeglass rod).

Cijan et al. [Radiation Protection Dosimetry, 2017] proposed an algorithm which considers the proportional correlation between the Hp(0.07) equivalent dose measured with a TLD at chest level during a certain period and the total Kerma Air Product (KAP) within the same period. Furthermore, the algorithm takes into account all possible measurement configurations, the type and the frequency of protection tools used. In the present work, we present a survey carried out at the A.O.R.N. “A. Cardarelli” in Naples (Italy), to assess the eye lens dose to the clinical staff in according to the above cited algorithm. Five operators with different roles (radiologists, anaesthetists, nurses) have been identified for three different interventional radiology procedures: vascular, neuro and cardio-vascular. Each operators, received TLD calibrated in Hp(0.07) to be positioned at eyes level (forehead or laterally) and a TLD calibrated in Hp(0.07) too, to be positioned at chest level above the lead apron. The values obtained from the TLD positioned at eyes level have been corrected for conversion factors from Hp(0.07) to Hp(3). The contemporary recording obtained by the two dosimeters allows to obtain a correlation between the two measurements.

All information, such as total KAP, exposure data both in acquisition and in fluoro, during each procedure, and type of protective tools used (glasses and/or ceiling screen, or neither of them), distance from the X-Ray source, was recorded. The preliminary results of this survey will be shown, including the draft of a protocol to assess the dose to the lens of the workers.

# ASPECTS OF THE RADIOLOGICAL MONITORING OF THE GASEOUS EFFLUENTS RELEASED IN THE DECOMMISSIONING OF THE BIOLOGICAL CONCRETE SHIELDING OF VVR-S NUCLEAR REACTOR

**Carmen Tuca, Ana Stochioiu, Radu Deju**

IFIN-HH, Bucharest, Romania

The demolition of the concrete biological shielding of the VVR-S nuclear research reactor, started in 2017 and currently in progress, represents one of the major tasks of the decommissioning project. The Reactor Block has a cylindrical shape of 6 m height (starting from ground level) and 0.5 m below ground level. The biological protection has 6 m diameter and is made both from normal (2.5 – 6 m) and heavy (0 – 2.5 m) concrete and also contains a steel structure embedded in the concrete, which contribute to the radioactive inventory of the released gaseous effluents during dismantling. The effluents radioactivity monitoring is done for normal, abnormal and emergency situations taking in consideration: specific characteristics of the radiation sources, radionuclide composition, exposure routes and potential dose levels for personnel and public members. The effluents are released in the reactor hall and in the outer atmosphere through the reactor stack (40 m high). They are monitored with fixed and mobile systems, operating in parallel, designed for direct and indirect measurements of the concentration of activity. The fix system is used for gross activity measurements, also for gamma ray measurements of the glass fibber filters attached to the ventilation system and reactor stack for the outer released effluents. The mobile systems consists in: i) Monitor for airborne particulate β, type AMS-4 Eberline, for early warning in the reactor hall; ii) Monitor for natural and artificial alpha/beta aerosols, type Thermo Scientific™ FHT 2000, in the reactor hall and reactor stack. Both of them are used for indirect measurement of the airborne activity deposited on the filter. The radioactive inventory measurements reveal the presence of the $^{60}Co$ and $^{137}Cs$. The maximum values of activity concentration for beta-gamma and alpha (natural and artificial) emitters was recorded in November, in the reactor hall and also at the reactor stack, during the demolition and cutting of the concrete and metallic structures placed between 1 m ÷ 2 m above the reactor floor, near the reactor core. Thus, for the reactor hall, the maximum concentration was surpassed at about 5 times for beta-gamma emitters, 19 times for alpha emitters an 7 times for alpha natural emitters as compared with the previous, anti-demolition, values. In this case there were taken supplementary protective measures for the workers in order to prevent the internal and external irradiation. At the reactor stack the maximum concentration of activity is under the values of derived emission limits, thus can be stated the public members are not radiological affected.

# ANALYSIS OF RADIOLOGICAL RISKS FOR CRITICAL GROUP MEMBERS AS A RESULT OF NUCLEAR ACTIVITIES IN IFIN-HH, ROMANIA

**Ana Stochioiu, Carmen Tuca**

IFIN-HH, Bucharest, Romania

The paper presents data on the risk assessment of the people from critical group due to the nuclear activities carried out in the Horia Hulubei National Institute for R & D in Physics and Nuclear Engineering (IFIN-HH) during 2013-2016. Radionuclides can reach to environment in two major ways: i) in the atmosphere, in gaseous effluents from the ventilation baskets; ii) in the receiver, the Ciorogarla River, located 2 km from the institute, by the liquid radioactive effluents. The land in the surrounding area IFIN-HH is used by the inhabitants especially for agriculture. For this area are basic vegetable growing, grain crops, fruit trees and livestock. The critical group includes infants and adults, who are supposed to have fruits, vegetables and most of the food obtained in their own gardens. In IFIN-HH nuclear research and engineering activities are carried out within nuclear and radiological installations such as: i) production and research of radioactive isotopes; ii) treatment of radioactive waste; iii) decommissioning the VVR-S nuclear research reactor. The value of the dose constraint for the persons in the critical group approved by the National Commission for Nuclear Activities (CNCAN) is $E_{constr.}$ = 100 μSv an$^{-1}$. For this value, the derived emission limits for each potential radionuclide and for each of the two emission pathways have been calculated. In the studied period, the radionuclides emitted in the atmosphere were: $^{131}$I, $^{3}$H, $^{137}$Cs, $^{60}$Co, and $^{154}$Eu which determined a maximum value of the collected dose of persons in the critical group of 7.33 10$^{-6}$ Sv·a$^{-1}$ in 2014. In the liquid effluents $^{60}$Co, $^{3}$H, $^{241}$Am, $^{192}$Ir, $^{137}$Cs, $^{235}$U, $^{238}$U were identified and the maximum dose value was 14.79 10$^{-6}$ Sv a$^{-1}$ in 2013. For the entire period, the two cumulative sources resulted in dose values ranging from 6.31 10$^{-6}$ Sv·a$^{-1}$ and 14.81 10$^{-6}$ Sv-a$^{-1}$. In conclusion, the radiological impact of the activities carried out within the institute on the persons from critical group was relatively constant every year, by collecting a much lower dose than the dose constraint.

**Key words:** Radiological risk, critical group, dose constraint

# COMPARISON OF PROFESSIONAL RADIATION EXPOSURES OF MEDICAL STAFF COVERED BY PERSONAL DOSE MONITORING CONSIDERING THE TYPE OF OCCUPATION AND WORKPLACE

**Gordana Žauhar[1], Branka Dresto Alač[2]**

1 Medical Faculty, University of Rijeka, Rijeka, Croatia
2 Faculty of Health Studies University of Rijeka, Rijeka, Croatia

Personal dosimetry involves systematically and legally prescribed measuring of dose received by an individual in the area of exposure to ionizing radiation. The effective dose to the whole body is estimated from these measurements and entered in of occupational exposure records for every worker for whom the assessment of occupational exposure is required. The obtained data are an important factor in the assessment of the level of radiation protection of individuals. In addition, based on the obtained data, it is possible to determine whether the measurements at individual workplaces are carried out in accordance with the necessary procedure, whether the implemented protection measures are carried out to ensure minimum exposure of workers, and that the employees themselves work in such a way that comply with all prescribed radiation protection measures. Personal dosimeter data are important for finding new safety techniques necessary for working with sources of ionizing radiation and can also serve as a basis for revealing employees who are exposed to higher doses than others.

In this paper, we have analysed the data for effective doses of 326 employees of Rijeka Clinical Hospital Centre covered by personal dosimetry in the period from 2000 to 2015. The collective effective doses were calculated and effective doses received for a five year period were analysed. Based on the collected data, we compared the doses received by employees of different groups of occupations.

The analysis has shown that the exposure level of workers working in the ionizing radiation zone is typically well below the dose limits. During 2015, most employees, over 96.3%, received an annual effective dose of less than 0.1 mSv. Only three persons received an annual dose higher than 0.5 mSv, and among them one person received an annual dose of 6.9 mSv.

Measured data indicate a well-established radiation protection system and adequate education of workers on radiation protection measures.

Comparison of the radiation exposure doses of medical workers of different professions employed in the zone of ionizing radiation has shown that the highest dose of radiation is received by internal medicine specialists, among them in particular cardiologists involved in interventional cardiology.

Therefore, the additional need is to take care of their protection, check the manner of their work taking into account the ALARA principle and ensure, if possible, more even workload of cardiologists participating in procedures that involve higher exposure to ionizing radiation.

# ON THE GAMMA ATTENUATION OF VARIOUS POLYMER COMPOUNDS

**Tuncay Bayram[1], A. Hakan Yilmaz[1], Sevil Savaskan Yilmaz[2], Yasin Misirlioğlu[2], Abdussamed Kucuk[2], Ertugrul Tutuncu[2]**

1 KTU Physics Department, Trabzon, Turkey
2 KTU Chemistry Department, Trabzon, Turkey

Based on the progress of nuclear science and technology applications, many studies are devoted to develop radiation protective materials. In particular lead is commonly used for protection from gamma ray because it is cheap and easily shaped and also it has high attenuation coefficient against gamma ray. On the other hand polymers are used in many technological applications and also there can be found many daily used materials produced by using various polymer structures.

In the present study we have investigated gamma ray attenuation coefficients of "16 Arms, Star, Coil- Hyperbranched Poly Amide Ester -b-Poly Caprolactone -Ebselen Hydride Copolymer", "16 Arms, Star, Coil- Hyperbranched Poly Amide Ester -b-Poly Caprolactone -Trimethyl Lead Copolymers(16 A, S, C-HBPAE-b-PCL-TMPb Copolymer)" and "16 Arms, Star, Coil- Hyperbranched Poly Amide Ester -b-Poly Caprolactone -Ebselen Hydride Copolymer(16 A, S, C-HBPAE-b-PCL-E H Copolymer)" as a function of gamma ray energy starting from 1 keV to 5 MeV. For this task Geant 4 and XCOM software have been used. The results show that occurrences of Se and Pb elements in the structure of copolymers increase the total attenuation coefficients of copolymer dramatically between the gamma energy ranges of ~5-700 keV. This result gives a clue for synthesizing of new polymer structures for producing radiation protective materials.

# RELEVANCE OF THE CHERNOBYL RESEARCH FOR THE EVALUATION OF RADIATION EFFECTS IN CASES OF LOW DOSE RATE EXPOSURE

**Sebastian Pflugbeil[1], Inge Schmitz-Feuerhake[2]**

1 German Society for Radiation Protection, Berlin, Germany
2 University of Bremen, Bremen, Germany

The surviving victims of the Atomic bombing in Japan in 1945 are used up to now as the predominant reference group for the evaluation of radiation effects by international and national radiation committees. This is also true for the actually valid recommendations of the International Commission of Radiological Protection ICRP, which were given in 2007 in ICRP Publication 103. These recommendations are in turn the basis for the European Directive 2013/59/EURATOM which is the current legal frame for radiation protection in the European Union.

The aim of our survey is to show that the compatibility of the Japanese data for situations of occupational exposure and environmental contaminations is limited. The grade of discrepancy depends on the kind of radiation effect. We know from studies about cancer in nuclear workers in the last decades that the radiation effect in adults is higher than predicted by the ICRP. Heritable effects are regarded as nearly not existing by them. But the stages of high sensitivity in the germ cell development may not be reached by a "flash" exposure as assumed in Hiroshima and Nagasaki.

While cancer and heritable effects are considered as "stochastic", the ICRP asserts high dose thresholds for effects from exposure in utero (100mSv) and for non-cancer radiation effects (500 mSv). Both threshold figures are not justified even referring to former and recent results of the A-bomb survivor study. Additional knowledge is gained from studies in populations affected by the Chernobyl accident in 1986.

Liquidators: some 100,000 men were deployed for decontamination tasks. Their exposure was higher than the very low mean doses in the nuclear worker studies. Therefore, – besides others – an increase of rare diseases was observed which were formerly not considered to be radiogenic. The studies show high relative radiation risks for distortions of the central nervous system resulting in neurological and psychiatric diseases.

Observations in contaminated regions: Numerous findings about congenital malformations, fetal loss, stillbirths, and infant deaths, as well as Down's syndrome in adjoining countries and central Europe after the Chernobyl release were published in the scientific literature. They show the high radiation sensitivity of embryos and foetuses and mutations in the descendants of the exposed populations. Many cytogenetic studies after Chernobyl confirm that the ICRP assumptions about too tiny exposures to accept these results are not valid.

**Conclusion:** the Chernobyl findings are most relevant for adequate radiation protection standards. A most valuable compilation of data was given by the late Alexey V. Yablokov and coworkers, Chernobyl. Consequences of the catastrophe for people and environment, *Annals of the New York Academy of Science* 1181, 2009.

# NANODOSIMETRY FOR RADIATION EXPOSURE ASSESSMENT

**Marcin Pietrzak[1,2], Stanisław Pszona[1], Aliaksandr Bantsar[1]**

1 National Centre for Nuclear Research, Otwock, Poland
2 Biomedical Physics Division, Faculty of Physics, University of Warsaw, Warsaw, Poland

An important task in evaluation of the cancer risk from radiation exposure is to properly weigh the various components of radiation sources according to their assumed contribution. Currently, quality factors of high and low LET radiation are defined by national and international commissions based on existing radiobiological data and presumed knowledge of the ionization density distribution of the radiation field at a given point of interest. This approach makes the determination of the average quality factor of a given radiation field a complex task.

The initiation of radiation induced damage to biological cells is dominated by inelastic interactions occurring at the location of the DNA or within its vicinity. The subcellular distribution of such interactions therefore plays a key role in the biological effectiveness of ionising radiation. Appropriate definitions of concepts such as radiation quality cannot be described by macroscopic quantities like absorbed dose. For this reason another approach is proposed, namely an experimental method which replace the concept of absorbed dose with another quantity that accounts for the particle track structure within radiosensitive biological targets. The crucial assumption here is that initial physical effect changes into measurable biological damage is likely ruled by the stochasticity of ionizations produced by the incident ions in subcellular nanometric volumes. Based on this hypothesis, experimental nanodosimetry aims at establishing a new concept of radiation quality that builds on measurable characteristics of the particle track structure at the nanometre scale.

This work gives an overview of nanodosimetric concepts and recent developments in the field of nanodosimetry. The value and limitations of this approach are discussed.

# DETERMINING THE ZONE OF INFLUENCE OF TRANSMISSION OVERHEAD POWER LINES FROM THE ASPECT OF NON-IONIZING RADIATION

**Maja Grbić, Aleksandar Pavlović**

Nikola Tesla Electrical Engineering Institute, Belgrade, Serbia

The paper presents methodology for determining the area in the vicinity of overhead power lines where the levels of non-ionizing radiation are significant in the context of current regulations referring to the protection of general public in the Republic of Serbia. A brief review of Serbian legislation on protection of general public from power frequency electromagnetic fields is given. The zones of influence of 110 kV, 220 kV and 400 kV transmission overhead power lines are determined by calculations. The configurations of power lines which result in the widest zone of influence are analyzed for each voltage level. The influence of phase conductor heights on the width of the zone is also considered. Determining the width of the zone of influence is very important for planning the construction of new power lines near residential areas, as well as for the construction of residential buildings near existing lines. It is also significant when it is necessary to determine the locations in the vicinity of overhead power lines where more detailed testing of non-ionizing radiation should be performed by measurements.

# SAFETY CULTURE AS A KEY ISSUE OF RADIATION SAFETY IN MEDICAL ACTIVITIES WITH IONIZING RADIATION SOURCES

**Liudmyla Aslamova[1], Oleg Nasvit[2], Ielyzaveta Kulich[1], Nadiia Melenevska[1]**

1 Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
2 State Agency of Ukraine on Exclusion Zone Management, Kyiv, Ukraine

The term 'Safety Culture' was first defined in 1986. Nowadays it introduced into all areas of activities with ionizing radiation sources. Importance of Safety Culture for medical applications goes from quick distribution of high technologies in medical equipment that lead to involve very qualified personnel.

Safety culture is the values, attitudes, motivations and knowledge that affect the extent to which safety is emphasized over competing goals in decisions and behavior. At the same time, everybody should understand that it is not separate or different from organizational culture, a "thing" with an objective existence, a policy, program or procedure. This note is important for effective implementation of safety culture into practice.

Nowadays the most wide used definitions are: Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance (INSAG-4, 1991); Safety Culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance (IAEA Safety Glossary, 2007).

If Safety Culture is implemented in medical activities with ionizing radiation sources, it characterized by few universal features attention to safety that involves many elements; individual awareness of the importance of safety; knowledge and competence, conferred by training and instruction of personnel and by their self-education; commitment, requiring demonstration at senior management level of the high priority of safety and adoption by individuals of the common goal of safety; motivation, through leadership, the setting of objectives and systems of rewards and sanctions, and through individuals' self-generated attitudes; supervision, including audit and review practices, with readiness to respond to individuals' questioning attitudes; responsibility, through formal assignment and description of duties and their understanding by individuals.

All features mentioned above must be taken into account in stages of Safety Culture development. Namely, safety is based on rules and regulation, becomes an organizational goal, can always be improved.

Thus Safety Culture is represented by 5 characteristics. Safety is a clearly recognized value, integrated into all activities, learning driven. Leadership and accountability for safety is clear.

# ENHANCING THE NUCLEAR SECURITY ON NUCLEAR RESEARCH REACTORS RA AND RB

**Miloš Mladenović, Ivana Maksimović, Dalibor Arbutina, Miodrag Milenović**

Public Company "Nuclear Facilities of Serbia", Belgrade, Serbia

Public Company Nuclear Facilities of Serbia (hereinafter PC NFS) is the only nuclear operator in Serbia. It was founded in 2009 under the Law on Ionizing Radiation together with the Serbian Regulatory Body. Since its establishment, PC NFS has continued all nuclear activities previously managed by Vinca Institute of Nuclear Sciences; Two research reactors (RA-final shut down and RB-zero-power critical assembly, operational but currently not-licensed), RWM facilities- old Hangars H1 and H2 with legacy waste, new hangar H3 (for the storage of intermediate and low level radioactive waste) together with the secure storage for the high activity sealed radioactive sources, and closed uranium mine Kalna are the part of the Company. The paper will provide our efforts, issues that we were facing with and results in strengthening the nuclear security on the research reactors RA and RB. Nuclear security is well recognized in the strategic plan of PC NFS and it is given the same priority as nuclear safety. Paper will provide international and domestic cooperation, our managing the interface between safety and security, strengthening the nuclear safety and security culture and implementing the good practice on the both research reactors. It will show the difference in methodologies in design of security systems for the research reactor planned for decommission and for the research reactor planned for the operation.

# GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE IN UKRAINE: APPROACHES AND CONCEPTS

**Liliana Petrenko**

Institute of Geological Sciences of NAS of Ukraine, Kyiv, Ukraine

Now Ukraine occupies 4th place in Europe and 8th place in the world at the total capacity of the nuclear power plant (NPP). The NPP produces up to 55% of electricity in the country. During the operation of reactors, a significant amount of spent nuclear fuel will accumulate. Huge amounts of intermediate-level radioactive wastes (RW) with significant long-lived radionuclides originated in Ukraine during the Chernobyl disaster (1986). It is planned that a geological repository will be created for the disposal of high-level RW (products of processing of spent nuclear fuel) and "Chernobyl" radioactive active substances in the country until 2048.

In Ukraine, mine and deep borehole disposal concepts are considered. Mine repositories are located in an area of the intense or significant water exchange zone (500 – 1000 m). Isolation of radionuclides is achieved by using very reliable containers of inert materials. Natural barriers play a secondary role. The main advantages of such a storage facility are the possibility of waste disposal to the final closure of the storage facility, the absence of strict restrictions on the size of packaging waste. The disadvantages include the insignificant distance between the disposal zone and the biosphere, a significant amount of mining, a significant area of the underground part, the total cost, etc.

The advantages of RW disposal in deep boreholes are the extremely slow migration of radionuclides due to: extremely low water exchange intensity, diffusion mechanism of radionuclide migration and low permeability of rocks. The main disadvantages of RW disposal in deep boreholes are: the complexity of waste disposal, restriction of packaging size with waste, complexity of storage monitoring.

In Ukraine, there is some progress in substantiating the possibility of creating a geological disposal of RW. At present, the main attention is paid to the crystalline rocks of the Chernobyl Exclusion Zone (ChEZ), which are analogous to the crystalline rocks of the sites of Sweden and Finland. In Ukraine: the existing data are generalized, the situation of prospective areas is clarified, and the methodology and means of performing safety assessments are developed.

The results of the preliminary safety assessment indicate both the prospects of the crystalline rocks of the ChEZ for the geological disposal of RW, and the urgent need for detailed field researches of prospective areas (including drilling).

It was also shown that the introduction of a new classification of RW in Ukraine, which foresees the use of 4 types of RW disposal instead of 2, would significantly reduce the cost and time limits for RW disposal. The combined use in Ukraine of a mine concept for the disposal of intermediate-level RW (at intermediate depths of 350-500 m) and a deep borehole concept for the disposal of high-level waste (in the range of depths 2000-5000 m) will help to reduce the costs of geological disposal of RW several times.

# CITIZEN MONITORING NETWORK IN THE CZECH REPUBLIC

**Petr Kuča, Jan Helebrant, Irena Češpírová, Jiří Hůlka**

National Radiation Protection Institute (SURO), Prague, Czech Republic

Citizen monitoring, evolved especially in Japan after the Fukushima Dai-Ichi accident, became a world-wild phenomena nowadays. It can significantly contribute to monitoring of radiation situation and provide large amount of information for support the evaluation of radiation situation both in normal and emergency situation.

Nevertheless, the citizen monitoring itself must be supported by appropriate information and guidance for the public covering

- basic information on the problematics of radiation protection as a whole,
- techniques how to perform the monitoring so that the results can be compared both together with other citizen measurements and with results of the monitoring performed by professional teams,
- tools for data collection and processing, and for presentation and sharing the results obtained on national and even world-wide levels,
- scientific support for the public helping them to understand what the measured values really means, especially in case of detecting some anomalies from the typical (background) levels in given area – and this support should be provided on interactive manner.

The presentation describes actual situation of citizen monitoring networks in the Czech Republic and future plans and perspectives for its progress and development.

The paper shows selected results of research project RAMESIS (ID: VI20152019028) supported by the Czech Ministry of Interior in the frame of security research.

# THE ROLE OF INTERNATIONAL STANDARDS FOR RADIATION PROTECTION INSTRUMENTATION

**Miroslav Voytchev[1], Radoslav Radev[2]**

1 IRSN, Gif-sur-Yvette, France
2 LLNL, Livermore, United States

The standards published by the International Electrotechnical Commission (IEC) and prepared by its Sub-Committee (SC) 45B "Radiation Protection Instrumentation" cover a very large scope. They address instrumentation used for the measurement and the quantification of ionizing radiation in the workplace, to the public and in the environment for radiation protection purposes. These standards cover also the detection of illicit trafficking of radioactive material and identification of radionuclides as well as the radiation-based security screening.

The IEC standards serve as basis for national standardization, as references when drafting international tenders and contracts and for conformity evaluation of instrumentation. It is to be noted that more than 80 % of all European (EN) standards are actually IEC standards that are transposed by CENELEC (the European Committee for Electrotechnical Standardisation) without or with some minor modifications.

Among the various requirements in the standards, the different types of tests for photon, neutron, beta and alpha radiation and their characteristics are the heart of these documents. Dose (rate) response linearity evaluation, relative intrinsic error determination, energy and angular dependences of the response, radionuclide identification and overload tests are just a few examples. In addition, the standards have electromagnetic (EMC), electrical, environmental and mechanical requirements and associated tests to demonstrate compliance with the requirements.

The criteria and the compliance test methods in these standards are the result of an optimization and compromise between the participating experts from many countries searching for acceptable detection performance that reflects the positions of the national regulatory agencies, the scientific and technological progress of the industry, the testing laboratories capabilities, the end users, the instrument production cost and the compliance testing procedure.

This presentation will provide an overview of the international IEC standards that set the minimum performance requirements for all radiation protection instrumentation. They provide manufacturers with internationally acceptable requirements and provide the users with assurance of the rigorous quality and accuracy of the measurements.

# ANALYSIS AND PROJECT OF THE HIGH DENSITY STORAGE RACKS FOR SPENT FUEL OF THE RESEARCH REACTOR IEA-R1

**Antonio Carlos Iglesias Rodrigues,**
**Tufic Madi Filho, Davilson Gomes da Silva**

IPEN-CNEN/SP, São Paulo, Brazil

The IEA-R1 research reactor works 40h weekly with 4.5 Mw power. The storage rack for spent fuel elements has less than half of its initial capacity. Under these conditions (current conditions of reactor operation 32h weekly will have 3 spend fuel by year, then, approximately 3 utilization rate Positions/year). Thus, we will have only about six years of capacity for storage. Whereas the desired service life of the IEA-R1 is at least another 20 years, it will be necessary to increase the storage capacity of spent fuel. Hence, it is necessary to double the wet storage capacity (storage in the IEA-R1 reactor's pool). After reviewing the literature about materials available for use in the construction of the new storage rack with absorber of neutrons, the BoralcanTM (manufactured by 3M) was chosen, due to its properties.

This work presents studies: (a) for the construction of new storages racks with double of the current capacity using the same place of current storages racks and (b) criticality analysis using the MCNP-5 code. Two American Nuclear Data Libraries were used: ENDF / B-VI and ENDF / B-VII, and the results obtained for each data bases were compared. These analyzes confirm the possibility of doubling the storage capacity of fuel elements burned in the same place occupied by the current storage rack attending to the IEA-R1 reactor needs and attending the safety requirements according to the National Nuclear Energy Commission – CNEN and the International Atomic Energy Agency (IAEA). To calculate the keff new fuel elements (maximum possible reactivity) used in full charge of the storage rack were considered. With the results obtained in the simulation we can conclude that doubling the amount of racks for spent fuel elements are complied with safety limits established in the IAEA standards and CNEN of criticality (keff <0.95). It is mandatory to use neutron absorber material.

**Key words:** Spent fuel storage, MCNP-5, Boron

# NEUTRON AND GAMMA RADIATION LEVEL ANALYSIS AROUND THE CYCLOTRON FACILITY

**Magdalena Długosz-Lisiecka[1], Teresa Jakubowska[2]**

1 Technical University of Lodz, Lodz, Poland
2 Provincial Specialist Hospital, name of M. Kopernika in Łódź, Lodz, Poland

This study aims to present the levels of neutron and gamma radiation results, obtained by monitoring the Cyclotron Facility area, during the $^{18}F$ or $^{11}C$ production. The $^{18}F$ target has thin circular foil composed of a metal alloy (Havar), that is highly activated by the proton beam and secondary neutrons. The area monitoring is carried out to evaluate the dose rates in areas that are not occupied by workers during the execution of their tasks, but outside of the working area, where general population can be exposed.

The study was based on data gathered from the area monitoring conducted by the radioprotection monitoring routine activities in last one year. Measurements were performed at 14 predetermined spots located, on the wall, outside of the bunker, around the Cyclotron Facility building. To determine the neutron and gamma dose rate, specific equipment have been applied, FHT 752 (BIOREM). The significant variation between minimum and maximum levels of the dose rate depends on the number of the carried out, irradiation time, irradiatiated material yield of the synthesis, thickness of the wall and chosen target. The maximum dose rate for neutron and gamma ray was noticed as 465 and 254 nSv/h, respectively.

# CBRN DECONTAMINATION OBSERVED FROM MULTIPLE PERSPECTIVES

**Dejan Vasovic[1], Stevan Musicki[2], Sladjan Hristov[3]**

1 University of Nis, Faculty of Occupational Safety in Nis, Nis, Serbia
2 University of Defence, Military Academy, Belgrade, Serbia
3 Serbian Armed Forces, Army Command, Nis, Serbia

Nuclear and chemical accidents lead to endangering the health of citizens and the environment due to contamination by radiological and chemical contaminants, and consequently there are permanent security risks for the population and material goods. Decontamination related to the CBRN (chemical, biological, radiological, nuclear) accidents represents a set of processes and activities aimed to total or partial removal and neutralization of radiological, chemical and biological contamination caused by intended or non-intended threat, thereby reducing the risk of contamination to people or the environment up to the permissible levels. At the first place, the ultimate goal of decontamination is the complete elimination of radioactive contaminants and the minimization of contamination levels of chemical and biological contaminants. Among others, the process of CBRN decontamination is subjected to: people, animals, food and water, technical means, clothing and equipment, land and buildings. The aim of this paper is to demonstrate the relevance of CBRN decontamination observed from the multiple perspectives: the available techniques, the available operative personnel and experience-knowledge to engage them in the most effective manner.

# CBRN DEFENCE: ORGANIZATION, RESOURCES AND TASKS OF ARMED FORCES

**Stevan Musicki[1], Dejan Vasovic[2], Srdjan Markovic[3]**

1 University of Defence, Military Academy, Belgrade, Serbia
2 University of Nis, Faculty of Occupational Safety, Nis, Serbia
3 Ministry of Defence, Belgrade, Serbia

The concept of CBRN (chemical, biological, radiological, nuclear) defence is a highly complex phenomenon and a scientific discipline within both the social and technical-technological sciences. CBRN defence has multiple meanings. In the most general sense, it refers to absence/elimination of threats, i.e. pressures that can threaten either people, material goods or environmental media, or their reduction to the lowest acceptable level. Effective and efficient CBRN defence activities can be seen from the perspective of civil structures or armed forces. In this sense, the organizational structure of the armed forces of any country represents a dynamic system, which within the wider community operates and exists under specific conditions and circumstances. Starting from its basic purposes, the regular armed forces of any state do not have unknowns regarding the rules and their core roles. However, the complex structure and the interdependence of different organizational structures within the country and of the armed forces have an impact on the implementation of measures in the field of CBRN defence and management of risk both in war and peacetime. The aim of this paper is to present structural organization, resources and tasks of Serbian armed forces compared to armed forces of a country similar to Serbia (Greece) and a highly developed country (US army).

# EVALUATION OF DOZE RATE FIELD OF INDUSTRIAL X-RAY EQUIPMENT FOR NDT

**Esmeralda Vataj[1], Uarda Gjoka[1], Fatos Ylli[1], Blerina Papajani[2]**

1 Institute of Applied Nuclear Physics, University of Tirana, Tirana, Albania
2 University "Aleksander Xhuvani", Tirana, Albania

Nondestructive Testing (NDT) is a non-invasive methods based on physical principles to evaluate the integrity and characteristics of material. Its measurement methodology covers a wide range of applications of materials and structures that relate to the entire life cycle, from manufacture to use and retirement.

Radiography is one of the most important and widely used NDT methods for volumetric examination. In general, Radiography Testing (RT) is the method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation, (high energy photons), to penetrate various materials. The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film.

In this work is presented the evaluation of dose rate field in and around the radiation beam for X-ray tube model MHF 200D, using large interval of voltage (20 to 200 kV) and current (0.5 to 8 mA). The X-ray machine is part of NDT laboratory at the Institute of Applied Nuclear Physics.

In this study are performed controls for variables that express the essential characteristics of beam radiation quality as kilovoltage (kV) and the determinations of Half Value Layer (HVL) for different values of voltage and current.

# ELECTROMAGNETIC ENVIRONMENTAL PROBLEM IN DENTAL CLINICS

**Mustafa Geçin, Selçuk Çömlekçi, Erdal Eroğlu**

Suleyman Demirel University, Isparta, Turkey

Nowadays, devices that are used in dental treatment are classified according to the working principles and electrical devices are used in treatment, in the preparation of dental prosthesis, in the mixers. As known, these electrical devices used in medical treatment generate electric field and magnetic field in the environment depending on their operation. In this study, the effects of the electromagnetic environment on the patients and doctors in the clinic were examined. During the treatment, the effects of these devices on the patient's head and doctor's hand depending on severity and periods are important. The electromagnetic density of the environment is increasing because of the proximity of the dental chairs and the number of dental chairs in the clinic is more than one. Transformers and electric motors in mixers and in drills used in shaping dental prostheses have been reported to cause headache, insomnia and weakness in long-term use for users. The electric field and the magnetic field are measured in the clinic. It has been determined that the magnetic field is above the limits of IEEE is determined. According to IEEE's CE95 standards for magnetic field, the exposure limit for the public is 1 uT and the exposure limit for the professional is 1 mT. In our measurements, it was determined that the magnetic field is above 3 mT. The digital plan of the environment was made in our work. The measured electric fields and magnetic fields have been mapped. This environmental problem should be solved by using engineering solutions. Accordingly, suggestions on how to isolate the devices from the environment and how to use them are presented.

# A LAB OF ONE'S OWN & MODERN SUFFRAGE: MOTHERS WHO SET UP A RADIATION LAB AND THOSE USED AS GUINEA PIGS

**Gordana Lastovicka-Medin**

University of Montenegro, Podgorica, Montenegro

"A woman in a white lab coat puts some yellow organic material on a slide, while grey liquid bubbles in vials behind her. Other women, one of them heavily pregnant, discuss some data on a computer screen. A courier delivers a small parcel which is opened and its contents catalogued. But this is no ordinary laboratory. None of these women trained as scientists. One used to be a beautician, another was a hairdresser, yet another used to work in an office. Together they set up a non-profit organisation – Tarachine – 50km (30 miles) down the coast from the Fukushima nuclear plant, to measure radiation in the city of Iwaki" (http://www.bbc.co.uk/news/magazine-35784923). The lab mainly measures the radioactive isotopes Cs-134 and Cs-13, and collects data on gamma radiation. Strontium-90 and tritium were only added to the list in April 2015. Since they emit only beta rays they weren't able to detect them until recently. Thanks to a generous donation, they now have the right equipment. This story and many others will be analysed in this paper, including voices from Chernobyl and mothers of Semipalatinsk in Kazakhstan which were used as human guinea pigs in the testing of nuclear weapons. Scientist said: "We thought that everything would go smoothly, that chromosome damage and genetic effects would be confined to the generation of people who were irradiated and they could not be inherited by future generations." But it turned out that this was wrong. Women suffer the most from this stoic denial that radiation affects the community. A female perspective of how women are dealing with the risk despite the governments, lack of radiation testing, children's health checks, financial and social support – the social responsibility to their community is researched. What is happening between science and emerging "suffrage" science as reaction on scientific community and consequences of science discoveries?

# METHODS OF EVALUATION USING MICROSHIELD CODE FOR THE BIOLOGICAL CONCRETE SHIELD AT THE VVR-S NUCLEAR RESEARCH REACTOR FROM BUCHAREST – MAGURELE, ROMANIA

**Ioan Iorga**[1,2]

1 Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest – Magurele, Romania
2 Faculty of Physics, University of Bucharest, Bucharest-Magurele, Romania

The VVR-S Nuclear Research Reactor owned by Horia Hulubei – National Institute for Physics and Nuclear Engineering (IFIN-HH), was built in Romania between: 1955 – 1957. The research reactor operated until 1997 and was permanently shut-down in 2002. During his life time, it was functional for a period of 113467 h, including 2000 h at 3.0–3.5 MW power. The research reactor operated until 1997 and was permanently shut-down in 2002. The total power output up to 1997 was 9.59 GWd. It had a utilization factor of 65 % (approximate 9510 effective days of operation) with an average of 1 MW thermal power. It was the first research reactor using the VVR-S type soviet design. The main role of the reactor was for research and radioisotope production. VVR-S means that is a thermal neutrons reactor model S moderately cooled and reflected with distilled water, fueled with enriched uranium 10% in the beginning and 36% subsequently.

Neutron activated materials were by far the major contributor to the total inventory of radioactive reactor. The dose rate of the samples was between 0, 13 and 114 μSv/h.

We needed to respect the radiation protection program the radiation dose limit is 20 mSv/year for the personnel professionally exposed, For this reason the simulation of the potential dose rate exposure and the shield calculation was necessary. Dose rate assessment was made using MicroShield 9.04 software in different annular cylinder geometry and complex integration for the close with reality. Simulation accomplishment with reality was over 75% taken into account the integration of all data and the geometry of the reactor biological concrete shield geometry.

Our final goal was to know how the radioactivity made an impact about of biological concrete shielding in preparation for the dismantling. In first step we made a theoretical model that was compared with the experimental measurement results.

Gamma spectrometric measurements were made and $^{60}Co$, $^{152}Eu$ remained the main radionuclides present in the concrete reactor building. It was measured samples of water resulting from core drilling and identified radionuclides were: $^{137}Cs$, $^{60}Co$ and $^{152}Eu$ with activity values below minimum detection activity. It was also sampled slam result in coring process; gamma spectrometric measured activity concentration was below the minimum detectable activity for $^{137}Cs$, $^{60}Co$, $^{152}Eu$ and $^{154}Eu$. The final results of the study were the input for the procedure for the biological shield demolish under the integrated management system controlled activity for our decommissioning project.

# A STUDY ON THE TECHNOLOGY OF PROBABILISTIC SAFETY ANALYSIS FOR SAFE MANAGEMENT OF RADIATION TREATMENT SYSTEM

**Hyeongmin Joo, Yong Nam Kim**

Kangwon National University Hospital, Chuncheon, South Korea

**Purpose:** the reliability of radiotherapy was evaluated and effective approaches were obtained in order to improve radiotherapy quality. In the famous cases, there are two cases were called “Failure Mode Effect Analysis (FMEA)” and “Probabilistic Safety Analysis (PSA)”. The goal of this study is to develop safety management program to evaluate the reliability & safety to predict quantitatively the mathematical probability for dose delivery error for radiation treatment system by using PSA.

**Methods and Results:** In the first step, we have to decide a top event. According to the various documents of radiotherapy, priorities are dose delivery accuracy and plan-clinic matching accuracy for patient. And so we combined two factors, it is called *radiotherapy error*. The next step is to define the following problems for deciding parameters and building a fault tree of parameters by using PSA methodology (e.g. mechanical motion error, human behavior error, dose errors in planning system etc.). In detail, we try to develop a methodology to apply the method of PSA, and modeled mathematically radiotherapy errors in the whole process radiation treatment system including the beginning of treatment planning, dose calculation, dose verification and human errors. But we don’t get enough data of some factors yet. Therefore, we just make two hypothetical fault trees.

**Conclusion:** As soon as we get enough data of some parameters, we will gain the meaningful data and decide significant parameters. And so we will improve the quality of radiotherapy assessment with appropriate methods.

# SIMULATED DOSE RATE CALCULATION FOR RADIOACTIVE EFFLUENT TRANSPORT PIPES AT VVR-S NUCLEAR RESEARCH REACTOR FROM BUCHAREST - MAGURELE, ROMANIA

**Ioan Iorga**[1,2]

1 Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania
2 Faculty of Physics, University of Bucharest, Bucharest-Magurele, Romania

The VVR-S nuclear research reactor owned by Horia Hubulei – National Institute of Physics and Nuclear Engineering (IFIN-HH), has functioned between 1957 and 1997 at a nominal thermal power of 2 MW, using low-enriched nuclear fuel (10%) type EK-10 and highly enriched fuel (36%) type S-36.

The reactor was fitted with a 30 m$^3$ radioactive effluents leakages pond connected by an underground pipe with two 300 m$^3$ radioactive effluents storage ponds belonging to the Radioactive Waste Treatment Plant (STDR). The underground structures was finally build until 1965-1967 when was installed the transfer radioactive effluents pipe between nuclear research reactor 30 m$^3$ radioactive effluents leakages pond and the two 300 m$^3$ radioactive effluents storage ponds.

The principal radionuclides implicated are the $^{60}$Co, $^{137}$Cs, with theirs correlation factors respectively, for beta evaluation we considered $^{90}$Sr – $^{90}$Y.

We used geometry simulation in close proximity with reality to observe de dose rate and activity. For dose rate assessment we use MicroShield 9.04 software on annular cylinder external dose point geometry, to simulate individual parts and integrating the results after a descriptive model corresponding with physical reality and probe factors.

We developed different approach to manage the dismantling in the proper way respecting the ALARA principle. The specific activity varies from 0.43 Bq/g – 23.89 Bq/g for $^{137}$Cs and for $^{60}$Co values were between 0.03 Bq/g – 0.67 Bq/g. the level of contamination for the ($^{137}$Cs and $^{60}$Co) measured during the cutting operations likely to be between: 11 Bq/cm$^2$ and 75 Bq/cm$^2$. This activity was very important especially in appreciation of the dose rate inside of the pipe before the cutting.

As a result of this approach, the decommissioning activities of the underground radioactive effluents pipe structures from the IFIN-HH VVR-S Research Reactor were successfully accomplished in a short time with minimal expenses, as well as without any environmental incidents, damages to equipment and injuries to working personnel and general public.

# MONITORING OF OCCUPATIONALLY EXPOSED WORKERS IN MONTENEGRO: AN OVERVIEW

**Aleksandra Milatović, Nikola Svrkota, Benard Berišaj**

Centre for Ecotoxicological Research, Podgorica, Montenegro

Persons occupationally exposed to ionizing radiation are subject to radiation protection due to potential harmful effects of radiation. Dose monitoring of professionally exposed workers is an essential regulatory measure in radiation protection. Centre for Eco-toxicological Research in Podgorica, acting as a technical support organization to regulatory authorities, is the first and only institution in the country performing personal dosimetry service (since 2007). Montenegro is a small, developing country with 670 000 population, the use of radiation sources being limited to common medical applications and a few industrial ones, with estimated 600 occupationally exposed individuals. 93 persons belong to Category A (controlled persons). The highest annual value of the personal equivalent dose, Hp (10), was found with a practitioner in Anghiography Department, amounting to 8.5 mSv. Results for all subjects monitored up to now are below internationally recommended dose limits. In this work we will give an overview of the occupational exposure of workers in different working fields.

**Key words:** Exposed workers, TLD, Category A, Category B

# MODELING OF THE NUCLEAR FACILITY S3 OF SPIRAL2: NEUTRON ENVIRONMENT AND RADIOLOGICAL STUDY

**Manssour Fadil**

GANIL, Caen, France

S3 (Super Separator Spectrometer) is a device of SPIRAL2 dedicated to the experiments with high intensity stable beams to study heavy and super heavy nuclei, especially the neutron deficient ones. Light nuclei, namely those produced by transfer reaction, will also be available in S3. In this work we present the modeling of S3, the simulation results of particles transport and the rays map (neutron and other light particles) in S3 building. Some consequences of these calculations like the damage for electronic components or for cryogenic liquids will also be presented. These studies used a Monte Carlo calculation method, namely with the Japanese code PHITS.

**Key words:** Modeling, Monte Carlo simulation, particle transport, neutron doses

# DATA FROM SECURITY STAFF PERSONNEL MONITORING IN BULGARIA

**Orlin Stoyanov**

National Centre of Radiobiology and Radiation Protection, Sofia, Bulgaria

This paper presents the results from personnel monitoring in specific areas of occupational exposure. The doses from individual exposure of security staff and caretakers were measured during 2016. The results show unexpected values of annual individual dose – 0.73 mSv. The highest value is 9.82 mSv. The results are compared with the doses in different professions, such as NPP and medical staff. For decreasing the doses of individuals, whose job assignments are incidental to the use of radiation, such as caretakers and security staff who may spend brief periods in areas where exposure is possible, we recommend everyday brief discussion of items such as the use of time and distance to limit exposure and qualitative discussion of the risks from the exposure that they may undergo.

# Radioecology 08

# ANALYSIS OF TERRESTRIAL NATURAL RADIONUCLIDES AND THE ASSESSMENT OF ANNUAL EFFECTIVE DOSE IN THE SOILS OF THE INSTITUTE OF APPLIED NUCLEAR PHYSICS IN ALBANIA

**Manjola Shyti[1], Irma Bërdufi[1], Florinda Cfarku[1], Gerti Xhixha[2]**

1 University of Tirana, Institute of Applied Nuclear Physics, Tirana, Albania
2 University of Tirana, Faculty of Natural Sciences, Department of Physics, Tirana, Albania

Significantly, terrestrial gamma radiation levels are affected from radionuclides that are present in soil which in turn can be used for the assessment of terrestrial gamma dose rate. This study is important because the employees of this institute in addition to professional exposure will be known with average annual effective dose equivalents (AEDEs) in soils that come from this area. The main radioactive materials are long-lived radionuclides such as $^{238}U$, $^{232}Th$ and $^{40}K$ known as NORMs (Naturally Occurring Radionuclide Materials). Natural radioactivity analysis has been done for the soil samples collected from the area of Institute of Applied Nuclear Physics (IANP) in Tirana, Albania. The specific radioactivities of Radium ($^{226}Ra$), Thorium ($^{232}Th$) and Potassium ($^{40}K$) were measured in these samples using a HPGe (High Purity Germanium) detector based on low background gamma-ray counting system. From the measured specific radioactivities of the above three natural radionuclides, the Radium equivalent activity ($Ra_{eq}$), the external hazard index ($H_{ex}$), the external gamma absorbed dose rate and annual effective dose were calculated. The obtained mean values of gamma absorbed dose rate and annual effective dose in soil samples were found to be comparable with the worldwide average as reported by United Nations Scientific Committee on the Effects of Atomic Radiation. The natural radioactivity levels in soils of IANP area had never been studied before. This study aims to determine the dose rate in order to assess the health risk from activity concentration of natural radionuclides as $^{238}U$, $^{232}Th$ and $^{40}K$ in soil. Also the Radium equivalent ($Ra_{eq}$) of samples is calculated and compare with similar data reported in literature. The $Ra_{eq}$ values were in the range of 29.2 to 200.6 Bq $kg^{-1}$ and the exernal hazard index ($H_{ex}$) is lower than unity varied from 0.08 – 0.54. The values of outdoor annual effective dose were in the range 0.02 to 0.11 mSv, shown that the area of IANP was radiologically safe.

# ACCUMULATION OF RADIONUCLIDES BY PLANTS OF DIFFERENT TAXONOMIC GROUPS WITHIN THE EAST-URAL RADIOACTIVE TRACE

**Lyudmila N. Mikhailovskaya, Vera N. Pozolotina, Elena V. Antonova, Makar V. Modorov**

Institute of Plant and Animal Ecology UB RAS, Ekaterinburg, Russia

The East Ural Radioactive Trace (EURT) is a result of the accident at the Russian Production Association Mayak in 1957 (so-called Kyshtym accident). Among the long-lived radionuclides, $^{90}$Sr was the primary contaminant. In 1967, the EURT area was contaminated again with radioactive sediments from the shores of Lake Karachay, which was used by the PA Mayak for dumping liquid radioactive waste. The primary contaminant was $^{137}$Cs. Investigations of the spatial and vertical distribution of $^{90}$Sr, $^{137}$Cs and $^{239,\,240}$Pu in the EURT soils and accumulation of these radionuclides by plants were carried out in 2009– 2015.

The aims: 1) estimation the heterogeneity of soils pollution by $^{90}$Sr, $^{137}$Cs and $^{239,240}$Pu within EURT central axis; 2) investigation the variability of the radionuclides accumulation by plants of different taxonomic groups growing on certain locations of this polluted area.

The spatial distribution of the radionuclides with increasing distances from the epicenter of the accident is satisfactorily approximated by the exponential function. Currently the essential amount of radionuclides is located in the 15–20 cm root layer of the soil.

The differences of accumulation of $^{90}$Sr by plants of different taxonomic groups were small at the gradient of contamination. Most of these values were in a narrow range about one order of magnitude. The main factor determining accumulation of the $^{90}$Sr by plants is its content in soils.

The $^{137}$Cs and $^{239,240}$Pu accumulation in the studied groups of plants varies more. Minimum values of the specific activity were found in woody and herbaceous plants, the maximum values were character for mosses, lichens. The differences in the specific activity of this radionuclide in plants reached more than two orders of magnitude. The specific activities of the $^{137}$Cs in plants depend not only on the density of soil contamination, but also on the species features (morphological features of the root system, stems, leaves and physiological needs of plants in elements-analogues, primarily potassium).

Species of the same family can be described as close and different accumulation capacity. Besides, significant variability in the plants accumulation capacity is conditioned by the high heterogeneity of soil contamination.

# SOIL-TO-WHEAT TRANSFER OF $^{137}Cs$ IN CONDITIONS OF POST-CHERNOBYL LANDSCAPE AND IN MODEL POT EXPERIMENT

**Tatiana Paramonova[1], Maria Godyaeva[1], Natalia Kuzmenkova[2], Olga Komissarova[1]**

1 Soil Science Faculty of Lomonosov Moscow State University, Moscow, Russia
2 Chemistry Faculty of Lomonosov Moscow State University, Moscow, Russia

Soil-to-plant transfer of artificial radionuclides is a principal problem in the areas of accidental radioactive fallout, especially with arable lands predominating. Express estimation of the radionuclides root uptake by cultivated crops is required to solve the problem of following land use and to assess safety of plant production. transfer factors (TFs) for groups of crops and soils with definite texture are commonly used to provide these forecasts. Nevertheless the versatility of existing TFs is still open to the question and series of investigations treating on $^{137}Cs$ root uptake by different crops in field conditions of radioactively contaminated lands (post-Chernobyl, post-Fukusima, etc. areas) and/or in laboratory are in progress.

To test a comparability of natural and laboratory data soil-to-wheat intensity of $^{137}Cs$ transfer in field conditions of the "Plavsky radioactive hotspot" (post-Chernobyl area in Tula region of Russia) and in model pot experiment had been studied. Soil component was presented in both cases by undisturbed 30-cm top-layer of Luvic Chernozems characterized by clay loamy texture, humus 6-7%, pH 6.5-7.2, and bulk density 1.1-1.2 g/cm$^3$. Initial radionuclide inventory in conditions of long-term contamination of soil was estimated as 154 kBq/m$^2$; and newly-formed severe level of chernozem pollution by $^{137}Cs$ as 9.15 MBq/m$^2$ had been created in model pots. Winter wheat (*Triticum durum*) of cultivar Moskovskaya-39 had been grown in the field and laboratory conditions. Account of general $^{137}Cs$ transfer from patterns of contaminated soil into wheat biomass had been made at identical inflorescence emergence vegetative stage; grain of wheat was later collected just before harvesting in field conditions.

Average $^{137}Cs$ activity concentrations in total wheat biomass in the field and experimental conditions, as well as levels of soil contamination were considerably dissimilar: 89 Bq/kg and 2078 Bq/kg correspondingly. However, aggregated transfer factor values ($TF_{agg}$, Bq/kg in plant / kBq/m$^2$ in soil) were almost equal: 0.63 in the field and 0.68-0.76 in laboratory. Clearly defined feature of $^{137}Cs$ distribution among above- and belowground parts of wheat biomass was increasing of the radionuclide activity concentrations in the last. Whereas mean $TF_{agg}$ in roots were 1.71 and 2.45-5.14 for field and laboratory conditions correspondingly, mean $TF_{agg}$ in aerial parts of the crop were 0.19 and 0.36-0.63 accordingly. The transfer of $^{137}Cs$ into wheat grain was even less, and $TF_{agg}$ had been accounted as 0.01.

In sum, in spite of differences in general conditions of field and laboratory observations biological features of $^{137}Cs$ root uptake for a fixed pair "soil-plant" may be revealed satisfactory. In particular, $^{137}Cs$ root uptake by winter wheat from chernozems is characterized by distinct discrimination and weak translocation from roots to shoots, as in the case of post-Chernobyl landscape, as well in model pot experiment.

# ARTIFICIAL ISOTOPE SPECIATION IN PLANTS' BIOMASS, RHIZOSPHERE AND ALLUVIAL SOIL OF YENISEI FLOOD PLAIN

**Marya Kropacheva, Mikhail Melgunov, Irina Makarova**

Sobolev Institute of Geology and Mineralogy SB RAN, Novosibirsk, Russia

One of the most interesting and important problems of modern radioecology is problem of an artificial isotopes' migration and redistribution in environment. Those isotopes exist in biogeocenosises for less than one century, and their behavior need to be investigated and compared with natural isotopes' behavior. Appropriate subject for such research is the Yenisei flood plain. Zheleznogorsk-city, also known as Krasnoyarsk-26, is situated on Yenisei river in 200 km lower on flow from Krasnoyask-city, and is the place where Krasnoyarsk Mining-Chemical Complex (KMCC) is situated. The Complex formed by three reactors and radiochemical plant with spent fuel storage facility. Two of the three reactors are direct-flow type, third one is close-cycle type. They were shut down in 1992 and 2010 respectively. The radiochemical plant with spent fuel storage facility continues to operate until now, so the isotopes continue to enter the river flood plain.

For more complete revealing of mobility of natural and artificial isotopes various components of the biogeocoenose were studied: alluvial soils from sample sites with different stream conditions, plants, rhizosphere (narrow layer of soil (about 1-5 mm) that is directly influenced by root secretions (carbohydrates, aminoacids) and associated soil microorganisms (such as bacteria, fungi, algae).

Data of sequential extraction show perceptible differences in artificial isotopes mobility in soil. Also, the isotopes mobility can be very distinct from that in rhizosphere. So, $^{137}Cs$ isotope is the least mobile and 90% of it is bound with residual solids both in soil and rhizosphere. Most part of $^{60}Co$ is contained in bound state; however, ratios of II, III and IV fractions in soil and rhizosphere vary notably. Such distinction between isotopes mobility in soil and rhizosphere is especially noticeable for Eu isotopes, which have affinity to exchangeable (I) fraction, organic (IV) fraction, and Fe, Mn oxide and hydroxide (III) fractions. In soil significant part of Eu isotope is bound with residual solids. $^{90}Sr$ isotope turns out to be the most mobile isotope. About 20-40% of it is bound with residual solids. Up to 30 % of $^{90}Sr$ can be contained in the exchangeable fraction. Significant amount of $^{90}Sr$ is contained in the carbonate (II) fraction, the organic (IV) fraction, and the amorphous silicates (V) fraction.

Distribution of artificial isotopes ($^{137}Cs$ and $^{90}Sr$) in the biomass of terrestrial vascular plants can change from year to year and depends significantly on the plant age. Young plants concentrate isotopes in the extracellular and intracellular fractions. Their maximal amount is associated with the intracellular fraction and, to a lesser extent, with the extracellular fraction. With plant aging, isotopes are either fixed in the cell wall structures, or washed out from the extracellular and intracellular spaces by different ways.

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# CAESIUM-137 AND POTASSIUM-40 IN BLUEBERRY-BASED PRODUCTS ON THE MARKET IN SERBIA

**Borjana Vranješ[1], Velibor Andrić[2], Mila Vranješ[2], Jelena Ajtić[1], Branislava Mitrović[1]**

1 Faculty of Veterinary Medicine, Beograd, Serbia
2 Vinča Institute of Nuclear Science, Beograd, Serbia

The aim of the work presented in this paper was investigation of the activity concentration of $^{137}$Cs and $^{40}$K in blueberry-based products that are available on the market in the Republic of Serbia. Samples were bought in stores during September 2017 and in total, ten packaged juices, two jams, two sweets and one fresh wild blueberry were measured. Blueberries are abundant in beneficial vitamins, minerals and other elements, and have an extraordinary nutritional and pharmaceutical value. The collected blueberry-based juices show the caesiums-137 activity concentration ranging from the minimal detectable activity (MDA) to 4 Bq/kg. Activity concentration of caesium-137 in jams ranges from MDA to 21 Bq/kg, and in blueberry-based sweets from 0.6 Bq/kg to 28 Bq/kg. A content of caesium-137 in fresh wild blueberry is 4 Bq/kg. In Serbia, the recommended level of activity concentration for caesium-137 in juices and sweets is 15 Bq/kg and 150 Bq/kg in fresh blueberries. The tested samples of juices, jams, fresh wild blueberry and one of the sweets meet the set criteria for caesium-137 while one sweets sample exceeds the limit. Naturally occurring radionuclide potassium-40 is detected in all the samples with the activity concentrations of 4–55 Bq/kg in juices, 14–19 Bq/kg in jams, 17-227 Bq/kg in sweets, and 32 Bq/kg in fresh wild blueberry.

# THREE AUTHIGENIC U(IV)- PHASES IN LAKE SEDIMENTS (OLKHON REGION)

**Yulia Vosel[1], Sergey Vosel[2], Mikhail Melgunov[3], Irina Makarova[1], Vera Strakhovenko[3]**

1 Sobolev Institute of Geology and Mineralogy of the Siberian Branch of the RAS, Novosibirsk, Russia
2 Voevodsky Institute of Chemical Kinetics and Combustion of Siberian Branch of the RAS, Novosibirsk State University, Novosibirsk, Russia
3 Sobolev Institute of Geology and Mineralogy of the Siberian Branch of the RAS, Novosibirsk State University, Novosibirsk, Russia

Modern ocean sediments studies showed the accumulation of uranium in their reduced part below Red-Ox border. The main reason of this concentration increase is the fact that during the diagenesis process the reduction of the uranyl ions of pore solutions occurs, forming their own U (IV) mineral phases. U (IV) mineral phases could not be detected by electronic microscope or some other physical methods in modern ocean sediments. Such phases have been found with electron microscopy only in phosphorites of continental shelves. Uraninite ($UO_{2+x}$), coffinite($USiO_4$) and ningioit ($CaU(PO_4)_2{*}2H_2O$) have been found there. Therefore, it can be assumed that only those mineral phases of uranium (IV) must be forming in modern sediments of salt and freshwater lakes.

The goal of this work is to find evidence of the existence of several of newly formed U (IV)-phases in the lake sediments columns. Namshi-Nur and Melkoe lakes from Ol'khon Region (Siberia, Russia) were selected for this study. In their waters uranium concentrations are large enough, measuring 22 ± 3 µg / L, and 25 ± 3 µg / L, respectively, and the isotopic ratios ($^{234}U/^{238}U$) are equal to 1.75 ± 0.08 and 2.66 ± 0.24, respectively. In our previous work, we proposed a method that allowed us to find the evidence of the existence of autogenic newly-formed U (IV)-mineral phases in the lake sediments of Ol'khon Region. The approach is to use sequential extraction procedure of sediments, with addition of several steps with nitric acid solutions of different concentrations and temperatures. The most chemically resistant mineral is uraninite, which is soluble only in concentrated boiling acid, while, for example, coffinite was readily soluble in the dilute acid at 25°C.

All samples were investigated with the alpha-spectroscopy method. The isotopic ratio ($^{234}U/^{238}U$) is very useful for distinguishing the uranium of clastic phases from uranium of authigenic phases. The existence of uranium from authigenic phases in the sample is indicated by increased isotopic ratio ($^{234}U/^{238}U > 1$). Authigenic phases precipitate, so they inherit the isotopic ratio of the water solution from which they were formed. The clastic minerals always have the isotopic ratio $^{234}U/^{238}U$ strictly equal to 1 (secular equilibrium).

Based on our studies we can conclude that the studied lake sediments have three different authigenic U (IV)-phases:

The first phase is easily dissolved in 0.5 M $HNO_3$, which is typical to coffinite ($USiO_4$).

Second phase – soluble only in the boiling concentrated HNO3, which is a feature of uraninite group of minerals ($UO_{2+x}$).

Third phase – soluble in concentrated $HNO_3$ at 90°C. This phase was found only in the sediments of Lake Melkoe.

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# ARTIFICIAL ISOTOPES ($^{241}$Am AND $^{137}$Cs) IN DIAGENETIC CONDITIONS OF BOTTOM SEDIMENTS ON THE EXAMPLE OF THE LAKE KRUGLOE (TOMSK REGION, RUSSIA)

**Yulia Vosel[1], Elena Lazareva[1], Sergey Vosel[2], Mikhail Melgunov[3], Marya Kropacheva[1], Vera Strakhovenko[3]**

1 Sobolev Institute of Geology and Mineralogy of the Siberian Branch of the RAS, Novosibirsk, Russia
2 Voevodsky Institute of Chemical Kinetics and Combustion of Siberian Branch of the RAS, Novosibirsk State University, Novosibirsk, Russia
3 Sobolev Institute of Geology and Mineralogy of the Siberian Branch of the RAS, Novosibirsk State University, Novosibirsk, Russia

This work is devoted to the investigation of sediments of the fresh lake in order to determine the extent of migration (scales and rates) of artificial radionuclides $^{137}$Cs and $^{241}$Am under diagenetic conditions in organomineral sediment.

A core of bottom sediments of the Lake Krugloe located within 30 km zone of Siberian Chemical Plant influence (the city of Seversk (Tomsk-7)) was investigated. In solid substance of the core and in granulmetric fractions $^{210}$Pb, $^{226}$Ra, $^{241}$Am, $^{137}$Cs, $^{238}$U, $^{228}$Ra, $^{40}$K were determined by direct, high-resolution, semiconductor gamma-spectrometry using a well semiconductor detector. Granulometric characteristics of the substance of upper sediment layer were studied by classical sedimentation method in accordance with the published methods. The content of the main cations and Fe in water and pore solutions was measured by the method of atomic absorption spectroscopy and content of dissolved U by ISP-MS.

Gamma-spectrometry measuring of granulometric fractions showed that distribution patterns of artificial radionuclides and $^{210}Pb_{ex}$ between fractions are similar. Dating by $^{210}Pb_{ex}$ allows to calculate that the age of the horizon at the depth of 10 cm corresponds to ~1950. The depth of the oxidized/reduced boundary was determined from the distribution of redox sensitive elements Fe and U dissolved in pore solution; it amounted to 10 cm. Just an insignificant penetration of $^{241}$Am and especially $^{137}$Cs into lower reducing conditions occurred. Thus $^{137}$Cs was present in the sediment earlier than in the environment. Core distribution of $^{137}$Cs is a slightly sloping step. Blurring of the lower boundary of the step made it possible to estimate the diffusion mobility of $^{137}$Cs.

Comparison of activity distribution of artificial radionuclides and $^{210}Pb_{ex}$ over granulometric fractions points to an atmospheric source of their deposition. Measurements of oxy-cline location show that most of the time the migration processes involving $^{137}$Cs and $^{241}$Am occurred in oxidizing conditions. Mobility of $^{137}$Cs is higher than that of $^{241}$Am. Diffusion coefficient of $^{137}$Cs are about $10^{-8}$ cm$^2$*s$^{-1}$, and this suggests that diffusion of $^{137}$Cs and $^{241}$Am isotopes occurs in the composition of colloidal particles.

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# ASSESSMENT OF 137CS INVENTORIES IN AGRICULTURAL LANDSCAPES: SOIL SAMPLING OF ACTUAL PLOUGHED HORIZON OR STANDARDIZED LAYERS?

**Tatiana Paramonova[1], Olga Komissarova[1], Leonid Turykin[2]**

1 Faculty of Soil Science, Lomonosov Moscow State University, Moscow, Russia
2 Faculty of Geography, Lomonosov Moscow State University, Moscow, Russia

Assessment of $^{137}$Cs inventories in soil is the key factor for elaboration of land use strategy. Most of uncertainties in this assessment derived from soil sampling procedure, in particular, from a chosen depth of soil collection. Sampling of fixed 0-10(15) cm surface layer for soils with undisturbed profile and sampling of ploughed horizon ($A_p$) for arable soils is common.

Estimation of $^{137}$Cs inventories in agricultural soils with a consideration of the radionuclide distribution in top 30-cm layer have been made in the area of the Plavsky radioactive hotspot (post-Chernobyl territory in Tula region of Russia with initial radioactive fallout 185–555 kBq/m$^2$). Arable soils are presented by clay loamy Luvic Chernozems. Soil sampling has been conducted on 8 test plots with main crops occupying the investigated space: wheat, barley, maize, potatoes, soybean, rape, amaranth, and legume-cereal grass mixture. Stratified random approach has been applied with sample's strata 0-10 cm, 10-20 cm, and 20-30 cm and thickness of $A_p$ simultaneously was taking into account.

The range of total $^{137}$Cs inventories in top 30-cm layer of arable chernozems of the Plavsky radioactive hotspot varied from 106 to 196 kBq/m$^2$ reflecting primary spatial heterogeneity of Chernobyl fallout and secondary translocation of the radionuclide due to erosion process. Arithmetic mean and median values of total $^{137}$Cs inventories in soil patterns were quit similar (156 kBq/m$^2$), while variation coefficient ($C_v$) was equal to 20%. The same concerned all sampled soils layers: average $^{137}$Cs inventories were 50 kBq/m$^2$ in the top 0-10 cm layer, 59 kBq/m$^2$ – in 10-20 cm layer, 42 kBq/m$^2$ – in 20-30 cm layer; $C_v$ ranged 25-29%. Considerable radioactive contamination detected in the 20-30 cm layer clearly demonstrated deep plowing up to 30 cm for the remediation of lands of the Plavsky radioactive hotspot after Chernobyl accident in 1986.

The depth of $A_p$ nowadays is essentially less and depends on type of cultivated crop. As regards the investigated agrosystems of the Plavsky radioactive hotspot area, the depth of cultivation is 10 cm for winter wheat and barley, 20-25 cm for maize, soybean, rape, amaranth, 25-30 cm for potatoes, and there is no annual agrogenic turbation processes for the grass mixture. So when comparing $^{137}$Cs inventories using the samples of actual $A_p$ the rise of uncertainties is obvious: the density of soil radioactive contamination seems to be 42-47 kBq/m$^2$ for cereals, 104-145 kBq/m$^2$ for row crops, and 154 kBq/m$^2$ for potatoes. Median is shifted relative to arithmetic mean, and $C_v$ builds up to 40%. In addition, soil sampling limited by actual $A_p$ prevents the assigning of $^{137}$Cs inventories in old $A_p$ that is unlikely reasonable.

Thus, rather deep sampling of standardized layer(s) to compare $^{137}$Cs inventories in soils of agricultural landscape could be considered as appropriate, while accuracy of the data obtained only from actual ploughed horizon(s) could be seemingly inadequate.

# ACTIVITY CONCENTRATION OF $^{40}K$ AND $^{137}Cs$ IN THE MUSCLE TISSUE AND LIVER OF THE GOLDEN JACKAL (*CANIS AUREUS)*

**Branislava Mitrović[1], Duško Ćirović[2], Jelena Ajtić[1], Velibor Andrić[1], Borjana Vranješ[1]**

1 Faculty of Veterinary Medicine, University of Belgrade, Belgrade, Serbia
2 Facullty of Biology, University of Belgrade, Belgrade, Serbia

The aim of this study is to determine the activity concentration of $^{40}K$ and $^{137}Cs$ in muscle tissue and liver of the golden jackal (*Canis aureus*). In 2016 and 2017, five adult male golden jackals were haunted in the Bojčin forest, Surčin municipality, which is a suburban area of the Belgrade city, the Republic of Serbia. The dominant foodstuffs in the jackal diet are small mammals (mostly moles) and carcasses of domestic animals, but also fruits in the summer season. Hence, the golden jackal can be an indicator of the $^{137}Cs$ migration through the food chain. The mean activity concentrations of $^{137}Cs$ and $^{40}K$ in the soil sampled from the Bojčin forest were 14 Bq/kg and 695 Bq/kg, respectively. The $^{137}Cs$ specific activity in most of the muscle tissue and liver samples of the golden jackal is below the minimum detectable activity (<0.1 Bq/kg). Very low $^{137}Cs$ activity concentration is detected in one muscle tissue (0.4 Bq/kg) and liver sample (0.2 Bq/kg). The mean activity concentration of $^{40}K$ in the golden jackal muscle tissue and liver is 100 Bq/kg and 90 Bq/kg, respectively.

# RUTHENIUM IN THE GROUND LEVEL ATMOSPHERE OVER KRAKOW (POLAND): DETERMINATION OF ITS ACTIVITY CONCENTRATION, DEPOSITION AND ABSORBED DOSE ASSESSMENT

**Krzysztof Gorzkiewicz[1], Renata Kierepko[1], Jerzy Mietelski[1], Ewa Tomankiewicz[1], Tomasz Mróz[2], Kamil Brudecki[1]**

1 Institute of Nuclear Physics Polish Academy of Sciences, Krakow, Poland
2 Pedagogical University in Krakow, Krakow, Poland

In late September and in October 2017 artificial radioactive isotope Ruthenium-106 has been found in air over Europe. Its presence was primarily detected in Northern Italy and Central Europe but the origin of emission still remains unknown at the time of writing. Ru-106 was detected by means of aerosol sampling stations used in continuous monitoring of concentration of radioactive isotopes in ground-level air. In Krakow Ru-106 was firstly detected on filter which had been exposed in period 25.09 – 02.10.2017 (aerosol sampler with nominal flow rate 500 $m^3/h$, filter type – Petryanov filter FPP-15-1.5). Conducted investigation involved assessment of activity concentration of Ruthenium in various environmental samples as well as estimation of absorbed doses.

Ruthenium-106 is an artificially obtained isotope and it is commonly produced in separation procedure of fission products after irradiation of highly-enriched U-235 targets with neutrons. Ru-106 is a pure beta-minus emitter and decays to the ground state of Rh-106 which further decays to excited states of Pd-106.

All measurements of activity concentration of Ruthenium were conducted using gamma radiation spectrometry. Ru-106 does not emit gamma-rays but within few minutes achieves secular equilibrium with its daughter isotope. The decay of Rh-106 is followed by emission of gamma rays (due to deexcitation of Pd-106) what allows to determine activity concentration of both Rh-106 and Ru-106 by means of low background gamma-rays spectrometers with HPGe detectors.

Conducted researches showed that the highest concentration of Ru-106 in ground level air in Krakow was present in period 2-3 October 2017 (24 hours of exposition) and reached 16.7 ± 1.2 $mBq/m^3$. Additionally, small traces of Ruthenium-103 were also detected (activity ratio $A_{Ru\text{-}106}/A_{Ru\text{-}103}$ = 3600 ± 794). Further measurements of filters showed that Ruthenium concentration was constantly dropping down and reached limit of detection on 5 October. However, in traces it was still observed in next weeks.

In order for determination of environmental contamination and the deposition of Ruthenium, many different samples have been collected and examined such as: 4 rain samples collected in September and October, soil sample, samples of mosses, 2 samples of leaves of oak tree and raspberry bushes and 2 samples of grass from two different places in Krakow.

Subsequent experiments and analysis were carried out to estimate doses absorbed by average citizen of Krakow due to inhalation and ingestion of Ru-106. Ingestion doses were estimated using Ru-106 concentration in cabbage and lettuce samples. Preliminary result of absorbed dose due to inhalation for adult person who inhales 20 $m^3$ of air per day was estimated at 0.01 mSv, what is about 300 times lower than average dose from natural sources in Poland (assuming conservative dose assessment).

# RECONSTRUCTION OF HISTORICAL LAND USE CHANGES IN FÂNTÂNELE LAKE'S AREA (ROMANIA), BASED ON $^{137}$Cs AND $^{210}$Pb$_{ex}$ MEASUREMENTS

**Daniela Vasilache, Robert-Csaba Begy, Călin Baciu**

Babes-Bolyai University, Faculty of Environmental Science and Engineering, Cluj-Napoca, Romania

The human fingerprint on the environment is more and more visible, vulnerability of the soil to human induced erosion processes varying in time and space depending on the climate, geology and land use changes. Romanian forests were affected by management changes since 1800, and especially after 1990s. This study presents an assessment of soil erosion effects on the sedimentation rates of Fântânele Lake, highlighting the major events of land use changes in its watershed. Radionuclide approaches (i.e. $^{137}$Cs, $^{210}$Pb$_{ex}$) were used to assess the influence of deforestation on the sedimentation rate of the selected artificial lake. The sampled sediment cores were dated using $^{210}$Pb method and the sedimentation rates were calculated with the Constant Rate Supply (CRS) model. In addition, soil cores were collected from the slope in order to quantify soil erosion. The $^{137}$Cs and $^{210}$Pb$_{ex}$inventories were determined by gamma and alpha spectrometry and for estimation of the sedimentation response to forestry activities, organic matter (OM) changes in the cores were obtained using Loss-on-Ignition (LOI) technique. Periods of increased sedimentation rates were observed, values between 0.014 ± 0.002 g/cm$^2$*y and 0.584 ± 0.066 g/cm$^2$*y being obtained for Fântânele lake. The reports from National Forests Management Agency ROMSILVA confirmed the obtained results, suggesting that inappropriate practices consequent to land restitution to the private owners, along with streamside harvest, stream crossings and road construction are the main factors identified to increase the sediment yield.

**Key words:** $^{210}$Pb dating, $^{137}$Cs, erosion, sedimentation rate, land use

# MONITORING OF URANIUM CONCENTRATIONS IN WATER SAMPLES COLLECTED NEAR POTENTIALLY HAZARDOUS OBJECTS IN NORTH-WEST TAJIKISTAN

**Petro Zoriy[1], Martin Schläger[1], Khatam Murtazaev[2], Jürgen Pillath[1], Myroslav Zoriy[1], Burkhard Heuel-Fabianek[1]**

1 FZJ, Jülich, Germany
2 Khujand State University, Khujand, Tajikistan

The water contamination near ecologically problematic objects was investigated between 2009 and 2014 in North-West Tajikistan as a part of a joint project between Forschungszentrum Jülich and Khujand State University. The main part of this work was the determination of uranium in water samples collected near the Degmay tailings dump, the Taboshar pit lake and the Syr Darya River. More than 130 water samples were collected and analyzed to monitor the uranium concentration near the investigated areas. Two different mass spectrometers and an ion chromatograph were used for element concentration measurements. Based on the results obtained, the uranium influence of the Degmay tailings on the rivers Khoja-Bakyrgan-Say and Syr Darya and surrounding water was not found. The uranium concentration in water samples was monitored for a lengthy period at seven locations Great differences in the uranium concentration in waters collected in 2010, 2011, 2012, 2013 for each location were not observed. Drinking water samples from the region of North-West Tajikistan were analyzed and compared with the World Health Organization's guidelines. Seven out of nine drinking water samples near Taboshar exceeded the WHO guideline value for uranium concentrations (30 μg/L). The average uranium concentration of water samples from Syr Darya for the period from 2009 to 2014 was determined to be 20.1(±5.2) μg/L. The uranium contamination of the Syr Darya was determined from the western border to the eastern border.

# EXTREMELY HIGH BERYLLIUM-7 SURFACE CONCENTRATIONS IN EUROPE: A CASE STUDY

**Jelena Ajtić[1], Erika Brattich[2], Miguel Angel Hernández-Ceballos[3], Darko Sarvan[1], Vladimir Djurdjevic[4]**

1 Faculty of Veterinary Medicine, University of Belgrade, Belgrade, Serbia
2 Department of Physics and Astronomy, Alma Mater Studiorum University of Bologna, Bologna, Italy
3 European Commission, Joint Research Centre, Knowledge for Nuclear Security and Safety Unit Radioactivity Environmental Monitoring Group, Ispra, Italy
4 Institute of Meteorology, Faculty of Physics, University of Belgrade, Belgrade, Serbia

Beryllium-7 is a cosmogenic radionuclide that, due to its maximum production in the stratosphere and upper troposphere, has often been used as a tracer of vertical transport processes in the atmosphere. In particular, high concentrations of surface airborne beryllium-7 could be a result of an uncommonly fast descent of air masses from the stratosphere into the troposphere. Hence, our aim is to investigate the maxima in the beryllium-7 surface concentrations to better understand the processes associated with the downward transport from the stratosphere to the troposphere.

Fourteen locations in Europe, with latitudes ranging between 37 °N and 69 °N, and longitudes between 6 °W and 28 °E, are analysed in our study. Over the 2001–2010 period, the beryllium-7 surface concentration measurements in the chosen sites were performed mostly once a week, giving a total of about 500 data points per each site. The data are contained within the online Radioactivity Environmental Monitoring (REM) Database.

We define the beryllium-7 maxima as values exceeding the 95$^{th}$ percentile calculated for each site. Over 2001–2010, 345 maxima are identified for the investigated 14 sites, out of which 61 maxima (18 %) occurred during three consecutive months: May, June and July 2006. Over this period, i.e. summer 2006, the contribution of detected maxima to the total number of maxima for each site ranged between 4 % and 32 %, with six sites showing a contribution of 20 % or larger. This number of extremely high beryllium-7 specific activities concentrated over only three months marks this period as unique.

In an attempt to identify underlying mechanisms that are associated with this exceptional episode of high beryllium-7 surface concentrations, we look into the potential vorticity, surface temperature and pressure, and precipitation maps over the region of interest during the time window when the extremes were observed.

RAD 2018

# CORRELATION OF RADIATION AND METEOROLOGICAL PARAMETERS DURING THE ENVIRONMENTAL RADIATION MONITORING IN THE PUBLIC COMPANY "NUCLEAR FACILITIES OF SERBIA"

**Vesna Radumilo, Ivan Knezevic, Dalibor Arbutina**

Public Company "Nuclear Facilities of Serbia", Belgrade, Serbia

Public Company "Nuclear Facilities of Serbia" is the only nuclear operator in Serbia. Under the radiation safety and radiation protection measures of the people and environment, Public Company conducts the environmental radiation monitoring around nuclear facilities. Monitoring includes also relevant meteorological measurements on the micro-location. This paper shows the correlation between the change of ambient gamma dose rate in the air and meteorological parameters: precipitation due to atmosphere leaching and the relative humidity in air. All the measurements were taken in the vicinity of nuclear facilities at the site of a meteorological tower on 114 meters above sea level. Monthly values of relative humidity and intense rainfall were obtained during 2016. The analysis of this relation clearly shows the impact of the intense rain and the relative humidity in air on the ambient gamma dose rate. Calculated Pearson's correlation coefficient shows the degree of the above-mentioned dependence.

# DETERMINATION OF TRITIUM ACTIVITY CONCENTRATION IN WATER IN VICINITY OF NUCLEAR FACILITIES IN SERBIA

**Nataša Todorović[1], Jovana Nikolov[1], Ivana Stojković[2], Marija Lekić[3], Nataša Lazarević[3]**

1 University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia
2 University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
3 Public Company "Nuclear Facilities of Serbia", Novi Sad, Serbia

Tritium is continuously distributed throughout man's environment, being a radionuclide generated both in interactions of cosmic rays in the atmosphere and as a result of human activity (including thermonuclear bomb tests, operation of nuclear reactors, and manufacture of nuclear weapons as well as various industrial and medical applications). The fact that its occurrence is mainly in the form of tritiated water (HTO) demands regular and precise control of tritium release from nuclear power plants into the environment, which is supported by international legislations and national regulations. Tritium monitoring is important around nuclear power plants and nuclear waste storage in whose vicinity exist water wells that supply the population with drinking water, thus preventing possibility of internal exposure through ingestion of drinking waters with elevated levels of tritium. Also, environmental monitoring of tritium is essential for assessment of actual or potential exposure of population, possible detection of any long-term changes trends in the environment resulting from operation of nuclear facilities and estimation of dispersion trend of tritium with the aim to obtain the baseline data on the present level of tritium, which would be valuable for estimating the environmental impact. According to the European Commission, the upper limit for tritium in water is 100Bql$^{-1}$ (European Commission, 1998). This value is not based on health effects relative to its consumption but more as a monitoring value. A tritium activity of 100 Bql$^{-1}$ could indicate that leakage or a release occur on a power plant and further analysis are then realized to check if other radionuclides are present in water.

In this paper, results of determination of tritium in water samples in vicinity of nuclear facilities in Public company "Nuclear Facilities of Serbia" are presented.

# THE EFFECT OF $TiO_2$ AND ZnO NANOPARTICLES ON THE BIOACCUMULATION OF STRONTIUM IONS BY AQUATIC PLANTS *SALVINIA NATANS* AND *ELODEA CANADENSIS*

**Monika Asztemborska, Marcin Bembenek, Małgorzata Jakubiak, Romuald Stęborowski**

Faculty of Biology, University of Warsaw, Warsaw, Poland

Nanotechnology is a dynamically developing field of scientific and industrial interest in the entire world. Nanoparticles (NPs) are increasingly used in many types of consumer products. Among the most commonly used are titanium oxide NPs (titania NPs, $TiO_2$ NPs) and zinc oxide NPs (ZnO NPs). The interactions of nanostructures with the biosphere may have unpredictable consequences and many studies focus on the potential hazards of NP contamination (nanotoxicology). Besides the toxicity, the influence of NPs on the chemical and physical behavior of soil or water components must also be considered. One of the possible effects caused by NPs is modification in the uptake of metal ions and other substances.

The aim of undertaken studies was examination of bioaccumulation of strontium ions ($^{90}Sr^{2+}$) by aquatic plants: *Salvinia natans* and *Elodea canadensis* in the presence of nanoparticles with sorption capacity: $TiO_2$ and ZnO NPs.

It was shown that NPs of titanium and zinc oxides have significant sorption capacity toward divalent ions of Sr. Under some conducive conditions, much about 50% of $^{90}Sr$ ions can be removed from a solution through sorption using ZnO nanoparticles. It was found that nanoparticles affect the bioaccumulation of strontium by aquatic plants. Bioaccumulation of Sr in *E. canadensis* was reduced by NPs of $TiO_2$ 100 nm, ZnO 50 nm, and ZnO 100 nm of about 38%, 47%, and 49%, respectively. Nanoparticles of $TiO_2$ 25 nm have negligible effect. Investigated nanoparticles of have reduced the accumulation of Sr in *S. natans* by 40%, 26%, 22%, and 23% for $TiO_2$ 25 nm, $TiO_2$ 100 nm, ZnO 50 nm, and ZnO 100 nm, respectively.

The studies have shown that in the presence of nanoparticles, the bioavailability of Sr ions by aquatic plants is reduced. In this way the possibility of strontium entering the food chain is limited. This can potentially reduce its toxic effect on the organism. However, accumulation and retention of strontium in the aquatic environment can be expected.

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# USING MUSSELS *MYTILUS GALLOPROVINCIALIS* AS AN INDICATOR SPECIES IN RADIOECOLOGY MONITORING OF THE NORTHERN ADRIATIC SEA

**Dijana Pavičić-Hamer, Delko Barišić**

Rudjer Boskovic Institute, Rovinj, Croatia

The source of radionuclides in the Adriatic Sea is global fallout primarily from the Chernobyl accident in 1986 and indirectly from the rivers discharges. Mussel *Mytilus galloprovincialis* is used as a indicator organism in monitoring marine pollution programs. A monitoring program for radioactivity in the northern Adriatic Sea was conducted by determination activity concentrations of artificial $^{137}$Cs, naturally occurring $^{40}$K, $^{232}$Th ($^{228}$Ra), $^{226}$Ra, $^{238}$U and cosmogenic $^{7}$Be in the soft tissues of mussels *M. galloprovincialis*, in spring and autumn periods from 2008 to 2017. Radionuclides were determined by gamma-ray spectrometry. A comparison of radioactive contamination was made between three locations of the northern Adriatic Sea (Lim bay, Raša bay and Bakar bay) under significant fresh water discharges. These are evident from the salinity's which were below average for the northern Adriatic Sea (38), especially in the Bakar bay (16). In Lim Bay $^{137}$Cs activity concentrations in surface seawater were low (1.70 Bq m$^{-3}$). In mussels $^{137}$Cs activity concentrations (< 0.3 Bq kg$^{-1}$ dray weight) were below the detection limit at all locations, except it were detected thrice in Raša Bay (0.7 Bq kg$^{-1}$) and in Bakar Bay (0.6 Bq kg$^{-1}$). Its presence in mussels tissue could be the consequence of its significant input through heavy rains and riverine outflows prior to sampling periods. The impact of the fresh water influx at all locations and higher the phytoplankton bioproduction proves increased activity concentrations of $^{7}$Be in mussels during the spring (26 Bq kg$^{-1}$) compared to autumn (19 Bq kg$^{-1}$). Activity concentrations of $^{40}$K in mussels did not vary significantly with season or location, the average $^{40}$K activity was 322 Bq kg$^{-1}$. Activity concentrations of primordial radionuclides $^{232}$Th ($^{228}$Ra), $^{238}$U and $^{226}$Ra in mussels were mostly below the detection limit with no seasonal changes. Increased activity concentrations of individual radionuclides in the mussels tissues proved the exceptional ability of pollutant bioconcentration and indicator potential of these organisms. Radioecological condition of the northern Adriatic Sea is satisfactory without significant radionuclide discharges from fallout and rivers.

**Key words:** Northern Adriatic Sea, mussels *Mytilus galloprovincialis*, radionuclides

# METHODOLOGY FOR ANALYSES OF URANIUM ISOTOPES IN DRINKING WATERS IN BULGARIA

**Lyuben Dobrev[1], Bozhidar Slavchev[1], Desislava Dimitrova[1], Blagorodka Veleva[2]**

1 Institute for Nuclear Research and Nuclear Energy – Bulgarian Academy of Sciences, Sofia, Bulgaria
2 National Institute of Meteorology and Hydrology – Bulgarian Academy of Sciences, Sofia, Bulgaria

Radiation monitoring programs for checking quality of drinking waters are in place in Bulgaria as in the other EU countries according to the EU Directive 98/83 and Euratom Directive 2013/51. The National Centre of Radiobiology and Radiation Protection of the Ministry of Health is responsible for monitoring of the radioactivity in drinking waters. They reported for elevated total alpha and beta activity concentrations and uranium mass concentration higher than the limit value in some water drilling supplies from southwestern part of Bulgaria (http://www.ncrrp.org/new/bg/Otcheti_dokladi-c189).

The reason for increased uranium isotopes concentrations, especially in ground waters in some regions of Southern Bulgaria, are uranium containing rocks (granites and sediments) and the consequences of former uranium mining deposits, thus enhancing the migration of natural radionuclides from the geological matrix to the water bodies.

The necessity of analyses of uranium isotopes in drinking waters arise when the screening levels set out at activity concentrations of 1 Bq/l and 0.1 Bq/l for total beta and total alpha radioactivity, respectively, in drinking waters are exceeded. In fact, the Euratom Directive 2013/51 and Bulgarian Ordinance No 9 (State Gazette 102 issued 12.12.2014) decrease twice the concentration of natural uranium as chemical element from 0.06 to 0.03 mg/l and 5 times the limit of total alpha activity from 0.5 to 0.1 Bq/l entered into force by Bulgarian legislation after 28.11.2015. If the total alpha activity is above 0.1 Bq/l, analysis of specific radionuclides is required and the secondary limits for alpha emitting radionuclides are set as follows: $^{238}U$ – 3.0 Bq/l; $^{234}U$ -2.8 Bq/l.

Therefore in order to analyze uranium isotopes in drinking water samples, required by national and local authorities in 2017, it was necessary to be developed and applied reliable methodology as follows: isotopic dilution with $^{232}U$ standard solution as a tracer; chemical separation by co-precipitation with $Fe(OH)_3$, followed by uranium separation by use of high selective UTEVA chromatographic resin. Thin source for alpha spectrometry is prepared by co-precipitation with $NdF_3$. The mineral content of the specific water samples highly influence the quality of the analysis and the chemical yield.

The results obtained show activity concentrations of $^{238}U$ from 0.03 to 0.71 Bq/l. The $^{234}U$ and $^{238}U$ activity concentrations are below the secondary limits set by Euratom Directive 2013/51. The calculated uranium mass concentration in 9 of 38 analyzed samples (including tap waters too) are above the limit for natural uranium of 0.03 mg/l. In some of the drinking waters the activity concentration ratio of $^{234}U$/ $^{238}U$ deviates from unity. This ratio varies from about 1 to 3.6, explaining higher total alpha activity in the samples with higher measured activity ratio.

# THE EFFECT OF ADDITIONAL ACUTE RADIATION ON HAEMATOLOGICAL PARAMETERS OF THE CRUCIAN CARP *CARASSIUS GIBELIO* FROM THE CHERNOBYL EXCLUSION ZONE

**Nataliia Pomortseva, Dmitri Gudkov**

Institute of Hydrobiology of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

The effectiveness of additional acute irradiation in the crucian carp from Lake Vershina in the Chernobyl Exclusion Zone (CEZ), which experiences prolonged radiation exposure at range of radiation dose rate 1.1-1.3 Gy/year, and from reference lake with background levels of radioactive contamination (0.005 Gy/year) was studied. As additional irradiation of fish the three sub-lethal doses of 2.5, 5.0 and 10.0 Gy were chosen. The blood samples were taken on 1, 7 and 30 days of experiment.

Analysis of the peripheral blood smears of the control sample of carp before irradiation showed that the frequency of disorders in erythrocytes was 1.7±0.2‰. On the blood smears there were erythrocytes with deformation of nuclear and cytolysis. In fish from the Vershina Lake (without additional irradiation) among the disorders was dominated the erythrocytes with parietal nuclei, deformation of nuclear, cytolysis and vacuolizated cytoplasm. The total part of disorders in erythrocytes was 9.0±1.5‰.

In fish from Vershina Lake on the first day after irradiation an increase in the destructive erythrocytes in comparison to the initial data by a factor of 2 times was observed. Analysis of fish from the reference lake showed an increase in destructive erythrocytes by 5.2 times. Erythrocytes with deformation of nucleus, pyknosis, vacuolizated cytoplasm and karyorhexis were recorded in the blood. On the 7th day in blood of fish from both lakes at all doses observed an increase in erythrocytes with structural disorders, and for the first time in the blood there were erythrocytes with proliferation disorders – amitosis, protuberances and septum in the nuclei. On 30th day in fish of Vershina Lake an increase in pathological effects by an average of 1.8 times the initial data, which was expressed in an increase in the number of amitoses, protuberances and vacuolization of the cytoplasm was registered. Analysis of fish preparations from the reference lake showed an increase in destructive erythrocytes by an average of 5.6 times.

Changes in relative composition of leukocytes in peripheral blood after additional irradiation have the phase changes. The changes were due to a decrease in the number of lymphocytes and an increase in granulocytes and monocytes. The process of recovery of lymphopoiesis in the kidney of crucian carcass was 1.3 times faster in fish from Vershina Lake than in fish from reference lake.

It can be concluded that in conditions of chronic radiation impact after additional sub-lethal radiation exposure, the proliferative activity of the hemopoiesis organs is usually sufficient to ensure a normal cellular composition of the blood of fish. However, the increase in structural defects and disorders of cell proliferation in peripheral blood of fish of the CEZ allows us to predict the instability of genome and increase of accumulation of chromosomal and genetic defects in fish organisms that can be transmitted to future generations.

# PRELIMINARY RESULTS OF URANIUM STUDIES IN RAINWATER SAMPLES IN POLAND

**Agata Walencik-Łata, Beata Kozłowska**

University of Silesia, Institute of Physics, Department of Nuclear Physics and Its Applications, Chorzów, Poland

Uranium can be released into the atmosphere through several pathways from natural and anthropogenic sources. In literature, except for a few papers, there is no data concerning the levels of uranium in rainwaters. Furthermore, very little is known about its origin and geochemical behavior.

The investigation of $^{234,238}U$ activity concentrations in rain and snow samples was performed. Samples were collected using a stainless steel open surface tray with a surface area of 1.6 m$^2$ connected with plastic barrel with volume of 60 L. The collection station was situated in the Silesia Voivodeship in Poland. Samples were collected in half month time periods or monthly, depending of the amount of rainwater. Immediately after rainfall water was acidified with the nitric acid and the volume of the rainfall was measured manually with glass cylinder. In the laboratory, samples of rain and snow were filtered and evaporated to the volume of 0.5 l. The separation of uranium from other alpha isotopes was performed with the use of the anion exchange resin Dowex 1×8 ($Cl^-$ type, 200-400 mesh). The measurements of $^{234,238}U$ isotope activities were performed with the use of α – spectrometer 7401VR (Canberra – Packard, USA) equipped with the Passivated Implanted Planar Silicon detectors with the surface area equal to 300 mm$^2$.

The results of uranium content in the rainfall covering one year period will be presented. Based on activities, $^{234}U/^{238}U$ activity ratio will be calculated. The obtained results of continuous measurements of uranium concentration in rainwater will be presented and discussed.

# PHYSICOCHEMICAL FORMS OF RADIONUCLIDES AND DOSE RATES ON BIVALVE MOLLUSCS (*DREISSENIDAE*) IN THE CHORNOBYL NPP COOLING POND

**Christina Ganzha, Dmitri Gudkov**

Institute of Hydrobiology of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

This study aims to evaluate the dose rate of ionizing radiation for bivalve molluscs *Dreissena sp.* from $^{90}Sr$ and $^{137}Cs$ in the Chornobyl NPP cooling pond (ChNPP CP), as well as to estimate the contribution of the physicochemical forms of radionuclides to the internal dose rate.

The radiation dose rate was calculated using the ERICA Assessment Tool 1.2 software. Since the investigated groups of *Dreissena sp.* in the CP habitat a rocky substrate, which has an insignificant radiation activity, the external dose rate was estimated on the basis of the total gamma background of the biotope and radionuclides contained in the water mass. Internal radiation dose rate was calculated on the base of physicochemical forms of radionuclide concentration in molluscs tissue, which were determined by the sequential extraction method.

Our estimation showed that internal dose rate for molluscs due to $^{90}Sr$ was $6 \cdot 10^{-3}$ Gy/year. The contribution of physicochemical forms of $^{90}Sr$ to the internal dose for molluscs revealed a dose fluctuation due to various physicochemical forms. Thus, the highest amount of the internal dose was registered due to organic form ($2 \cdot 10^{-3}$Gy/year), and its total contribution to the dose rate was 40%. The part of the exchange form of $^{90}Sr$ to the dose rate was about 5%, the intracellular form – 20%, and the mineral residue – 34%. The lowest dose rate values was observed for water-soluble and exchange forms of the radionuclide – 1 and 7%, respectively.

The value of dose rate from $^{137}Cs$ for molluscs was about $2 \cdot 10^{-3}$ Gy/year. Contribution of water-soluble and exchange forms was 7% each. The contribution of acid-soluble and organic forms to the dose rate was 22 and 23%, respectively. The highest contribution of $^{137}Cs$ to the internal dose for molluscs was observed in the mineral residue – 41%. Consequently, the analysis of the contribution of physicochemical forms of $^{137}Cs$ to the internal irradiation of *Dreissena sp.* showed that the molluscs obtains the lowest internal dose rate from the radionuclide in the water-soluble and exchange form. The maximum value of the internal dose rate was formed due to $^{137}Cs$ in the mineral residue.

The external dose rate for *Dreissena sp.* in the ChNPP CP, formed due to radionuclides that are soluble in water, was insignificant compared to the internal dose. The main dose rate for molluscs was formed from the incorporated $^{90}Sr$ and $^{137}Cs$ in tissues.

The highest contribution to the internal dose rate was found for the incorporated radionuclides in fixed forms, namely, in acid-soluble, organic and mineral residues. At the same time, the more significant was internal irradiation from $^{90}Sr$ in the form, associated with organic matter, and from $^{137}Cs$ – in the mineral residue.

# NATURAL RADIONUCLIDES AND HEAVY METAL CONCENTRATIONS IN MARINE SEDIMENTS IN VIEW OF TOURISM ACTIVITIES IN HURGHADA CITY, NORTHERN RED SEA, EGYPT

**Hesham M.H. Zakaly[1], MA. Uosif[2], H. Madkour[3], M. Tammam[2], S. Issa[4], R. Elsaman[2], Atef El-Taher[2], Atef El-Taher[2]**

1 Ural Federal University, Yekaterinburg, Russia
2 Al-Azhar University, Assuit, Egypt
3 National Institute Of Oceanography and Fisheries, Hurghada, Egypt
4 University of Tabuk, Tabuk, Saudi Arabia

The natural radioactivity concentration of $^{40}K$, $^{232}Th$ and $^{226}Ra$ was measured in marine sediment samples collected from coastline of National Institute of Oceanography and Fisheries (NIOF) and Safier Hotel area in Hurghada city using NaT (Tl) spectrometry. The values of activity concentrations in the collected sediment samples varied from 7±1 to 53±4, 6±1 to 32±6 and from 167±11 to 1120±63 $Bqkg^{-1}$for $^{226}Ra$, $^{232}Th$ and $^{40}K$ respectively. The results have been compared with the other radioactivity measurements in literature in different cities. The average activity of$^{226}Ra$ and $^{232}Th$ were lower than the permissible activity levels, while the average activity of $^{40}K$ were higher than the permissible activity levels in the samples from NIOF area but, lower than in the samples from Safier Hotel area. The total organic matter (TOC), carbonates ($CaCo_3$) and Heavy metals distribution have been measured. Also the concentration frequency distribution and the ratio of ($^{232}Th/^{226}Ra$), ($^{232}Th/^{40}K$) and ($^{226}Ra/^{40}K$) for all measured samples were presented. Additionally, the radiological hazards were evaluated and diagramed with Surfer program in maps.

# ACTIVITY CONCENTRATION OF URANIUM, THORIUM AND POTASSIUM N THE URINE OF THE ROE DEER (C. CAPREOLUS) FROM THE AREA OF VOJVODINA (NORTHERN PROVINCE OF SERBIA)

**Željko Mihaljev, Milica Živkov Baloš, Sandra Jakšić, Brankica Kartalović**

Scientific Veterinary Institute, Novi Sad, Serbia

Peaceful uses of nuclear energy (nuclear weapons testing, nuclear reactor accidents, industrial and medical use of radioactive compounds) and application of phosphate mineral fertilizers in agricultural production lead to substantial environmental contamination. Land contaminated with radionuclides represents the first link in the food chain and hence the radioactive contamination of crop and livestock production. The largest source of radiation activity in the biosphere is a natural radionuclide potassium-40. Some other natural radionuclides, which have always been present on Earth, include also radioactive elements like 232Th, 235U and 238U. The exposure to low-level radiation originating from these natural elements has been always affecting all living beings on Earth, and it is considered background radiation or natural phon. Radioactivity can cause cancerogenic illnesses and other health changes of humans and whole living world in general. It substantially influences the changes in the environment.

To determine the levels of natural radionuclides, 21 urine samples from roe deer (Capreolus capreolus) were collected from different localities (protected nature reserves) in the territory of Vojvodina. The samples were prepared by wet digestion using microwave labstation (Ethos, Milestone). Potassium content was determined using the atomic absorption spectrometry (Spectr AA–10, Varian), at wavelength 766.5 nm and using cesium as the ionization-suppressor. Potassium-40 is present in the natural potassium containing by weight a share of 0.0119%. The levels of potassium-40 activity in urine samples were calculated from total potassium, using the mass activity value for potassium being 31.561 Bq/g K.

Concentrations of thorium and uranium in all samples were analysed by a technique of inductively coupled plasma with mass spectrometry (ICP-MS 7700, Agilent). The isotopic abundance of 235U/238U is 0.72%/99.28%. The activity levels of uranium-235 and uranium-238 in urine samples were determined according to total uranium concentration using mass activity values 0.570 Bq/mgU for 235U and 11.10 Bq/mgU for 238U. The activity of thorium was obtained using a specific activity of 4.11 Bq/mgTh for 232Th.

It can be concluded that potassium-40 is predominant natural radionuclide in the urine of roe deer (Capreolus capreolus) as compared to other radionuclides, being in the range of 128–381 Bq/L. Results of urine analysis showed different ranges concentrations in radionuclides activity: 18.4–231.9 mBq/L for 238U, 1.11–11.90 mBq/L for 235U and 1.03–89.02 mBq/L for 232Th. ICP-MS method has been shown as a very sensitive for quantitative determination of Th and U concentration in biological samples. Therefore, ICP-MS offers an attractive alternative for monitoring of Th and U in environmental samples.

**Key words:** Potassium, thorium, uranium, urine, ICP-MS

# NATURAL RADIONUCLIDES IN WATER NEAR U-MINE IN BRAZIL

**Beata Kozłowska[1], Agata Walencik-Łata[1],
Susana O. de Souza[2], Fabinara Dantas Freire[2]**

1 University of Silesia, Katowice, Poland
2 Universidade Federal de Sergipe, São Cristóvão, Brazil

A big concern exists whether there is any radiological impact related to the existence and operation of uranium mine located near the Caetite city, in the southwest of Bahia state in Brazil. The question arises if the observed slightly elevated levels of radioactivity concentrations of some radionuclides in soils and water in this region result from the artificial process of human exploitation of uranium ore or from natural concentrations of these radionuclides in the soil.

Water samples collected at different locations between the municipalities of Caetite and Lagoa Real were analyzed for the activities of $^{234,238}U$ uranium isotopes presence in water. Moreover, the radioactivity of $^{226,228}Ra$ radium isotopes was also evaluated, where $^{226}Ra$ is uranium daughter while $^{228}Ra$ isotope is present in $^{232}Th$ thorium decay series.

The goal of our studies was to identify potential problems caused by mining to the population of Caetite region. The attempt to answer the question whether there is any environmental impact resulting from the uranium exploitation and processing will be discussed.

# EFFECTS OF SHARP TEMPERATURE CHANGE ON THE BINDING OF AMERICIUM WITH HUMIC AND FULVIC ACIDS IN SOILS

**Miryana Varbeva, Petya Kovacheva**

University of Sofia “St. Kliment Ohridski”, Faculty of Chemistry and Pharmacy, Sofia, Bulgaria

Am-241 is an artificial radionuclide produced during the nuclear fuel cycle and belongs to the group of radionuclides, having very high radiotoxicity. It can be released to the environment from nuclear reactors, nuclear explosions, radioactive waste storage facilities, and accidents, as well as from manufacturing products containing americium. Elucidation of the effects of the extreme weather conditions, like sharp temperature increase (hot summer) or decrease (cold winter) on the geochemical forms of Am in different soil types is especially important for adequate risk assessment after radioactive contamination. The aim of the present study is to investigate the effects of soil properties on the binding of Am-241 to humic and fulvic acids at the sharp temperature increase or decrease. Soil samples, collected for this study were taken from ten regions in Bulgaria. The soil samples were contaminated with aqueous solution of Am(III) and conditioned for one week at 10-18 $^{o}C$ and 20-30 % soil moisture. Afterwards each sample was divided to three subsamples and stored at -18 $^{o}C$, 18 $^{o}C$ and 40 $^{o}C$ by using a freezer and climate chamber for a period of one month. Aliquot of each sample were shaked with 0.1 M $Na_2P_4O_7$ (pH = 9) to extract the complexes with humic and fulvic acids. The fulvic complexes were separated by adding k.$H_2SO_4$ to the extracts, which caused precipitation of the humic complexes. All extracts were filtered by 0.20 μm cellulose nitrate filters and measured by gamma-spectrometry. HPGe detector Canberra 7221 coupled to a 16000-channel analyzer DSA-1000 was used to measure Am-241 by its gamma peak at 59.5 keV. Cation exchange capacity was found to be the main important factor, influencing the binding of Am to humic and fulvic acids. % Am, bound to humic and fulvic acids was not significantly influenced by the sharp temperature changes in the soils with high CEC (> 20 cmol+/kg). % Am, bound to humic and fulvic acids was found to be higher in the soils with low CEC.

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# EFFECTS OF SOIL PROPERTIES ON THE BINDING OF EUROPIUM TO HUMIC AND FULVIC ACIDS AFTER RAPID WARMING

**Miryana Varbeva, Petya Kovacheva**

University of Sofia "St. Kliment Ohridski", Faculty of Chemistry and Pharmacy, Sofia, Bulgaria

Distribution of rare earth elements in the nature is important to be studied in order to assess their geochemical behavior and potential bioaccumulation in case of environmental pollution. Europium is used in old fashioned TV-screens or luminescence lamps and may enter the nature during recycling process. The rapid variations of basic climatic parameters, like sharp temperature increase, may change the geochemical fate of Europium and influence its distribution within the food chain. Application of radioactive isotopes is a very efficient approach to identify the changes of geochemical forms of elemental contaminants, caused by variations of weather conditions after the soil pollution. The aim of the present study is to investigate the impact of rapid warming on the binding of Europium to humic and fulvic acids in soils with different characteristics. The experiments were performed by using Eu-152 as a tracer of stable europium. The experiments were performed with soils, taken from ten regions in Bulgaria. The soil samples were contaminated with aqueous solution of Eu-152 in nitrate form and conditioned for one week at 10-18 $^oC$ and 20-30 % soil moisture. Afterwards each sample was divided into two subsamples and stored at 18 $^oC$ and 40 $^oC$ by using a climate chamber for a period of one month. The complexes with humic and fulvic acids were extracted by 0.1 M $Na_2P_4O_7$ (pH = 9). The fulvic complexes were separated by adding k.$H_2SO_4$ to the extracts, which caused precipitation of the humic complexes. Gamma-spectrometry with HPGe detector was used to determine the radioactivity of Eu-152, bonded to the soil organic substances. The results showed that the temperature increase influenced mainly the europium humates in soils with high sand content. Rapid warming caused highest increase of Eu complexes with humic acids in the soil with low CEC and alkaline pH. The content of water-soluble europium fulvate complexes was found to be lower than the europium humates, which shows lower mobility of europium organic compounds in the soils.

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# DETERMINATION OF NATURAL RADIOACTIVITY LEVELS IN SOIL SAMPLES IN ANATOLIAN DISTRICT OF ISTANBUL

**Osman Günay[1], Serpil Aközcan[2]**

1 Okan University, Istanbul, Turkey
2 Kırklareli University, Kırklareli, Turkey

The soil, rocks and minerals in the earth's crust contain naturally occurring radionuclides. These natural radioactivity ($^{226}$Ra, $^{232}$Th and $^{40}$K) concentrations in the world vary from region to region and determine the level of background radioactivity in the world.

Istanbul province is in the western Anatolia in Turkey. It has a population of approximately 15.000.000. Istanbul is the most important city in Turkey both in terms of economy and tourism. Therefore, the concentrations of natural radioactivity must be measured continuously. There is no information about radioactivity level in the Istanbul surface soils samples so far. For this reason, the concentrations of the natural radionuclides were measured in soil samples from 20 different sampling stations in Kadıkoy, Kartal and Pendik district of Istanbul. The coordinates of the sampling points were determined by the Global Positioning System (GPS).

The concentrations of natural radionuclides in soils were determined using gamma ray spectrometry with an HPGe detector. Radionuclide concentrations measured were compared with those found in the samples from other locations of Turkey and from different countries.

# MEASUREMENTS OF GAMMA RADIATIONS AT THE ERCIYES MOUNTAIN (CENTRAL ANATOLIAN)

**Serpil Akozcan, Mehlike Beste Ozturk**

Kirklareli University, Kirklareli, Turkey

The assessment of the radiation doses to humans from natural sources is of particular importance because they contribute significantly to the collective dose of the world population. The great interest expressed worldwide for the study of naturally occurring radiation and environmental radioactivity has lead to the performance of wide studies in many countries of the World. In the present study the concentration of natural radionuclides $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soils of Erciyes Mountain, Turkey was determined by gamma ray spectrometry. The average concentration of the $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soil samples comes out to be 62, 65 and 792 Bq $kg^{-1}$. Finally, absorbed dose rate in air values were calculated from the naturally occurring radionuclide concentration in soils. The results are compared with values giving in UNSCEAR and literature.

# BEHAVIOUR OF BERYLLIUM-7 AND LEAD-210 TIME SERIES MEASURED IN SERBIA AND SLOVENIA OVER 1991-2015

**Darko Sarvan[1], Dragana Todorović[2], Milica Rajačić[2], Jelena Krneta Nikolić[2], Vladimir Djurdjevic[3], Benjamin Zorko[4], Branko Vodenik[4], Denis Glavič Cindro[4], Jasmina Kožar Logar[4], Jelena Ajtić[1]**

1 University of Belgrade, Faculty of Veterinary Medicine, Belgrade, Serbia
2 University of Belgrade, Vinča Institute of Nuclear Sciences, Belgrade, Serbia
3 University of Belgrade, Faculty of Physics, Belgrade, Serbia
4 Jožef Stefan Institute, Ljubljana, Slovenia

Cosmogenic beryllium-7 (Be-7) and a long-lived radon progeny lead-210 (Pb-210) are radionuclides commonly measured in the environmental radioactivity programmes. Although their production mechanisms and points of entry into the atmosphere differ, there is a strong interconnection between their behaviour since they are transported through the atmosphere attached to aerosols. Thus, their abundance is governed by the atmospheric processes and both are considered good tracers of air mass origin.

In this paper, we use the Be-7and Pb-210 specific activities measured in Serbia and Slovenia to investigate the degree of their similarities across a distance of about 500 km. Specifically, in an attempt to distinguish major influencing mechanisms, we apply factor analysis to the radionuclides' measurements conducted over 1991–2015 in Belgrade, Serbia, and Ljubljana and Krško, both in Slovenia. The factor analysis also includes the following meteorological parameters at each sampling site: temperature, cloud cover, relative humidity, precipitation and atmospheric pressure (not available at the Krško site).

The results of the factor analysis show that the communalities of only two factors are already larger than 0.5 for most of the variables. The exceptions are the atmospheric pressure in Belgrade and precipitation in both Belgrade and Ljubljana. The factor loadings of two factors show that: 1) the Be-7 specific activity, temperature, cloud cover and relative humidity are encompassed by factor 1 in all the sites; while 2) the Pb-210 specific activity is described by factor 2 together with atmospheric pressure in Belgrade and Ljubljana, but with precipitation in Krško (where atmospheric pressure is not available). These results imply that the Be-7 and Pb-210 are under different dominant underlying mechanisms.

Over the investigated 24 years, both the Be-7 and Pb-210 measurements across the three sites show a very good agreement in the measurement ranges and overall means. However, a closer examination of the differences in the data time series reveal an exception to this general agreement – during 2005–2012, there is a pronounced increase in radionuclides' concentrations in Ljubljana and Krško, relative to Belgrade. Therefore, factor analysis is also performed for this shorter time period. The obtained factor loadings show a change in the influence of the major two factors. Compared to 1991–2015, the influence of factor 2 on Be-7 increases in Belgrade and decreases in Ljubljana. On the other hand, an influence of factor 1 on Pb-210 decreases in Belgrade, but increases in Ljubljana and Krško. These opposing changes might explain the relatively high differences in the radionuclides' concentrations seen over 2005–2012.

# ACTIVITY CONCENTRATION OF TRITIUM ($^3H$) IN PRECIPITATION - LONG-TERM INVESTIGATIONS PERFORMED IN CROATIA AND SLOVENIA

**Jadranka Barešić[1], Marko Štrok[2], Barbara Svetek[2], Polona Vreča[2], Ines Krajcar Bronić[1]**

1 Ruđer Bošković Institute, Zagreb, Croatia
2 Jožef Stefan Institute, Ljubljana, Slovenia

Systematic studies of isotope composition of monthly precipitation in Croatia and Slovenia have been performed since 1976 and 1981, respectively. The monitoring included measurements of radioactive isotope of hydrogen – tritium ($^3H$) as well as stable isotope ratios of hydrogen ($^2H/^1H$) and oxygen ($^{18}O/^{16}O$). Isotope data are partly available in the Global Network of Isotopes in Precipitation (GNIP) at https://nucleus.iaea.org/wiser. This work presents details on long-term monitoring of tritium activity concentration in precipitation at Zagreb, Croatia, and Ljubljana and Portorož, Slovenia, performed in collaboration between Ruđer Bošković Institute (RBI) and Jožef Stefan Institute (JSI).

Sampling locations have been changed during the long-term monitoring. Local contamination with technogenic tritium was noticed at the RBI site and therefore precipitation has been collected at the Zagreb-Grič site at the Meteorological and Hydrological Service of Croatia, in the center of Zagreb since 1996. Monitoring in Ljubljana was performed between 1981 and 1993 at the synoptic station Ljubljana–Bežigrad located at the Hydrometeorological Survey of Slovenia (today Slovenian Environment Agency – ARSO), between 1993 and 2000 at the JSI (station Ljubljana–IJS), and finally, since 2000 at the Reactor Centre of the JSI (station Ljubljana–Reaktor) in the vicinity of Ljubljana. In addition, monitoring has been performed at the ARSO synoptic station Portorož airport since 2000. Zagreb and Ljubljana are both continental stations while Portorož represents a coastal station.

The long-term data records showed tritium pattern typical of continental stations of the Northern Hemisphere. Seasonal variations were superposed on the basic decreasing trend of mean annual values until app. 1997. The maximal $^3H$ activity concentration at station Zagreb was observed between May-July, mostly in June. A secondary maximum was also observed three times in January and February. The lowest $^3H$ activity concentrations were almost uniformly distributed from October to February, with a slightly more frequent occurrence in December. The seasonal distribution at the Ljubljana station was characterized by the most frequent appearance of the maximum in July, no secondary winter maximum, and the minimum was most frequently measured in November, although it was distributed from October to March. The ratio of the maximum to minimum value for Zagreb and Ljubljana precipitation ranged from 2.2 to 5.7 and from 2.3 to 5.5, respectively, without a significant trend.

Data recorded during last 2 decades, however, show almost constant mean annual $^3H$ activity concentration ranging between 5 and 10 TU with the average of about 9 TU for the continental stations Ljubljana and Zagreb, while for the coastal station Portorož lower value of about 7 TU was observed. Seasonal variation remained with winter activities close to the natural pre-bomb $^3H$ activity concentrations (≤5 TU), and summer values rarely above 20 TU.

# SEASONAL VARIATIONS OF $^{210}Po$ ACTIVITY CONCENTRATIONS IN MUSSEL AND RELATED DOSE ASSESSMENT TO THE POPULATION

**Serpil Akozcan**

Kirklareli University, Kirklareli, Turkey

$^{210}Po$ is one of the most radiotoxic radionuclides, which is evident from the committed effective dose per unit of intake. The alpha decay of $^{210}Po$ accounts for most of the radioactive dose to marine organisms. Results of 2 years monitoring of $^{210}Po$ activity concentrations in soft tissue of the species *Mytilus galloprovincialis* from the coast of Gelibolu (Marmara Sea) are presented. Samples were dried and radiochemical separation of $^{210}Po$ was performed. Measurements of $^{210}Po$ were performed by alpha spectrometry. The results of $^{210}Po$ activity concentrations were found to vary between (235 ± 16) and (561± 34) Bq kg$^{-1}$ dry weight.

# GROSS ALPHA AND BETA RADIOACTIVITY CONCENTRATIONS OF AROMATIC PLANT, SOIL AND WATER IN BITLIS

**Şule Karatepe, Sultan Şahin Bal, Murat Kürşat,
M. Fatih Kuluöztürk, Engin Yılmaz**

Bitlis Eren University, Bitlis, Turkey

In this study, soil and water samples in the area where aromatic plants were grown and aromatic plants were obtained gross alpha and gross beta radioactivity levels. Samples were measured by nuclear spectroscopic system which contains a gas-flow proportional counter (PIC-MPC 9604). In the obtained results; gross alpha radioactivity concentrations were determined between 0.276±0171 – 3.306±1.359 Bq/g, 0.003±0.002 – 0.135±0.096 Bq/l and 0.514±0.311– 10.417±6.988 Bq/g, respectively aromatic plants, water and soil samples. Gross beta radioactivity concentrations were determined between 0.029±0.011 – 5.844±2.536 Bq/g, 0.040±0.029 – 2.580±1.129 Bq/g and 0.439±0.219 – 5.221±2.268 Bq/g, respectively aromatic plants, water and soil samples. Then the obtained results were compared with the literature.

**Key words:** Aromatic plants, gross alpha and beta radioactivity

# AN EPISODE OF RU-106 IN AIR OVER EUROPE, SEPTEMBER-OCTOBER 2017


**Florian Gering[1], Peter Bossew[1], Thomas Hamburger[1], Christian Katzlberger[2], Marc DeCort[3]**

1 BfS (German Federal Office for Radiation Protection), Neuherberg / Munich, Germany
2 AGES (Austrian Agency for Health and Nutritional Safety), Vienna, Austria
3 European Commission, JRC, Directorate for Nuclear Safety & Security, Ispra (VA), Italy


Around end September to early October 2017, $^{106}$Ru was recorded by air monitoring stations across parts of Europe. This purely anthropogenic radionuclide can be detected very rarely only. Therefore the episode drew considerable interest in the monitoring community, although the activity concentrations and resulting exposure were far below radiological concern. $^{106}$Ru in aerosols could be detected for about one week and in some regions of Central and Eastern Europe several mBq/m$^3$ were measured as one-day mean.

Discussions about a possible source continue until today (end 2017). Atmospheric back-modelling led to trajectories likely originating in the Southern Ural region of Russia and possibly Northern Kazakhstan. The Russian Mayak reprocessing plant and a radioisotope factory in Dimitrovgrad have been named as possible sources, but both enterprises deny any releases.

Suspiciously, no other anthropogenic radionuclides have been observed alongside, except minute concentrations of comparatively short-lived $^{103}$Ru (half life 39 d vs. 376 d for $^{106}$Ru). Therefore, a reactor accident can be excluded, although both Ru isotopes are fission products generated in nuclear reactors (commercial spent fuel contains several kg Ru per t U, depending on burn-up), as can be a release from a waste storage facility. $^{106}$Ru is used in radiotherapy and possibly, but rarely by any account, in satellite radiothermal generators. For these purposes it is extracted from the fission product stream during reprocessing

In oxidizing milieu Ru forms volatile $RuO_4$, which may lead to unintended fractionate Ru release, if conditions are given. Not knowing the details of the reprocessing scheme used in the Mayak plant, we cannot say how realistic such scenario is in our case; we shall summarize information as available. However, Ru (similar to Zr) is known to be troublesome in PUREX reprocessing (which as far as known, is also used in Mayak) because of its chemistry (*J Nucl Sci Techn* 26 (3) 1989, 358 – 364).

Ru fractionate release could be observed during the Chernobyl accident where the fire provided the oxidizing condition. The Ru re-condensed and probably underwent chemical modification in the air, forming droplets, and in consequence so-called hot particles consisting of pure Ru, which could be found in the environment across Europe in early May 1986 (*Rad. Prot. Dosimetry* 22 (3) 1988, 149 – 157; *Pöllänen Rad. Prot. Dosimetry* 71 (1) 1997, 23 – 32). So far, however, nothing is known about the physical and chemical speciation of the $^{106}$Ru observed in autumn 2017.

The exposure resulting from $^{106}$Ru activity concentration in air exceeded 150 mBq*d/m$^3$ in some parts of Central and Eastern Europe. This leads to doses of above 0.2 µSv regionally, assuming the radiologically most efficient speciation, lacking better information, and inhalation dose conversion factors from ICRP 119 (*Ann. ICRP* 41(Suppl.), 2012.). We show an interpolated map of the exposure distribution over parts of Europe where sufficient measurements are available to us. Overlaying demographic data, we give an estimate of collective dose. The data-based exposure map is compared with ones resulting from atmospheric forward modelling, assuming different sources. Corresponding estimated source terms are given.

A few stations also recorded traces of $^{106}$Ru in fallout. We compare these data with what could be expected based on atmospheric dispersion, depletion and deposition models.

# LONG-TERM ASSESSMENT OF THE BEHAVIOUR AND ORIGIN OF $^{210}$Pb AND $^{210}$Po RADIONUCLIDES IN THE ATMOSPHERE


**Magdalena Długosz-Lisiecka**

Technical University of Lodz, Lodz, Poland


The presence of significant $^{210}$Po activity, unsupported by its grandparent radionuclide $^{210}$Pb, in the surface atmosphere of industrialised regions originates from human technical activities. One of the possible sources of the unsupported $^{210}$Po in industrial areas is coal combustion for electricity generation. The significantly higher volatility of $^{210}$Po in comparison to Pb or Bi element enables the escape of significant amounts of this element through even very efficient dust capturing systems (electrofilters) both in the form of gases and fly ash, especially at the smallest fractions of <1 μm. Coal combustion for electricity generation has therefore been proposed as a potential source of additional amounts of atmospheric $^{210}$Po.

The presence of an excess of $^{210}$Po cannot be explained by its in-growth from the radioactive decay of $^{210}$Bi. About 50% of the $^{210}$Po radionuclide released during the coal combustion process can be emitted into the air as gaseous or ultrafine products. Subsequently, these products quickly attach to the surface of fine particles suspended in the air. Consequently, an excess of $^{210}$Po activity in aerosols has been reported. In this manner as much as 11 GBq of $^{210}$Po per year can enter the urban air from the local coal power plants in the city of Łódź, Poland. A simple calculation confirmed that as much as 11 GBq of $^{210}$Po per year is freely released into the atmosphere in central Łódź from three local coal power plants.

It is also well known that the activity concentration of $^{210}$Po and $^{210}$Pb depends on the square of the particle matter radius. Most $^{210}$Po and $^{210}$Pb activity is connected with fine and ultra fine particles. In my studies, 72% of $^{210}$Pb and 82% of $^{210}$Po activity was measured in aerosol fractions with a particle size range of 0.1–0.3 mm. Radionuclide $^{210}$Po, which is more volatile than its parents $^{210}$Pb and $^{210}$Bi, leaves the boiler with the flue gas in gaseous form and condenses as the temperature of the flue gas drops. In coal burning conditions, the condensation of the attached Po element on aerosols is very effective. Some activity of Po in a non-absorbed form has also been traced and measured.

# DETERMINATION OF $^{226}$Ra, $^{210}$Po AND $^{210}$Pb IN NATURAL MINERAL WATER

**Violeta Pintilie[1], Antoaneta Ene[2], Lucian Puiu Georgescu[2], Adelina Pintilie[3], Dana Iulia Moraru[4]**

1 ”Dunarea de Jos” University, Doctoral School of Mechanical and Industrial Engineering, Galati, Romania
2 ”Dunarea de Jos” University, Faculty of Sciences and Environment, Galati, Romania
3 University of Bucharest, Faculty of Chemistry, Bucharest, Romania
4 ”Dunarea de Jos” University, Faculty of Food Science and Engineering, Galati, Romania

According with Directive 2009/54/EC, „natural mineral water” is microbiologically wholesome water, originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or bore exits. It is usual to replace the consumption of the tap water with natural mineral water. There were 68 brands of natural mineral water registered in 2016 in Romania by the National Agency for Mineral Resources. 17 types of natural mineral water were collected during 2016 from supermarkets situated in three counties from Romania (Galati, Braila and Vrancea), in order to assess the equivalent effective doses from $^{226}$Ra, $^{210}$Po, $^{210}$Pb for adults. For this study, the most frequently sold natural mineral waters in this region from Romania were chosen to be analised. The concentrations of $^{226}$Ra were evaluated using a SARAD instrument, after 30 days of storage necessary for $^{222}$Rn/$^{226}$Ra secular equilibrium. The concentrations of $^{210}$Po and $^{210}$Pb were determined by self deposition onto nickel disk and the gross alfa measurements with the aid of the MPC 900 instrument. The values for concentration of $^{226}$Ra, $^{210}$Po, and $^{210}$Pb were ranging from 5 to 78 mBq $L^{-1}$, 0.015 to 0.980 mBq $L^{-1}$and 0.15 to 12 mBq $L^{-1}$, respectively. The values for the equivalent effective doses due to ingestion of radionuclides from natural mineral water ranged from 0.017 μSv $y^{-1}$ to 15.94 μSv $y^{-1}$. The results showed that the highest contribution to the effective dose is due to $^{226}$Ra contained in natural mineral water. The obtained values were compared to the World Health Organization recommended value for annual effective dose (100 μSv $y^{-1}$).

**Key words:** Natural mineral water, polonium, radium, lead, equivalent effective dose

# PURIFICATION OF WATER SOLUTIONS FROM SOME RADIONUCLIDES WITH NATURAL AND SYNTHETIC INORGANIC SORBENTS

**Hanna Vasylyeva[1], Yuriy Kylivnyk[2], Olexandr Sych[1]**

1 Uzhgorod national university, Uzhgorod, Ukraine
2 Institute for Sorption and Endoecology problems, Kyiv, Ukraine

The sorption of Sr, Ba and Y isotopes on Transcarpathian natural zeolite, zirconium dioxide and some other synthetic inorganic sorbents was investigated. In order to study the cleaning effect of sorbents, solutions of radionuclides based on distilled water and a model solution were prepared. The model solution was a water cooler designed by the NPP (Nuclear power plant). For this purpose, the water of natural mineralization was irradiated by neutrons from the Pu(a)Be source. Density of flow neutrons was $10^6$ n/cm$^2$ s. Energy E n = 5-10MeV, within a month. Then the solution of radionuclides was prepared with such water.

The preliminary results show that the radionuclides are absorbed from the model solution worse.

# COMPARISON OF CONCENTRATION ACTIVITIES OF RUTHENIUM ISOTOPES MEASURED OVER SLOVENIA AND SERBIA

**Benjamin Zorko[1], Jelena Ajtić[2], Branko Vodenik[1], Denis Glavič Cindro[1], Milica Rajačić[3], Toni Petrovič[1], Jelena Krneta Nikolić[3], Marija Janković[3], Nataša Sarap[3], Ivana Vukanac[3], Gordana Pantelić[3], Dragana Todorović[3]**

1 Jozef Stefan Institute, Ljubljana, Slovenia
2 University of Belgrade, Faculty of Veterinary Medicine, Belgrade, Serbia
3 University of Belgrade, Vinča Institute of Nuclear Sciences, Laboratory for Environmental and Radiation Protection, Belgrade, Serbia

The isotopes of ruthenium (Ru-106, Ru-103) were detected by several European environmental networks involved in the monitoring of atmospheric radioactive contamination in late September 2017. The radioactive cloud passed over the countries in the east and south-east of Europe, while other countries in Europe were just brushed up with very low activity concentrations of Ru-106. Ruthenium is very rare and hence its presence may suggest that an event of some nature occurred. Ruthenium-106 is a fission product from the nuclear industry and it is also used in medical procedures, such as brachytherapy treatments. Ruthenium-106 is a beta emitter with a half-life of 1.02 year so the isotopic presence may persist for some time, with its duration depending on many factors. Apart from the disintegration of Ru-106 to the ground state of a short-lived Rh-106, some characteristic gamma rays are emitted. The origin of Ru-106 in the atmosphere is still unclear.

Among the countries that were affected by the passage of the radioactive cloud containing isotopes of ruthenium were the Republic of Slovenia and Republic of Serbia. The activity concentrations of Ru-106 in the air detected in several stations of both countries were of a similar magnitude. The activity concentrations were determined by standard gamma spectrometry measurements at the Vinča Institute of Nuclear Sciences and Jožef Stefan Institute for the Serbian and Slovenian sampling sites, respectively. Ruthenium was also detected in trace levels in other environmental media (precipitation).

Several statistical calculations to compare measurement results in Slovenia and Serbia are carried out. Those calculations also take into account other radionuclides, such as cosmogenic beryllium-7 and a long-lived radon progeny lead-210, to investigate possible atmospheric processes accompanying the release of ruthenium.

# URANIUM IN FOODSTUFF SAMPLES FROM TWO REGIONS IN BULGARIA WITH RELATIVELY HIGH LOCAL LEVELS OF RADIOACTIVE BACKGROUND

**Ivanka Yordanova, Donka Staneva, Radoslava Lazarova**

"N. Poushkarov" Institute of Soil Science, Agrotechnologies and Plant Protection, Sofia, Bulgaria

Bulgaria is a country in which uranium mining was developed in the past.

Therefore, it was of interest to study the content of uranium in foodstuffs to answer the strong public interest in the topic due to higher concentration of this element measured in waters from two regions in Bulgaria – Haskovo and Plovdiv around which a large scale uranium mining was carried out in the past (around Haskovo under the classical mining method, around Plovdiv – geotechnologically).

Vegetable (alfalfa, carrots, potatoes and tomato paste) and animal (milk and minced meat) samples were studied and it was found that radioactivity concentration of two natural isotopes of uranium in $Bq.kg^{-1}$ is in the following intervals:

Uranium-234 – from 0.004 ± 0.001 to 1.00 ±0.10;

Uranium-238 – from 0.004 ± 0.001 to 0.76 ±0.09.

Analysis of the results obtained showed that the data are comparable with the average values in Europe which led to the conclusion there was no radiological hazard of increased uranium content in the foodstuff from these regions.

# NATURAL AND ARTIFICIAL RADIOACTIVITY OF SOILS AROUND IRON AND STEEL INDUSTRY MEASURED BY LOW-BACKGROUND HIGH RESOLUTION GAMMA-RAY SPECTROMETRY

**Antoaneta Ene[1], Ana Pantelica[2], Florin Sloata[1]**

1 Dunarea de Jos University of Galati, Galati, Romania

2 Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Magurele, Romania

Possible emission of radioactivity in iron and steel process involves the necessity of radiometric measurements to identify and quantify the natural and/or artificial radioisotopes in iron and steel materials and products, as well as in soils around industrial enterprise. Gamma-ray spectrometry is a powerful non-destructive analytical tool for the qualitative and quantitative determination of the gamma emitters.

The aim of this study was to investigate the radioactivity level of soils around the Iron and Steel Works of Galati, SE Romania. The low-background high resolution gamma-ray spectrometry technique was applied at GamaSpec laboratory of "Horia Hulubei" National Institute of Physics and Nuclear Engineering (IFIN-HH) in Magurele-Bucharest, Romania, in order to assess the level of the natural and artificial radioactivity of eight soil samples collected in the vicinity of the metallurgical industry at Galati. The spectrometric chain was equipped with a HPGe (EG&G Ortec) detector of 2.0 keV resolution at 1332 keV of $^{60}$Co, and 30% detection efficiency relative to 3"x 3" NaI (Tl) standard, coupled to a PC based multichannel analyzer (Maestro-32 MCA Ortec). GAMMAW software program was used for the spectra processing.

For the low-level background counting of samples, a lead shield of 10 cm thickness, coated with Sn and Cu foils of 1 mm, and 1.5 mm thickness, respectively, were used to reduce ambient background radiation, covering the energy range from zero to 2000 keV. To determine the radium radioactivity, the samples were sealed and measured after ~3 weeks in order to establish the radioactive equilibrium between $^{226}$Ra and its gaseous radioactive descendant $^{222}$Rn (radon).The dried and homogenized soil samples were measured in Sarpagan beaker placed on the detector end cap, for counting times ranging in the interval 5.28-20.5 h.

The analyzed natural radionuclides were the following: $^{226}$Ra (from $^{214}$Pb and $^{214}$Bi activities, descendents of $^{222}$Rn from $^{238}$U-$^{226}$Ra series), $^{238}$U (from $^{234}$Th activity), $^{232}$Th (from $^{228}$Ac, $^{212}$Pb and $^{208}$Tl activity), $^{235}$U,$^{210}$Pb ($^{238}$U-$^{226}$Ra series) and $^{40}$K. The analyzed artificial radionuclides were $^{60}$Co, $^{137}$Cs and $^{241}$Am. The soils collected in the vicinity of the slag dump presented the highest natural radioactivity level. The concentrations of artificial radionuclides were not correlated with the concentrations of natural radioactivity.

# PRELIMINARY RESULTS ON STUDY OF THE BEHAVIOR OF Pb-210, Cs-137 AND Po-210 ISOTOPES IN THE SEDIMENT COLUMN UNDER DIFFERENT CHEMICAL CONDITIONS

**Robert-Csaba Begy, Szabolcs Kelemen, Daniela Vasilache**

Babes-Bolyai University, Institute of Interdisciplinary Research Bio-Nano-Sciences, Cluj-Napoca, Romania

The sediment deposits can be considered a date base of the changes in environmental processes and pollution in recent past. The most used radionuclide for dating the sediments layers for established the date of different events are Pb-210,Ra-226,Po-210 and Cs-137 (in some cases Am-241) in Pb-210 dating method. The determination of Pb-210 in this method, for a better precision, is made by measuring the alpha emitter daughter Po-210. The Po-210 is produced by the disintegration of Pb-210 inside of the sediment column where the produced Po-210 can be present in a chemical form which is soluble in water. This study focuses on the isotopes behavior which is used in sediment dating by using Pb-210 method especially the difference between Pb-210 and Po-210. The solubility of Po compounds can produce migration of Po-210 between sediment layers. For a proper chronology, the determination of the behavior of the radionuclides in sediment column is crucial. Five sediment column with known concentration of the investigated radionuclides (Pb-210,Ra-226,Po-210 and Cs137) was prepared in laboratory condition, in different chemical condition (Ph, $Cl^-$ and $NO_3^-$ ions) and stored 6 months. The columns were sliced again and the radionuclides concentration was investigated.

# ACCUMULATION AND RETENTION OF RADIONUCLIDES (Sr/Cs) BY SAPROPHYTIC FUNGI: POSSIBLE EFFECT ON UPTAKE OF THESE RADIONUCLIDES BY PLANTS

**D. K. Gupta, W. Schulz, G. Steinhauser, C. Walther**

Institut für Radioökologie und Strahlenschutz (IRS), Leibniz University of Hannover, Hannover, Germany

It is proven from the experimental data that due to fungus and microbial activity radionuclides are retained in the organic layer of the soil. It is also cleared from previous results that fungus is the long living biomass in the organic layer of soils. Fungal mycelia, when compared to above-ground fruit bodies, is the major contribution to the total fungal biomass.

In our present study, we used two different fungi namely *Leucoagaricus naucinus* and *Schizophyllum commune* to check the growth of both fungi in soil as well as to check the radionuclide retention capacity of both in the experimental soil at laboratory condition with winter rye plant. For this, we used barren soil from Chernobyl exclusion zone from the area of the former Kopachi village (5 km southeast of Reactor Unit 4), which was used as an agricultural field before the accident. In lab condition, we divided the whole experiment in 4 treatments (namely: (1) control without any external radiostrontium ($^{85}Sr$) addition; (2) control with external $^{85}Sr$ addition (1050 KBq; (3) soil with addition of 1050 KBq of $^{85}Sr$ + *Leucoagaricus naucinus* (5 g $Kg^{-1}$ of soil); (4) soil with addition of 1050 KBq of $^{85}Sr$ + *Schizophyllum commune* (5 g $Kg^{-1}$ of soil) in the pots carrying 3 Kg of soil and cultivated them for 21 days. After 21 days, we checked some oxidative stress parameters like nitric oxide (NO), Hydrogen peroxide ($H_2O_2$) by epifloroscence microscope, some histochemical parameters to check oxidative damage markers like superoxide radicals ($O.^-$) as well as lipid peroxidation and also checked some biochemical assays such as chlorophyll and carotenoids to confirm which fungus is retaining higher amount of radionuclide in their biomass and helping tested plant to grow better in this adverse condition.

The details of both fungi as well as plant results are going to be discussed in the meeting.

# LONG-TERM VARIATION OF $^7$Be IN PARTICULATE MATTER OF SURFACE AIR FROM SEOUL AND DAEJEON, SOUTH KOREA

**Chang-Jong Kim, Jong-Myoung Lim, Wanno Lee**

*Korea Atomic Energy Research Institute, Daejeon, South Korea*

$^7$Be is produced throughout the atmosphere as a product of the spallation of oxygen and nitrogen nuclei by energetic cosmic rays. $^7$Be attached to aerosols in the atmosphere soon after production and bring to surface of the earth by precipitation. And airborne radionuclides are adsorbed on the surface of aerosol particles and form radioactive aerosol. Therefore the transport and distribution of particulate pollutants of radionuclides can be traced and predicted based on the behavior of $^7$Be.

Since 1989 our institute had been monitoring $^7$Be to use it as a natural tracer of particulate matter coming from atmosphere. In this paper, $^7$Be measurements carried out by our institute from 1998 to 2017 in Seoul and Daejeon, South Korea are shown. The atmospheric particulate sampling was performed continuously at ground level and combined to form monthly sample. $^7$Be activities were obtained by means of gamma-spectrometry. The average annual $^7$Be concentration is little difference, ranging from 1.5 to 5.2 mBq/m$^3$ in Seoul, from 1.7 to 5.1 mBq/m$^3$ in Daejeon, respectively. However, tendency of $^7$Be concentrations increase gradually for both cities since 1998.

# NATURAL RADIATION MEASUREMENT IN SOME BEACH SAND SAMPLES, ISTANBUL-TURKEY

**Osman Günay[1], Kadir Günoğlu[2], İskender Akkurt[2]**

1 Okan University, İstanbul, Turkey
2 Suleyman Demirel University, Isparta, Turkey

Natural Radioactivity has been since creation of universe and the land based radioactive elements constitute the major part of the natural radioactivity. Terrestrial radioactivity is caused by the radioactive elements that existed in various amounts in soil and rocks as they have different geographical and geological structure of the region and the mineralogical composition of soil and rock. In this study, $^{226}$Ra, $^{232}$Th and $^{40}$K activity concentrations of some oil samples that collected from Kadıkoy beach in Istanbul were measured. The samples were measured using a gamma ray spectrometry that contains a 3”x3” NaI(Tl) detector. Radium equivalent activity, outdoor external dose, indoor external dose and total average annual effective dose were also calculated.

# RISK ANALYSIS AND ANNUAL EFFECTIVE DOSE DUE TO TERRESTRIAL AND COSMIC RADIATION IN THE REGION OF NIĞDE PROVINCE (TURKEY)

**Mehmet Erdogan[1], Kaan Manisa[2], Hasan Bircan[2], İbrahim Çevik[1], Nesli Bingöldağ[3], Recep Bıyık[3]**

1 Selçuk University, Konya, Turkey
2 Dumlupınar University, Kütahya, Turkey
3 Turkish Atomic Energy Authority, İstanbul, Turkey

Radiation is energy emission that comes from a source and travels through space and may be able to penetrate various materials. Light, radio, and microwaves are types of radiation that are called nonionizing radiation. Cosmic rays, x-rays, gamma-rays, UV-rays (partly), alpha and beta particles and neutron are called ionizing radiation. Gamma photons are the most energetic photons in the em spectrum. They are emitted from the nucleus of some unstable (radioactive) atoms.

The radiation exposure for people and all living things is inevitable. The most of these exposures are due to natural sources. The terrestrial and cosmic radiation sources are the most important contribution to these exposures which originated from the fractionation of U-238, Th-232, gamma radiation of K-40 and high-energy cosmic particles incident on the earth's atmosphere. The main contribution to these exposures comes from terrestrial sources. Terrestrial radionuclides are found various concentrations in the crust of earth depending on geological conditions of the region. They also cause exposure risks externally due to their gamma-ray emissions. This study assesses the terrestrial and cosmic radiation dose rates from the naturally occurring radionuclides in the region of Niğde Province of Turkey. The measurements were performed on surface soil using NaI(Tl) scintillation type gamma-ray detector. The average external annual effective doses are also calculated from such terrestrial and cosmic gamma radiation dose rates for each individual.

**Key words:** Natural radiation, terrestrial and cosmic radiation, annual effective dose, Niğde Province

# DETERMINATION OF NATURAL RADIOACTIVITY IN SOILS FROM ÇORLU REGIONS IN TEKIRDAĞ PROVINCE, TURKEY

**Kaan Manisa[1], Mehmet Erdogan[2], Ali Usluer[1], Hakan Çetinkaya[1], Ulaş Işık[1], Latife Sahin Yalcin[1]**

1 Dumlupınar University, Kütahya, Turkey
2 Selçuk University, Konya, Turkey

Natural radiation, which has three major sources: terrestrial radiation, cosmic radiation and internal radiation, makes the largest contribution to the total radiation dose because of the intake of natural radionuclides through inhalation (mainly radon) and ingestion. Terrestrial radiation sources include the ground, rocks, air, building materials and drinking water supplies. Internal radiation is in our body because of what we eat and drink, and the air we breathe. The most significant part of natural radioactivity mainly from U-238, Th-232 and K-40 in soil arises from the terrestrial gamma-ray radiation.

In this study, the analysis of natural radioactivity from U-238, Th-232 and -40 in soil samples collected from the region of Çorlu in Tekirdağ province was carried out using a NaI(Tl) gamma-ray spectroscopy system. From the activity concentrations of U-238, Th-232 and K-40 the total absorbed outdoor gamma-ray dose rates and the corresponding annual effective dose rates were calculated.

# Radon and Thoron

# 09

# ALPHA PARTICLE PENETRATION IN RADIOMETRIC FILTER MATERIALS USING MONTE CARLO COMPUTER PROGRAM (SRIM)

**Mostafa Mostafa[1], Michael Zhukovsky[2]**

1 Ural Federal University, Yekaterinburg, Russia
2 Institute of Industrial Ecology UB RAS, Yekaterinburg, Russia

Software package SRIM (The Stopping and Range of Ions in Matter) allows calculating the parameters of the ions interaction with target material using a Monte Carlo simulation method based on a quantum mechanical treatment of ion-atom collisions. In this work, SRIM software package is using to simulate the interaction of alpha particle into the material of radiometric filters to estimate the effect of alpha particle self-absorption in alpha radiometric measurements, especially in the range of Radon and Thoron alpha energy (5-9 MeV). The effect of the filter material on the transmitted efficiency of alpha energy is presented. As the energy increases the self-absorption of material is decreased.

**Key words:** SRIM, radiometric filters, alpha particles penetration

# RADON CONCENTRATIONS IN MULTI-STOREY BUILDINGS IN MONTENEGRO

**Perko Vukotic[1], Ranko Zekic[2], Nevenka Antovic[3], Tomislav Andjelic[2]**

1 Montenegrin Academy of Sciences and Arts, Podgorica, Montenegro
2 Centre for Ecotoxicological Research, Podgorica, Montenegro
3 Faculty of Natural Sciences and Mathematics, University of Montenegro, Podgorica, Montenegro

Change of radon concentration in dwellings with floor level depends on the characteristics of geological substrate, building construction and materials, climate conditions and living habits of dwellers, all of which can be very specific to individual countries and regions. This change was studied in the six multi-storey buildings in four towns, two in a warmer and two in a colder part of Montenegro, with different habits of dwellers in heating and ventilation during the year.

These six buildings have in common that they are built on a flat ground and made of concrete, with thickness of foundation and floor slabs greater than 5 cm. Two sampled buildings in Podgorica have no basement – one has 6 floors and the other ground floor and 5 upper floors. Both buildings in Niksic have basement – one has 9 floors and the other ground floor and 5 upper floors. Building in Bijelo Polje has basement and 8 floors, and that in Bar has 7 floors without basement.

Radon was measured in one dwelling on the most of floors of these buildings by passive dosimeters during two consecutive 6-month periods.

It is found that annual average radon activity concentrations in 35 dwellings of these multi-storey buildings are very low, mostly at a level of 20 Bq/m$^3$, and nowhere exceeding 53 Bq/m$^3$. Such low radon concentrations are obviously due to high-quality foundation slabs which prevent ingress of radon from ground into building, so that the main radon source in dwellings is building material.

Since radon concentrations in dwellings vary very little from floor to floor in each of these buildings, practically within the measurement error, there is no clear general trend of changes in radon concentrations with floor levels. However, it can be said that there is a decrease in radon concentration from the ground floor to the first floor, with a ratio of the mean values of radon activity concentrations, for all 6 buildings together, of 1.20. Based on the mean values of radon concentrations it seems that such a trend of decreasing continues also from the first to the third floor, however, it is so weakly pronounced that changes of these radon concentrations are within their standard deviations. Therefore, a firm conclusion that such trend really exists cannot be derived. Values of radon concentrations above the third floor oscillate, probably depending on living habits of dwellers.

All this means that radon from the ground has an influence, albeit weak, only to radon concentrations at the ground floor of the studied six multi-story buildings, while in dwellings on the upper floors the other factors have impact, like building materials and habits of dwellers.

# A POSSIBLE RELATION BETWEEN PRE-SEISMIC VARIATIONS OF NATURAL ULF-ELF ELECTROMAGNETIC NOISE AND REGIONAL THUNDERSTORM ACTIVITY

**Nadezda Yagova[1], Ashwini Sinha[2], Aleksandr Schekotov[1], Evgeny Fedorov[1], Geeta Vichare[2]**

1 The Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences (IPE RAS), Moscow, Russia
2 Indian Institute of Geomagnetism, Navi Mumbai, India

An existence of specific pre-seismic variations in parameters of natural geomagnetic field variations in the frequency range from fractions of Hz to several Hz has been reported in numerous studies. However, the problems of statistical validity these effects, their relation to earthquake parameters, and possible physical mechanisms are not solved yet. In the present study, we verify the hypothesis about spatial re-distribution of local and regional thunderstorms as a possible source of these variations and discuss its possible relation to radon emanation by an active fault.

# MEASUREMENTS OF RADON CONCENTRATION IN NATURAL MINERAL WATER

**Ana Sofia Silva[1,2], Maria de Lurdes Dinis[1,2]**

1 CERENA-Polo FEUP – Centre for Natural Resources and the Environment, Faculty of Engineering, University of Porto, Portugal;

2 PROA/LABIOMEP – Research Laboratory on Prevention of Occupational and Environmental Risks, Faculty of Engineering, University of Porto, Porto, Portugal

Natural mineral waters used in therapeutic treatments in thermal establishments have diverse chemical compositions, sometimes containing significant amounts of natural radionuclides, such as radon, which may increase the risk of exposure to natural radiation of both workers and users of thermal establishments.

In order to minimize the harmful effects of exposure to ionizing radiation, several recommendations have been published internationally.

The WHO refers the need for control when the radon concentration in drinking water exceeds the level of 100 Bq/L. However, the European Commission, by means of Recommendation 2001/928/EURATOM, on the protection of the public against radon exposure to drinking water supplies (public water supplies), beside a reference level of 100 Bq/L, established an action level of 1000 Bq/L, to which a corrective action must be carried out based on the radiological protection. However, the EU action level of 1000 Bq/L does not apply to mineral waters as it is assumed that these are not consumed on a regular basis and therefore no reference value has been established.

The Directive 2013/51/EURATOM establishing the requirements for the protection of the public health in general with regard to the radioactive elements present in water intended for human consumption, provides a parametric value (minimum allowable concentration) of 100 Bq/L for radon concentration (not applicable to natural mineral waters). On the other hand, the Decree-Law 23/2016 establishes the requirements for the protection of the health of the general public with regard to radioactive substances present in water intended for human consumption, states that a parametric value for radon concentration should be set at 500 Bq/L and where the radon concentration exceeds 1 000 Bq/L, correction measures are warranted.

The objective of this study was to evaluate the radon concentration in natural mineral waters of 17 Portuguese thermal establishments between 2013 and 2015 and analyse the compliance with the different parameter values for radon concentration from legal requirements.

The evaluation of the radon concentration in water was carried out in several places of each thermal establishment. Sampling of the radon concentration in the natural mineral water revealed the anomalous presence of values for this parameter, sometimes higher, both at the reference level and at the action level. The high values obtained in some cases are worrying and show the need of a more detailed and extensive study, both in space and time for workers protection. Approximately 50% of the results obtained for the radon concentration in the natural mineral water are higher than the reference level recommended by the EU, while 20% of the results exceeded the action level. These results may also imply high concentrations of radon in indoor air (and hence occupational exposure to radon), since the natural mineral water will constitute a continuous source of this radionuclide.

# MEASUREMENT OF RADON CONTENT USING CR-39 SOLID STATE TRACK DETECTOR


**Olesya Symkanych[1], Sergiy Sukharev[1], Oleg Glukh[1], Svetlana Delegan-Kokayko[1], Natalia Svatyuk[2], Vladimir Maslyuk[2], Kristina Krch[1]**

1 Uzhgorod National University, Uzhgorod, Ukraine
2 Institute of Electron Physics, National Academy of Sciences of Ukraine, Uzhgorod, Ukraine


Recently increases an interest of scientists to studying the content of radon in the environment and its impact on people. Radon is a product of the decay series of uranium and thorium, which are present in varying concentrations in the atmosphere and the earth's crust. Radon has three isotopes: $^{222}$Rn, usually called radon, and which is the decay product of $^{238}$U; $^{220}$Rn, called thoron, and which is the decay product $^{232}$Th, and $^{219}$Rn, called aktinon, the decay product of $^{235}$U. The half-life of $^{222}$Rn is 3.82 days, while $^{220}$Rn (55.6 sec) and $^{219}$Rn (3.96 sec) are characterized by much faster radioactive decay. Radon, as a noble gas, is able to migrate freely in air, soil and other environments, and lead to human radioactive exposure. It was studied that among all natural radioactive elements $^{222}$Rn is the most dangerous. Continuous irradiation by radon and its decay products may increase a risk of lung cancer.

In addition, radon can be generated from $^{226}$Ra, contained in building materials. This part of radon can enter the indoor air due to diffusion processes of building blocks and air convection, and thereby pose a threat to humans. The radiation intensity is defined as an amount of radioactive emanation coming out of the material through unit area per unit time. It depends on the concentration of the radioactive elements in the material, their ability to radiation, as well as on the diffusion coefficient of radon, defined by the porosity and density of the material.

According to http://www.icrp.org/publication.asp?id=ICRP%20Publication%2065, the rationing of exposure is proposed to make on gaseous radon, that is justified by the wide practice of integrated passive methods of measurement, mainly based on the use of solid-state track detectors of CR-39 type. This is the method that we used to measure the radon in the testing areas. The essence of this method is a passage of alpha-particles through CR-39 plastic and producing hidden damages in the molecules of the polymer. These damages can be revealed after etching of the plastic, for example, in NaOH solution. Reading and calculating the density of tracks of radioactive decay can be done by means of microscope with ~1000X magnification and special software. Measured density of the tracks corresponds to the radon concentration.

Using of this approach for measuring the radon concentration allows to evaluate the existing risk of possible radiation effects and to create the maps of the radon distribution in the studying areas that will increase the level of radiation safety.

# FIRST $^{222}$Rn ACTIVITY CONCENTRATION MEASUREMENTS IN NEWLY DISCOVERED PARTS OF DEEPER-LYING PASSAGES OF BEAR CAVE IN KLETNO (SOUTH-WEST POLAND)

**Lidia Fijałkowska-Lichwa[1], Tadeusz Andrzej Przylibski[2]**

1 Wrocław University of Science and Technology, Faculty of Civil Engineering, Division of Geotechnics, Hydrotechnics, Underground Construction and Hydrological Engineering, Wrocław, Poland
2 Wrocław University of Science and Technology, Faculty of Geoengineering, Mining and Geology, Wrocław, Poland

In underground workplaces (tourist facilities, adits, caves) open in Poland does not exist permissible annual average concentration value of $^{222}$Rn. Also in Poland the values in the range 500 – 1500 Bq/m$^3$ recommended by international organizations (IAEA, ICRP) are not respected. Until 6 February 2018 Poland as a Member State is obliged by the EU Council Directive (2013) to establish the maximum permissible annual average $^{222}$Rn value in such of workplace, on the level not more than 300 Bq/m$^3$.

For a dosimetric study the authors selected new parts of deeper-lying cave passages of considerable length, exceeding the hitherto known volume of karst voids in Bear Cave system, discovered by explorers in 2012, where the measured values of $^{222}$Rn activity concentration are larger than indicated by law regulations (e.g. Council Directive, 2013).

Bear Cave in Kletno was formed in a lens of marbles belonging to the Stronie series. The main sources of radon in cave are the Stronie series schists and gneisses, especially Śnieżnik orthogneisses. Radon migrates to the cave through a system of fissures and cracks in the mica schists and gneisses.

The monitoring of $^{222}$Rn activity concentration in the air of new corridors of Bear Cave in Kletno, started on 4th September 2013. The measurements were conducted continuously for almost three years, till 10th July 2016, at two measurements points. Two probes SRDN-3a equipped with a semi-conductor detector were set at a height of about 1 m above the floor of the corridors.

The average values of $^{222}$Rn activity concentration for almost three years of observation were in the range 2600 – 2900 Bq/m$^3$. Similar patterns of 24-h changes in $^{222}$Rn activity concentration were recorded on the both points during of the whole measuring cycle. They only differed in the absolute values. The highest values were recorded in summer and spring, the lowest in autumn and winter. They were in the range 2400 – 3000 Bq/m$^3$ at the second and between 2300 and 3700 Bq/m$^3$ at the first measuring point.

The authors did not find significant diurnal fluctuations in activity concentration of $^{222}$Rn. The variations had irregular character and were quite small; therefore, the authors cannot distinguish any periods within a day when radon activity concentration is clearly higher or lower. This fact points to the poor permeability of the cracking zone in the orogene, which makes air exchange with the atmosphere possible only in long-term periods favourable to convection. This observation confirms the strong connection of all cave passages with each other. This also complements the research conducted by the authors in the middle part of cave.

Mean effective dose in new corridors of cave changes from 0.008 to 0.014 mSv/h between September 2013 and July 2016. The maximum value was noted in July 2016 and reaches 0.07 mSv/h. The calculated values of the effective dose are not dangerous for tourists, which will be spent there not more than 1 hour a day.

# MEASURING OF SOIL RADON BY LIQUID SCINTILLATION COUNTING

**Henryk Bem[1], Magdalena Dlugosz-Lisiecka[2], Andrzej Gasiorowski[2], Piotr Szajerski[2]**

1 Higher Vocational State School in Kalisz, Kalisz, Poland
2 Institute of Applied Radiation Chemistry, Lodz University of Technology, Lodz, Poland

The objective of this research was to elaborate a simple method of soil radon measuring on the base of its direct absorption in typical 20 ml glass scintillation vials after passing -3 dm3 of soil gas through 16 ml of water immiscible non-volatile scintillation cocktail Ultima-Gold F. The soil gas is removed by hollow tube inserted into the soil at a specified depth (0.3 to 1m) and connected to a small gas pump. Preliminary experiments show that 5 minutes pumping of air with flow rate of 0.3 L/min is sufficient to achieve equilibrium between scintillator and gas phases. In the state of radon absorption equilibrium its activity in the scintillation solution corresponds to radon concentration in the soil. In practice it can be simply calculated after determining the calibration coefficient values by exposure of the vials in the radon flow-through Rn-222 source with the exactly known radon production rate from. The elaborated method seems to be very useful for measuring of the radon potential in the sites recommended for future house construction, since the infiltration of radon from the ground is usually the predominant source of indoor radon human exposure. Therefore, such protocols for measuring soil radon potentials are elaborated by US EPA and recommended for EU countries according to its Directive 2013/59/Euroatom.

# RADON CONCENTRATIONS IN DRINKING WATERS OF TRABZON PROVINCE, TURKEY

**Belgin Küçükömeroğlu[1], Selcen Uzun Duran[1], Ayşegül Şen[1], Ali Çiriş[1], Halim Taşkın[2], Uğur Çevik[1]**

1 Karadeniz Technical University, Trabzon, Turkey
2 Cekmece Nuclear Researches and Training Center, İstanbul, Turkey

In this study, we present the results of radon concentration measurements in drinking waters taken from the sources in the region of Trabzon located in the Eastern Black Sea part of Turkey. The radon activity concentrations of drinking water samples collected in four seasons of 2016-2017 were measured by using the radon gas analyzer (Alpha GUARD PQ 2000 PRO). The radon concentrations were found to vary from 0.15±0.05 Bq/L to 11.00±1.23 Bq/L in winter, from 0.35±0.15 Bq/L to 13±4 Bq/L in summer, from 0.63±0.18 to 16.50±2.5 in spring and from 0.78±0.04 to 16.00±2.83 in autumn for drinking water. The effective doses in drinking waters for all seasons were calculated. The calculated minimum and maximum effective doses are 4.1 µSv/y and 97 µSv/y, respectively. Also, any potential radiological risk for the local population was determined. The obtained results were compared with international recommendations and concentrations reported for other countries.

# FIBER OPTIC SENSOR FOR RADON MONITORING: PROOF OF CONCEPT

**Diana Guimarães[1], Catarina Monteiro[1], Luis Peralta[2], Susana Barbosa[1]**

1 INESC TEC, Porto, Portugal
2 LIP, Lisboa, Portugal

The radioactive gas Radon-222 is a decay product of Radium-226, which is present in the earth's rocks and soil in varying concentrations. Radon can diffuse through the soil and enter indoors or even be transported in water. This odorless gas is the main contributor to background natural dose levels, accounting for 50% of the total dose. It is also identified has a main source of lung cancer (second only to smoking). The inhalation of Radon can result in deposition of its short lived progeny into the respiratory tract, leading to the emission of highly energetic alpha-particles (from Polonium-214 and Polonium-218) that can result into biological damage.

Therefore, the measurement of radon and its monitoring is of uttermost importance. The compactness and the possibility of performing radiation real-time monitoring without electromagnetic interference makes optical fibers into an alternative to more conventional sensors. Recently, fiber optics have been used for radiation measurement using radiation induced attenuation or scintillation processes. The use of scintillating materials has been explored has a solution for detection of low level doses, and could possibly be used to detect gamma radiation as well as beta particles originated by radon's progeny decay.

In this work a compact fiber optical sensor, consisting of encased scintillating fibers coupled to a photomultiplier was developed. To monitor the temperature and humidity inside of the sensor case a Raspberry Pi with a Sense HAT board was implemented. The microcomputer was also used as data storage and as wireless interface to the photomultiplier for remote access. The response of the scintillating optical fiber to different types of radiation (α,β,γ) was assessed using a multichannel analyzer and several radioactive sources (Strontium-90, Americium-241 and Cesium-137). The influence of the number of fibers, its length and the fiber tip finishing was also studied taking into account the limitation of the photomultiplier window size. After light collection optimization, the sensor was placed in a box connected to a radon exhalation setup consisting of a container with rocks containing natural uranium. The accumulation of radon was successfully monitored by the detector. This prototype system provides continuous measurements at high temporal rates (minute or less) and for long time periods autonomously.

# RADON EXHALATION RATE OF SOME BUILDING MATERIALS COMMON IN SERBIA

**Dragan Avramović[1], Igor Čeliković[1], Predrag Ujić[1], Ivana Vukanac[1], Aleksandar Kandić[1], Aleksandar Jevremović[1], Boris Lončar[2]**

1 "Vinča" Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
2 Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

Several epidemiological studies conducted in Europe, America and Asia have confirmed that indoor radon increases the risk of lung cancer and is the second most important factor, after smoking, that causes the lung cancer. Beside the soil underneath the building which is considered to be a dominant source of radon, building material is also considered as an important one. In modern times, people tend to live in the houses/buildings that are more energy efficient, thus reducing the heat dissipation and ventilation rate of indoor air, which directly leads to an increase of radon concentration indoors.

Regarding the building materials, in the European Commission guidance it is regulated that annual effective dose received from the external exposure due to radionuclides in building materials should not exceed 1 mSv and for this case it is estimated indoor radon concentration coming from the building material is unlikely to exceed concentration of 200 Bq $m^{-3}$. Nevertheless, it was shown that under some conditions, especially in cases of small air exchange rate, the internal exposure coming from indoor radon concentration can exceed external exposure coming from the $^{226}$Ra concentration. Although, it is not mandatory to control radon exhalation rate from building materials, due to abovementioned arguments, it is important to better understand and estimate its contribution to the dose.

In the present work radon exhalation rate of building materials common in Serbia as well as materials for building decoration are measured. Measurements were performed using the accumulation chamber method and build up of radon concentration in the chamber was measured using SARAD RTM1688-2 device.

Radon exhalation rate depends not only on the $^{226}$Ra concentration in building material, but on numerous other factors such as: emanation coefficient, porosity, grain size... The samples were crushed, dried and sorted using sieves with different pore size. In this contribution we also report on the investigation of radon exhalation rate of several building materials as a function of grain size of the sample and its humidity.

# THE COMPREHENSIVE RADON SURVEY IN SINGLE-FAMILY HOUSES IN VOJVODINA REGION

**Sofija Forkapić[1], Robert Lakatoš[2], Kristina Bikit-Šreder[1], Igor Čeliković[3], Predrag Repić[1], Dušan Mrđa[1]**

1 University of Novi Sad, Faculty of Sciences, Novi Sad, Serbia
2 University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
3 University of Belgrade, Vinča Institute of Nuclear Sciences, Belgrade, Serbia

In this paper, we propose a methodology for a detailed and comparative study of radon and thoron problem in houses with elevated radon levels. A comprehensive radon survey has been carried out in 2017 in 15 single family houses which 50% of them exceed the reference annual level of 400 Bq/m$^3$ set in national legislation. The measurement locations were selected based on the previous results of the first national indoor radon survey in Serbia performed by using CR-39 track detectors. Different complementary techniques were applied to measure again indoor radon concentrations accompanied with radon in soil gas measurements and gamma spectrometry determination of radionuclide content in soil and radon progeny activity concentrations of the filter paper after indoor air sampling. The problem of thoron was also discussed because thoron very frequently accompanies radon and in some cases it can cause strongly false positive radon overestimation. For indoor and soil gas measurement two RAD 7 active devices were used. This continuous alpha spectroscopy monitor is capable to distinguish radon and thoron gas by means of registered alpha counting of $^{218}$Po and $^{216}$Po respectively. In order to investigate retrieval of radon entry thoron exhalation rate from soil were measured and correlated to various related quantities.

# RADIOLOGICAL ASSESSMENT OF GAMMA AND RADON DOSE RATES AT FORMER URANIUM MINING TUNNELS IN EGYPT

**Mohamed Hanfi**

Ural Federal University, Yekaterinburg, Russia

Radiological assessment was carried out at the mining tunnels (El Missikat and El Eradiya tunnels) in Egypt due to exposure to radon ($^{222}Rn$), thoron ($^{220}Rn$) and gamma radiation. $^{222}Rn$/ $^{220}Rn$ measurements were carried out with two techniques; instantaneous (active) and discriminative (passive) radon and thoron solid state nuclear track detectors (SSNTDs) were used for longer representative measurements. The detectors exposed for long time inside the tunnels. The results showed that radon and thoron in general is very high due to non-ventilation drafts inside the tunnels and gamma radiation was low. The total annual effective doses were exceeded to the permissible limit 20 mSv/y. According to IAEA recommendations, the two tunnels are regulated and controlled areas. A radiation hazard could be associated with exceptional situations, such as elevated exposures to ionizing radiation at tunnels, so work within these tunnels must be prevented only after the application of IAEA regulation for radiation protection standards. The exposure for radon and thoron gases for long time can be damage the body cells and it will cause cancer.

# NUMBER, SPECIFIC SURFACE AREA AND MASS DISTRIBUTION COMPARISON OF RADIOACTIVE AEROSOLS

**Hyam Khalaf[1], Michael Zhukovsky[2], Mostafa Mostafa[1], Maxim Vasyanovich[2]**

1 Ural Federal University, Ekaterinburg, Russia
2 Institute of Industrial Ecology UB RAS, Ekaterinburg, Russia

Information about number, specific surface area and mass distributions of aerosols is extremely important for the assessment of radiation exposure at inhalation intake of radioactive aerosols. In this study these distributions were compared with activity distributions of radon decay products. The experiments were conducted in 2 $m^3$radon chamber under controlled conditions on aerosol concentration and size distribution, measured by diffusion aerosol spectrometer (DAS) in the range from 5 nm to 10 mm. Activity distribution of aerosols was measured by diffusion battery and two types of cascade impactors. Aerosol concentration during the experiments was in the range from $2\times10^3$ to $2\times10^5$ $cm^{-3}$.

The measurements conducted by diffusion battery demonstrated that at low aerosol concentration nearly 80 % of radon decay product activity connected with aerosol particles with AMTD ~ 1 nm (so called unattached fraction). After injection of aerosols in experimental chamber the activity of unattached fraction decreased practically to zero but it was observed increasing of activity for aerosols with AMTD ~ 10 nm.

After aerosol injection, the distribution over the specific surface area of the aerosol had a bimodal distribution with median diameter of accumulation mode ~120 nm (GSD=1.3).The median diameter of coarse mode changed in time due to deposition of aerosols on the walls of chamber from 5 mm (GSD=1.6) 40 min after injection to 2 mm (GSD=2.5) 120 min after injection. The distribution of aerosols by activity measured by the cascade impactor was practically independent of the time from the moment of injection of aerosols into the chamber. The parameters of activity distribution are AMAD ~500–650 nm and GSD=1.5. Comparison of the distribution of activity with the distribution by number, specific surface area and mass showed that it most closely corresponds to the average distribution over the specific surface but does not exactly correspond to any of the listed distributions.

# DEPOSITION FRACTIONS OF INHALED INDOOR RADON DECAY PRODUCTS IN HUMAN RESPIRATORY SYSTEM WITH VARIOUS LEVELS OF PHYSICAL EXERTION

**Sara Sakr[1], Abdelrhman Ahmed[1], Amer Mohamed[1], Mona Moustafa[1], Mostafa Mostafa[2]**

1 Department of Physics, Minia University, El-Minia, Egypt
2 Ural Federal University, Ekaterinburg, Russia

Radon decay products are the second cause of lung cancer after smoking. Therefore, a lot of dosimetric model has been built in to calculate the effective dose and effective depth dose in different region and tissues of human respiratory system. The first step of dose calculation is the deposition fraction estimation. Deposition fraction of radioactive aerosols in human respiratory system is mainly depending on their size. In this work, the activity size distributions of accumulated inhalable particles of $^{222}$Rn decay products ($^{214}$Pb and $^{214}$Bi) are tested in indoor air. A low-pressure Berner cascade-impactor is using as an aerosol sampler (size range of 70–6000nm). Most of the measured attached activities of ($^{214}$Pb and $^{214}$Bi) are associated with the aerosol particles of the accumulation mode (200 nm to 2000 nm). The activity distribution of the two radionuclides is typically identical. The active median aerodynamic diameter (AMAD) for $^{214}$Pb is 420 nm with a geometric standard deviation (GSD) of 3.4 and for $^{214}$Bi is 410 nm with a geometric standard deviation (GSD) of 3.4. Given that dose estimation is sensitive to environmental conditions and based on the obtained experimental results, an analytical method was introduced to compute the local energy deposition of ($^{214}$Pb and $^{214}$Bi) by adult male for various levels of physical exertion (sleeping, sitting, light exercise and Heavy exercise).

# INDOOR RADON CONCENTRATION RELATED TO GEOLOGICAL SOILS AT DIFFERENT WORKPLACES OF ALBANIA

**Kozeta Tushe[1], Hamza Reci[2], Brunilda Daci[1], Elida Bylyku[1], Irma Berdufi[1], Emanuela Kiri[2]**

1 Institute of Applied Nuclear Physics, Tirana, Albania
2 Institute of Geosciences, Energy, Water & Environment, Tirana, Albania

Radon Exposure in the workplaces is one of the main exposures for the general population after that in dwellings. These workplaces are generally at the ground and /or first floor, where radon concentration is generally higher than at upper floors.

This study deals with the measurements of indoor radon concentration in several workplaces located above different geological conditions. Measurements of indoor radon concentration have been carried out using passive bare detectors based on CR -39, in 50 workplaces including one site at the Centre of Applied Nuclear Physics, Tirana.

According to the rule of methodology, the radon passive detectors have been located inside the workplaces for a long period of time (from three to six months), allowing to get average values, which represent much better the true values of the radon concentration inside of a closed environment. The exposure time of detectors is in the range 3-4 months, respectively (autumn – winter). According to the assessment made by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), radon in the natural environment constitutes about 50% of the human exposure to natural radiation or 1.2mSv/year. For all results is calculated the effective dose due to the radon contribution (mSv/y). Based on the results of the measurements, the minimum value of radon concentration found is 53 Bq/m$^3$ to 400 Bq/m$^3$ in workplaces, while the reference level is 300 Bq/m$^3$. Around the 90 % of the radon concentration values are within reference levels. The results of this study represent a variation of radon concentration related to underground soils. We conclude that more detailed studies are needed in areas with different geology and construction materials for a better spatial distribution of Radon concentration particularly in public places.

# COMPARISON OF SEVERAL METHODS FOR MEASURING $^{222}$Rn IN DRINKING WATER BETWEEN TWO LABORATORIES

**Marina Poje Sovilj[1], Jovana Nikolov[2], Ivana Stojković[3], Goran Šmit[4], Nataša Todorović[2], Vanja Radolić[1]**

1 Department of Physics, University of Osijek, Osijek, Croatia
2 University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia
3 University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
4 Department of Chemistry, University of Osijek, Osijek, Croatia

In 2001, the European Union published a Recommendation on the protection of the public against exposure to radon in drinking water supplies, with the accent on the necessity of conducting national survey, performing $^{222}$Rn measurements in drinking water (2001/928/EURATOM). Also, in 2013 European Union published another Recommendation laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption (2013/51/EURATOM). With these EU recommendations, the analysis of drinking water, came to the focus of interest in many laboratories in EU. Both above mentioned laboratories, each in their own country, invest large efforts in measuring radon in drinking water.

Three different measurement techniques and four different measuring devices were used for $^{222}$Rn measurement in drinking water samples: degassing method followed by the measurement in an ionization chamber (AlphaGuard measuring system), liquid scintillation technique (Quantulus and Tri-Carb liquid scintillation counters) and the technique of alpha spectrometry (RAD7 radon detector).

The results obtained by three different techniques and four different devices are compared and discussed with the aim of intercomparison between two laboratories and future scientific collaboration in the field.

# THE NRPI INTEGRAL SYSTEM FOR THE MEASUREMENT OF AN AVERAGE AIR EXCHANGE RATE IN BUILDINGS

**Karel Jilek, Ales Fronka, Michal Fejgl, Jan Lenk, Ivan Hupka**

National Radiation Protection Institute, Prague, Czech Republic

The air exchange rate between indoor and outdoor air is the key physical process which influences among other things also behavior of all types of aerosol and gaseous contaminants, including radon gas in buildings and mediates their transport from the outside air to the interiors of buildings. Hence, measurement of the air exchange rate plays the important role for dose assessment also from inhalation of radon gas in buildings.

A several years ago, a new technique and method for determination of an average air exchange rate in buildings (apartments, multiple storey family houses, kindergartens, etc.) have been developed at the National Radiation Protection Institute of Prague (NRPI). Recently, the method has been certified by the highest relevant Czech state authority – the State Office for Nuclear Safety. Currently, both the method and the technique are used in practice in the frame of the Czech National action plane in accordance with an applicable legislation.

After introduction of the self technique, some examples of its use in field and the most interesting results will be presented. Generally, the technique allows wide-spread survey in buildings and estimation of the air exchange rate ranging from 0.05 $h^{-1}$ to approx. 3 $h^{-1}$ within exposition duration lasting from a several days up to a several months with a total uncertainty about 30 %.

# HIGH RADON EXHALATION RATE IN MOSCOW

**Tatiana Petrova[1], Petr Miklyaev[2]**

1 Lomonosov Moscow State University, Moscow, Russia
2 Sergeev Institute or Environmental Geoscience, Moscow, Russia

The data of radiological survey on building sites in Moscow obtained during last 15 years were analyzed (more than 3000 building sites). Data included measurements of gamma dose rate, radium content in soils and radon exhalation rate. The analysis finds the strong abnormal radon exhalation rate values at 52 building sites (about 1 – 5 Bq $m^{-2}$ $s^{-1}$). These values are comparable to the radon exhalation of the uranium tailings dump or of the active fault zones. However, both uranium tailings and active faults are not found on these building sites and generally in Moscow. Also, high radium content in soils and bedrocks in Moscow was not observed, which could be the cause of the abnormal radon exhalation. Technogenic causes are also excluded. In our opinion the abnormal radon exhalation can be associated with geodynamic active zones, which were identified on the territory of Moscow on the geomorphological and geological data. Abnormally high values of radon exhalation rate indicate the increased permeability of the geological environment in geodynamic active zones.

# CASES OF VERY HIGH SEASONAL VARIATIONS OF RADON LEVELS IN FAULT ZONES

**Petr Miklyaev[1], Tatiana Petrova[2], Albert Marennyy[1]**

1 Research and Technical Center of Radiation Safety and Hygiene, Moscow, Russia
2 Lomonosov Moscow State University, Moscow, Russia

Radon exhalation rate in fault zones was studied in two different regions – Baikal region (Primorsky ridge) and Northern Caucasus (mountain Beshtau). The aim of the research is to determine the influence of fault zones on the radon migration in the geological environment. The results show extremely high seasonal variations of the radon exhalation rate in the fault zones on both regions. In summer were obtained abnormally high values of radon exhalation. This is about 0.8 – 1.0 Bq $m^{-2}$ $s^{-1}$ on Primorskiy ridge (Baikal region) and 10 – 20 Bq $m^{-2}$ $s^{-1}$ on mountain Beshtau (Northern Caucasus). These radon exhalation levels does not have a local origin because the mean values of radium concentrations in soils and bedrock are about 50 Bq kg-1 (Primorskiy ridge) and 150 Bq kg-1 (Beshtau mountain). These values cannot explain very high radon levels. In winter radon exhalation rate on both regions is drastically reduced to values of 0.01 Bq $m^{-2}$ $s^{-1}$ and 0.1 Bq $m^{-2}$ $s^{-1}$ respectively. In both cases there is a clear relationship between radon exhalation and air temperature. The report discusses the causes of the observed phenomenon.

# FAST PROTOCOL FOR RN-222 DIFFUSION MEASUREMENTS IN BUILDING MATERIALS

**Piotr Szajerski, Arkadiusz Zimny**

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

Rn-222 radionuclide and its daughter isotopes Po-218 and Po-214 are the main source of natural radiological exposure. They contribute in nearly 50% to total annual dose absorbed by humans. The most important radon sources in homes are soil and building materials. The main method for limiting Rn-222 concentration in air is efficient ventilation; however, this method lower only resulting radon concentration without affecting pathways of radon inflow into buildings. Alternatively, possible ways for lowering Rn-22 concentration are based on application of low Ra-226 bearing building materials and special insulation materials with low radon diffusion coefficients. Recently much attention has been paid towards elaboration of more effective methods limiting amount of radon coming into buildings. Many new insulation materials have been introduced into building sector connecting anti-moisture and anti-radon properties. This study presents results concerning anti-radon properties of the insulation and building materials based on measurement and evaluation of radon diffusion rate.

Technique applied for radon diffusion rate measurement is a modified method based on two chamber experimental setup, in which investigated material separates two chambers: Rn-222 diffuses from inlet to outlet reservoir. To inlet reservoir the exactly known activity of Rn-222 is injected and Rn-222 concentration is measured only in outlet reservoir. For data analysis, numerical model describing experimental setup has been elaborated. Numerical algorithm allows for effective parameters optimization to fit model to experimental data. Data analysis procedure leads to determination of radon transport parameters: radon transmittance and permeability coefficients.

Taking into account obtained results, we found radon transmittance parameters from $10^{-6}$ to $10^{-10}$ m/s. The worst performance was observed for typical polyethylene foil insulation materials, whereas the best efficiency was observed for dedicated anti-radon insulation membranes.

Presented results confirm the correctness of the proposed method and data analysis procedure. Advantage of our technique is application of only one radon detector connected in line with outlet reservoir. Experimental protocol allow for obtaining results already after ca. 24 h.

# A STUDY OF BUILDING FACTORS AFFECTING INDOOR RADON CONCENTRATION

**Bistra Kunovska[1], Zdenka Stojanovska[2], Kremena Ivanova[1], Antoaneta Angelova[1]**

1 National Centre of Radiobiology and Radiation Protection, Sofia, Bulgaria
2 Faculty of Medical Sciences, Goce Delcev, University, Stip, Macedonia

The building factors, associated to possibility of radon infiltration and its accumulation in the building, could influence indoor radon concentration within wide range. The effect of building specific factors: period of construction, type of foundation, type of facade of the measured dwellings and type of window frames on indoor radon concentrations variations was examined in the study. Each of the group of factor was splinted to at least two subgroups (cofactors). The factors, used in this analysis, were derived from the householders' answers to the relevant questions about various physical features of the dwelling. The data set of long-term radon measurements in 2778 houses in Bulgaria has been collected in National radon survey (2015-2016) under National Radon Program. The distribution of all radon data sets has been found to be log-normal. The variation of indoor radon concentration is from 12 to 1314 Bq/m$^3$.

**Key words:** National survey, radon variation, building factors, Bulgaria

# Radiation Detectors

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# GROWTH OF TlBr SEMICONDUCTOR CRYSTALS IN CERAMIC SUBSTRATES FOR GAMMA-RAY DETECTOR FABRICATION

**Toshiyuki Onodera[1], Keitaro Hitomi[2], Kouhei Kimura[1], Tadayoshi Shoji[1]**

1 Tohoku Institute of Technology, Sendai, Japan
2 Tohoku University, Sendai, Japan

Thallium bromide (TlBr) is an attractive compound semiconductor material used for room temperature gamma-ray detectors such as gamma camera and single photon emission tomography (SPECT) in nuclear medical applications. The procedure for fabricating TlBr detectors base on the common manufacturing techniques used for other semiconductor detectors, which consists of crystal growth of cylinder-shaped TlBr crystals, crystal cutting into wafers, the wafers surface polishing and electrode construction on both side of TlBr wafers. There mechanical procedures may induce the lattice defects and crystal distortion in the wafer and these problems affect charge transport properties for carriers and leakage current in TlBr detectors. In particular, the distortion is critical damage for TlBr detectors with thin and large area since TlBr has soft hardness like plastic nature (Knoop hardness number: 12 for TlBr, 38 for CdTe, 1150 for Si). In this study, TlBr crystals in a ceramic substrate were grown by the Bridgman method in order to fabricate mechanically enhanced TlBr detectors. After the crystal growth, the TlBr crystals with the ceramic substrates were sliced and polished, and Au electrodes were formed on the both side of the TlBr wafers. Gamma-ray energy spectra and current-voltage characteristics of TlBr detectors were measured to evaluate the influence of the growth technique and the detector structure in the detector performances. In addition, crystal orientation and uniformity of the TlBr wafer was evaluated using electron backscatter diffraction (EBSD) method.

# TEMPERATURE STABILIZATION OF SIPM-BASED GAMMA-RADIATION SCINTILLATION DETECTORS

**Viktors Ivanovs, Sergej Gushchin, Viktors Fjodorovs, Valerijs Ivanovs, Dmitrijs Kuznecovs, Anatolijs Lucanskis, Vadims Ogorodniks**

ZRF RITEC SIA, Riga, Latvia

Currently, silicon photomultipliers (SiPMs) with various scintillators are used as gamma radiation detectors for different applications. Many tasks require the ability to use detectors in environments with varying operating temperature. However, significant dependence of the SiPM’s characteristics as well as the dependence of the scintillator’s characteristics on temperature makes it difficult to use detector in such environments. The gain of a SiPM increases with bias voltage increasing and decreases with temperature increasing, but scintillator’s light yield may increase and/or decrease with temperature depending on a type of a scintillator. The presence of such dependence makes it necessary to use special technics for detector’s parameters stabilization.

For stable operation of scintillation detectors, the bias voltage can be adjusted to compensate temperature changes. This is typical way to stabilize the SiPM’s gain. Usually is applied adaptive power supply that uses near linear temperature dependence of the bias voltage readjustment. However, the complex dependence of the scintillator light yield does not allow using this approach to stabilize detector’s characteristics.

There was proposed and tested a method and electronic module for SiPM’s gain and scintillator’s light output temperature instability compensation. Our method is based on an application of SiPM biased power supply that is controlled and managed by the microprocessor. Calibration data of a photo peak (662keV) temperature dependence are stored in the microprocessor memory. The exact value of the bias voltage for each temperature is calculated by the formula of the 5th-degree polynomial. This method made it possible to realize a high accuracy of the photo peak position stabilization in the tested (-20$^{0}$C-+50$^{0}$C) operation temperature range.

The test results of SiPM-based gamma-radiation BGO and CsI(Tl) scintillation detectors as well as the results of their practical application in medical surgical probes are presented.

# myOSL – A NEW SERIES OF PORTABLE AND STATIONARY EQUIPMENT FOR OSL-DOSIMETRY BASED ON BeO

**Daniel Richter[1], Iwona Słonecka[2], Stefan Schischke[3], Kay Dornich[1]**

1 Freiberg Instruments GmbH, Freiberg, Germany
2 Central Laboratory for Radiological Protection, Warsaw, Poland
3 RadPro International GmbH, Wermelskirchen, Germany

The near tissue equivalency of BeO as a dosimetric material can be exploited best by optically stimulated luminescence (OSL). Its wide dose range and sensitivity make it a first choice for many dosimetric applications, including personal and medical dosimetry. Application in OSL dosimetry requires instrumentation capable of reading and zeroing the BeO, in order to allow re-use of the dosimeters. We here present two new OSL-readers designed for rapid mass measurement in personal dosimetry and for single element use.

The *myOSLraser* is developed for the *myOSLdosimeter*, which consists of 2-BeO-elements (Hp(0.07) and Hp(10)). The reading as well as the required zeroing is achieved in a single unit within seconds for a standard dose in personal dosimetry and thus no separate zeroing device is required. For irradiation purposes the separate *myOSLirradiator* is equipped with a Sr-90/Y-90 source (37 MBq). The measurement of large numbers is possible with the *myOSLautomatic* attachment, an automated feeding system for 200 *myOSLdosimeters* which can be attached. Management of automated measurement, zeroing and user instruction is provided together with the individual dosimeter identification by a standard bar-code.

The *myOSL* readers and dosimeters comply with IEC-62387. The excellent reproducibility of the dosimetric material and performance of the OSL-reader is shown, for example, by 0.66% standard deviation for 136 repeats of a 1mSv b-irradiation for a single dosimeter. Such is achieved by state of the art stabilization of stimulation and detection. The dosimeters therefore exhibit an excellent linear dose response, a large dose range applicability and high sensitivity.

*myOSLchip* is a single BeO-element OSL-reader/eraser. Due to its low weight it is truly portable and can be even battery operated. The positioning of the single element in the *myOSLchip dosimeters* is manually operated, thus allowing full user control for measurement and bleaching. Individual dosimeter calibration is possible, and rough doses can be measured even without calibration based on a universal average count sensitivity factor. The number of dosimeters and measurement data managed by the device is restricted in portable use, but full use of the *myOSLdosimetry* software can be made in non-portable operation and connection to a PC.

The *myOSLdosimetry* software allows a full scale data management for both devices, including the individual dosimeter calibration, device calibration as well as the normalization of the device, which allows the independent use of any *myOSLraser* for reading any *myOSLdosimeter*. Results are given in mSv and dosimeters exceeding single or total accumulated threshold doses are automatically flagged. Reporting functions allow the automated production of individual reports, *myOSLdosimeter* histories etc.

# ANNEALING STUDIES OF IRRADIATED P-TYPE SENSORS DESIGNED FOR THE UPGRADE OF THE ATLAS PHASE-II STRIP TRACKER

**Leena Diehl, Riccardo Mori, Ulrich Parzefal,**
**Marc Hauser, Karl Jakobs, Liv Wiik-Fuchs**

University of Freiburg, Freiburg, Germany

The upgrade for the High Luminosity LHC in 2025 will challenge the silicon strip detector performance with high fluence and long operation time. Sensors have been designed and tests on charge collection and electrical performance have been carried out in order to evaluate their behavior. Besides that, it is important to understand and predict the long-term evolution of the sensor properties.

In this work, we present detailed studies on the annealing behavior of ATLAS12 strip sensors designed by the ITK Strip Sensor Working Group and irradiated from 5*10^13 to 2*10^15 n_eq/cm^2. Systematic charge collection, leakage current and impedance measurements have been carried out during the annealing time at 23 and 60°C until break-down or the appearance of charge multiplication. Sensors showing charge multiplication have been then kept at high voltage for a long time in order to monitor their stability.

The difference in the annealing behavior between the two temperatures has been analyzed. From the impedance measurements for the samples irradiated to low fluences it was possible to extract the effective doping concentration. This was compared to similar measurements on n-type sensors and with a theoretical model.

The results show that ATLAS12 sensors anneal similarly to the previously designed ATLAS07 and the behavior is well described by the theoretical model. Nevertheless, a significant difference on the time constant of the beneficial and reverse annealing has been reported, especially at lower temperatures. For the highest fluences and longer annealing time, e.g. 5000 minutes at 60°C, charge multiplication has been observed. The phenomenon is however temporary and disappears with the long-term voltage stress.

# MEASUREMENTS AND CALCULATIONS OF GAS GAIN IN XE-5% TMA MIXTURE – PRESSURE SCALING

**Tadeusz Kowalski**[1], **Özkan Şahin**[2]

1 AGH, University of Science and Technology, Faculty of Physics and Applied Computer Science, Krakow, Poland
2 Department of Physics, Uludağ University, Bursa, Turkey

In this contribution we present a systematic study of single anode cylindrical detectors in gaseous Xenon using trimethylamine (TMA) as quencher gas. The choice of quench gas can have a significant effect on the gas gain and energy resolution. Gas gains ($^{55}$Fe has been used as the radiation source) and energy resolutions for $^{109}$Cd radiation source (Ag $K_\alpha$ line of 22.1 keV X-rays) were measured for pressures between 250 and 1800 hPa and concentration of TMA of 5%. We observed stable operation at all pressures, and a strongly enhanced gas gain, by Penning-like energy-transfer processes. The experimental data have been fitted with Magboltz to investigate the Penning energy transfer rates and the secondary processes playing a role in avalanche formations. The probability of the Penning transfer rate and the second ionization Townsend coefficients were determined for all pressures. The gas gain fits with Penning and feedback corrections are all in excellence agreement with the experimental data. The maximum gas gain reached values as high as ~$10^3$ (~$10^4$) at 250 (1800) hPa. The Diethorn, Williams & Sara and of Aoyama models of the first Townsend coefficient have also been used to determine the basic gas properties. The obtained and presented results can be nice for micromegas-TPC operating in Xe-TMA mixture.

# $CeBr_3$ – A WELL-CHARACTERIZED NEW SCINTILLATOR FOR GAMMA-RAY SPECTROMETRY

**Wolfram Westmeier, Klaus Siemon**

Dr. Westmeier GmbH, Rbsdorfergrund, Germany

Pure crystals of $CeBr_3$ material were initially produced by Schott Lithotec (Mainz) who then transferred production of several types of pure crystals to the enterprise Hellma Materials GmbH (Jena). $CeBr_3$ is a scintillating material which is very suitable for photon spectrometry in the X-ray and gamma-ray range, in particular because of its high quantum yield. When properly coupled with a photomultiplier the resulting detector unit can serve for X-ray and gamma-ray spectrometry in successful competition with new high-resolution crystals like e.g. the proprietary material $LaBr_3$:Ce which has a resolution (FWHM at 662 keV) of around 3%. The resolution of peaks in spectra measured with $CeBr_3$ is typically around 4%. The somewhat poorer resolution of $CeBr_3$, however, is well compensated by the fact that the detector is free of intrinsic radioactive material, like the natural abundance of $^{139}La$ in lanthanum, and its $^{227}Ac$ contamination is significantly smaller than in $LaBr_3$:Ce.

Having apparent advantages of $CeBr_3$ detectors in mind, spectral properties of the material were surveyed[1)] and applicability of $CeBr_3$ detectors for spectrometric applications was tested.

As most users of scintillation spectrometry have in the past worked with NaI(Tl) detectors, the comparisons are mostly focused on that material as a reference. Emphasis is laid onto the systematic display of properties of $CeBr_3$ detectors, such as the full-energy peak efficiency function or the resolution function as function of photon energy, as these functions are relevant for quantitative peak analysis in measured spectra. To enable quantitative peak analysis the intrinsic peak-shape of $CeBr_3$ gamma-ray peaks was investigated and the resulting peak-shape function was tested in analyses of spectra. For qualification of the $CeBr_3$ material the internal contamination through $^{227}Ac$ and its influence on the spectrum were experimentally determined.

Modern scintillation spectrometers often consist of a detector with PMT, plug-on multichannel analyzer and notebook PC which controls the unit and provides power to the MCA for over five hours of running time. Thus, portable scintillation spectrometry using a $CeBr_3$ detector is well suitable for in-situ measurements such as for example:

- Environmental survey
- Survey and quantification in nuclear medicine
- Supervision in and around nuclear facilities
- Boarder transit controls
- Production water and scales in the oil and gas industry
- Prospecting

# PHOSPHATE GLASSES AS PASSIVE DETECTORS OF IONIZING RADIATION DOSE MEASUREMENTS

**Andrzej Gasiorowski, Piotr Szajerski**

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

Currently, commercially available dosimetric systems are based mainly on alanine or thermoluminescence (TL) dosimeters ($Al_2O_3$ or LiF based TLD detectors).

Most commonly used TLD dosimeters are lithium fluoride (LiF) based detectors dedicated for personal and environmental dose monitoring. These TL dosimeters have been developed from 1960's mainly by T. Niewiadomski's team. LiF dosimeters exhibit advantageous features over other dosimetric systems: low minimal dose, high sensitivity, low signal loss vs time and fast readout method.

Unfortunately, lithium fluoride system does not allow for measurement of high radiation doses over an extended period of time, especially in difficult and harsh conditions, such as irradiation facilities, radioactive wastes repositories or nuclear power plants.

Therefore, it is important to develop a new types of detectors, which would be more resistant against absorbed dose and allow for applications in difficult conditions

Phosphate glasses can be considered as promising candidates for high dose measurement. They are very resistant against ultra-high radiation doses (matrix for high level waste immobilization). Additionally phosphate glasses exhibit excellent physical properties such as slow crystallization rate, long time durability, medium processing temperature (800-900˚C), high mechanical strength, and high corrosion resistance.

We developed method of synthesis and fabrication of rare earth activated phosphate glasses based dosimeters. Samples were synthesized by melt-quench method followed by grinding and tabletting into composite pellet detectors. Obtained glasses contain 0,5% w/w rare earth oxides (ex. cerium, terbium, samarium). Irradiation was carried out by two high dose rate irradiation sources: Co-60 and linear electron accelerator (LINIAC, ELU-6E). Doses up to 35 kGy were applied.

Presented results focuses on possible application of phosphate glasses doped with rare earth metal oxides in ionizing radiation dosimetry. Our results indicate on high TL signal emission induced upon irradiation. Most of the samples exhibit complex TL curves with multiple peaks existing from 120°C up to 350°C. Obtained glow curves indicate vast energetic spectrum of radiation induced electron traps.

Investigated detectors exhibit linearity of integrated TL signal vs irradiation dose up to 35 kGy. Presented detectors are resistant to light, chemicals and mechanical damage. Observed fading of TL signal can be minimized by preheating samples before readout.

Rare earth doped phosphate glasses posses TL signals that are useful for ionizing radiation dosimetry, therefore they seem to be promising passive radiation detectors for high intensity irradiation conditions

# A STUDY OF USING POLYCARBONATE AS A REUSABLE RADIOCHROMIC INTEGRATING DOSIMETER FOR MEASUREMENTS OF HIGH DOSES OF IONIZING RADIATION

**David Zoul[1], Martin Cabalka[2], Markéta Koplová[1]**

1 Research Centre Rez, Husinec-Řež, Czech Republic
2 Nuclear Research Institute Rez, Husinec-Řež, Czech Republic

The aim of this research is to study the possibility of utilization of polycarbonate as a reusable radiochromic integrating dosimeter for measurements of high doses of ionizing radiation (range of 0.1 – 10 kGy). The region of linear dependence of optical density of polycarbonate samples on the dose of gamma radiation as well as the degradation of the material and the possibilities of its acceleration due to annealing have been investigated.

The samples have been exposed to radioactive doses in required range for short period of time (in hours) in cobalt irradiation facility. After the exposure the optical density of the samples was measured at regular intervals.

For repeated use of polycarbonate integrating dosimeters the annealing can be utilized. This method allows to accelerate fading, e.g. by heating the sample at a higher temperature or exposing the sample to intense light or UV radiation. Due to controllability and reproducibility of the annealing conditions it is advantageous to choose the former option.

In order to verify the effect of oxygen concentration on the changes of the optical density and the rate of oxygen diffusion to the material, some samples were stored in pure oxygen atmosphere produced by electrolytic dissociation of distilled water using a fuel cell. The measurements showed small increase of oxygen diffusion rate and demonstrated the impact of increased oxygen concentration on the rate of change of the optical density of the material.

# EFFECT OF IRRADIATION ON INTERFACE STATE AND SERIES RESISTANCE CHARACTERISTICS OF $Y_2O_3$ MOS CAPACITORS

**Saleh Abubakar, Senol Kaya, Ramazan Lok, Aliekber Aktag, Huseyin Karacali, Ercan Yilmaz**

Abant Izzet Baysal University, Bolu, Turkey

Numerous dielectric materials such as; $Gd_2O_3$, $Sm_2O_3$, $TiO_2$, $HfO_2$, and so on, have been studied and investigated on account of replacing the conventional gate dielectric layers ($SiO_2$) for the MOS based technologies. However, most of these dielectric material's radiation responses are not found in the literature. In this study, the effect of irradiation on interface state and series resistance of $Y_2O_3$ MOS Capacitors for Future Radiation Sensors was studied, and an initial valuation of the $Y_2O_3$ dielectrics used in gamma radiation sensors was discussed. Charge trapping and relevant irradiation responses of the devices are significant for the requirement of high-k dielectrics for a long-term dependability of high-k dielectric materials. Therefore, irradiation effects on the series resistance (Rs) and interface state ($D_{it}$) characteristics of the $Y_2O_3$ MOS capacitors were investigated and analyzed. The electrical improvements of the thin films were analyzed using capacitance-voltage (C-V) and conductance-voltage (G/ω-V) measurements. On the other hand, the composed oxide traps densities increase with irradiation while interface state density trend changes by irradiation. This behaviour for interface states was accredited to the passivation of the dielectric layer from the semiconductor. The results show that both series resistance ($R_s$) and interface state ($D_{it}$) characteristics critically varied with gamma irradiation. Positive $Y^{+2}$ and $Y^{+3}$ atoms ionized by irradiation may be the reason of the composed trap densities in the device.

# DETERMINATION OF STRUCTURAL AND PHOTOELECTRIC CHARACTERISTICS OF ZnO POLYCRYSTALLINE THIN FILMS AND ZnO NANOROD ARRAYS OBTAINED BY SPRAY PYROLYSIS

**Atanas Tanushevski[1], Maja Lazarova[2], Ivan Boev[2]**

1 Faculty of Natural Sciences and Mathematics, University "Sts.Cyril and Methodius", Skopje, Macedonia
2 Faculty of Natural and Technical Sciences, Goce Delčev University, Štip, Macedonia

ZnO polycrystalline thin films and ZnO nanorod arrays were obtained by spray pyrolysis method, at a substrate temperature of 450 °C. From the analysis of the XRD diffractograms, the hexagonal crystal structure of the ZnO films and ZnO nanorods was determined. On the other hand, the grain sizes of the films and nanorods were determined using the Debye-Scherrer relation. The optical properties of the films and nanorods were determined by measuring the dependence of the transmission on the wavelength of the light. Also, the optical band gap of 3.28 eV for the ZnO films and 3.20 eV for the ZnO nanorods were estimated. The photoconductivity spectrum of thin films and nanorods was performed in the visible light range and their photoconductivity was studied when they were illuminated by X-rays, where the incident X-rays increase the conductivity of thin films and nanorods. The surface morphology of the ZnO films and the ZnO nanorods were studied by a scanning electron microscope, as well as the grain size of the film and the dimensions of the nanorods.

**Key words:** Zinc oxide, optical band gap, photoconductivity, surface morphology

# RADIATION EFFECTS ON LIGHT-DEPENDENT RESISTANCES

**Pablo Escobedo[1], Alberto J. Palma[1], María Sofía Martínez García[2], Antonio Martinez-Olmos[1], Antonio M. Lallena[1], Damian Guirado[3], Miguel Angel Carvajal[1]**

1 University of Granada, Granada, Spain
2 Autonomous University of Madrid, Madrid, Spain
3 Universitary Hospital San Cecilio, Granada, Spain

Semiconductor ionizing radiation dosimeters operating in the current mode are particularly useful for real-time measurement of dose rate and absorbed dose in ionizing radiation because their low size, cost and direct readout to electronic circuitry. The have been employed in applications such as radiotherapy, industrial processing and high-energy physics experiments. The dose rate can be determined by measuring the intensity of the radiation induced current, and moreover, the integration of that current provides the value of the accumulated charge in the sensor, which is proportional to the accumulated absorbed dose. Several interesting works have been published in this research field. The radiation effects on light-, voltage- and temperature-dependent resistances, commercial PIN diodes, and on phototransistors showing their features as resistive or current-mode dosimetric sensors.

A light-dependent resistor or photoresistor (LDR) is a light-controlled variable resistor. The resistance of a LDR decreases with increasing incident light intensity. A LDR is typically applied in light-sensitive detector circuits, and light-activated and dark-activated switching circuits. In this work, a couple of commercial light-dependent resistors have been preliminary characterized as radiation sensors for radiation beams typically used in radiotherapy. The NORPS-12 (Silonex Inc., UK) and the NSL-19M51 (Luna Optoelectronics, USA) are CdS photoconductive cells with a spectral response similar to that of the human eye, encapsulated in a moisture-resistant coating and enclosed in a plastic casing, having the latter with a ¼ diameter of the former. These devices were irradiated in darkness with 18 MV photons (LINAC Artiste, Siemens) in a 10x10 cm field located in the LINAC isocenter. To avoid backscattering effects, six centimeters of solid water was located underneath. In this preliminary study, real-time resistance measurements were carried out by a digital multimeter (DMM34410, Agilent Tech. USA) in the unbiased condition.

Up to now, our results can be summarized as follows: i) a measurable resistance change was achieved under radiation, showing a monotonic trend with the dose rate; ii) this change presented a rise time around 2 seconds; iii) the NORPS-12 LDR showed a significant resistance drift (even in darkness) after each irradiation season. This fact discards it as a reliable dosimetric sensor; iv) the NSL-19M51 LDR showed no significant drift and a quadratic dependence of the resistance with the dose rate (R^2=0.991) between 0.5 and 3 Gy/min.

Future work will be focused on designing a compact reader unit to measure the induced photocurrent from these kind of resistors, and the detailed study of their response as a function of the LDR biasing and radiation beam conditions (energy, dose rate, incidence angle, among others).

# MOSFET PROBE FOR INTRA OPERATIVE RADIOTHERAPY

**Miguel Angel Carvajal Rodríguez[1], Miguel Jiménez Melguizo[2], Pablo Escobedo Araque[1], Damian Guirado Llorente[2], Antonio Martínez Olmos[1], Alberto José Palma López[1]**

1 University of Granada, Granada, Spain
2 Universitary Hospital San Cecilio, Granada, Spain

**Introduction.** Intra-operative radiotherapy (IORT) is a technique that consists of the application of an electron beam just after the surgically tumour extraction, with the aim of destroying the residual tumoral cells. In this work the description and characterization of an ad-hoc probe for IORT dose measurement is reported. This probe is based on commercial DMOS transistors to reduce the overall system cost.

**Experimental setup.** The irradiations were carried out in the LINAC Artiste (Siemens, Germany) located at the University Hospital "San Cecilio" of Granada (Spain). Four sessions of 4 Gy and a final one of 20 Gy were provided to two probes under test. To measure the increment of the threshold voltage due to ionizing radiation, the reader unit developed by our research group was used (*Sensors and Actuators A Phys*. 249 (2016) 249–255). To minimize the thermal drift, the parasitic diode was used to measure the real temperature of the silicon die (*Sensors and Actuators A Phys*. 249 (2016) 249–255).

**Probe improvements.** The probe is composed mainly by two DMOS transistors model ZVP3306F (Diodes Zetex, USA), which are biased in parallel during the sensing configuration, and stacked during the read-out process. The probe operation consists of:

• Sensing state: The source and drain of the DMOS transistors (M1 and M2) are grounded, and a positive bias voltage is applied to the gates.

• Read-out state: M1 and M2 are stacked and a drain current ID= 600 μA is applied.

• Temperature measurement state: M1 and M2 are stacked with a reverse current of -600 μA.

• Storing state: All terminals are grounded (JFETs normally ON).

The main novelties of this dosimetric probe with respect to our previous probes (*Sensors and Actuators A Phys*. 252 (2016) 67–75) are:

• Two biased and stacked DMOS transistors during sensing process: Until now, our probes were based only on a unique biased transistor, or an added unbiased transistor stacked with the previous one (*Sensors and Actuators A Phys*. 252 (2016) 67–75). In this work both transistors are biased at the same time, therefore a higher sensitivity is achieved.

• Miniaturization of the probe to make possible its inclusion into a 5 mm diameter catheter: To reduce the thickness of the probe, a 0.4 mm Printed Circuit Board (PCB) was used to solder the DMOS transistors. This PCB is connected through a five-terminal cable of 1.70 m long to another PCB were the JFETs are placed.

**Preliminary results and conclusions.** The average sensitivity values achieved in the irradiations of the two probes were (14.4±1.3) mV/Gy and (13.8±1.1) mV/Gy, with 20 V of gate-source bias voltage. This sensitivity is a promising result reached by a DMOS commercial transistor to be used in IORT. The future tasks to carry out are the study of the angular dependence and the reduction of the bias voltage and the drain current to minimize the initial output voltage drift.

# CHARACTERISATION OF THE SEGMENTED CLOVER DETECTORS FROM THE ELIADE ARRAY AT ELI-NP


**Simona Ilie[1,4], Calin Alexandru Ur[1], Octavian Sima[2,3], Gabriel Suliman[1]**

1 Extreme Light Infrastructure – Nuclear Physics, ELI-NP, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest, Magurele, Romania
2 Faculty of Physics, University of Bucharest, Bucharest, Magurele, Romania
3 Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest, Magurele, Romania
4 University Politehnica of Bucharest, Doctoral School of Engineering and Applications of Lasers and Accelerators (S.D.I.A.L.A.), Bucharest, Romania


The Extreme Light Infrastructure—Nuclear Physics (ELI–NP) is one of the three pillars of the Extreme Light Infrastructure Pan-European initiative. The main goal of the ELI-NP facility is the study of photonuclear physics and its applications.

ELI-NP, currently under construction in Magurele, Romania will host two major research systems. The first one is a very high intensity laser system, capable of delivering twin laser pulses of 10 PW. The second facility is an advanced high energy (gamma) photon source based on Compton back scattering of laser light on high energy electrons which will deliver a very intense gamma beam system with unprecendented bandwidth and spectral density.

To complement and optimally use the photon beams available, the ELI-NP team are building, in international cooperation, a few advanced detector systems, to be used in dedicated experiments. One of the experiments which will take benefit most from the gamma beam characteristics are the nuclear resonance fluorescence (NRF) experiments. The detector array for these experiments (**ELI**-NP **A**rray of **De**tectors, ELIADE) will contain eight HPGe segmented clover detectors and four LaBr3 detectors and will be used to detect with high efficiency the gamma-rays with energies of up to several MeV in the presence of the high radiation background produced by the gamma beams. The segmented HPGe clover detectors are built by closely packing four single HPGe crystals in the same cryostat. Each of the crystals is electronically divided in eight segments.

Each of the segments behaves like an independent miniature HPGe detector, and the signals are acquired using digital electronics.

The focus of the ELI-NP involved in the development of the ELIADE array is the construction and testing of the Data Acquisition and Analysis systems and the full characterisation of the detectors. The data acquisition that will be used in the experiments is based on 14 bit 250MS/s digitisers (v1725 by CAEN). The DAQ needs to take data from more than 300 channels, making it one of the most complex data acquisition systems in the world. The DAQ is based on the new MIDAS framework coupled to custom made software.

For testing and evaluation purposes, an analog DAQ system consisting of spectroscopic amplifiers (Canberra model 2026) is coupled to a Multiport II MCA (Canberra) and Genie2000 data acquisition software.

To characterise these detectors, energy resolution and relative efficiency measurements are routinely carried out using in parallel the analog and digital acquisition system and $^{152}$Eu and $^{60}$Co point-like sources. The obtained results will be presented in this work.

# READOUT ELECTRONICS FOR TPC DETECTOR IN THE MPD/NICA PROJECT

**Stepan Vereschagin**

Joint Institute for Nuclear Research, Dubna, Russia

The TPC barrel is placed in the middle of a Multi-Purpose Detector and provides tracing and identifying of charged particles in the pseudorapidity range $|\eta| \le 1.2$.

Tracks in the TPC are registered by 24 readout chambers placed at both end-caps of the sensitive volume of the barrel. The readout system of one chamber consists of the front-end card (FEC) set and a readout control unit (RCU). FECs collect signals directly from the registration chamber pads, amplify them, digitize, process and transfer them to the RCU.

To ensure good reconstruction of all tracks, the 95232 electronic channels must meet strong requirements: the signal to noise ratio – 30, the equivalent noise charge < 1000 $e^-$, power consumption less than 100 mW per channel.

# EXPLOITATION OF FREE CARRIER ABSORPTION IN QUEST FOR TEN PICOSECOND TARGET FOR TIME RESOLUTION OF RADIATION DETECTORS

**Gintautas Tamulaitis[1], Etiennette Auffray[2], Mikhail Korjik[3], Saulius Nargelas[1], Augustas Vaitkevicius[1]**

1 Vilnius University, Vilnius, Lithuania
2 CERN, Geneva, Switzerland
3 Institute for Nuclear Problems, Minsk, Belarus

Fast timing becomes one of the key parameters of radiation detectors for many of their future applications in high energy physics and medical imaging. The ambitious 10 ps target for time resolution of radiation detectors put forward by Crystal Clear Collaboration at CERN a few years ago is currently evolving into a feasible specification for future radiation detectors. In this report, we present our recent results on free carrier absorption in scintillating materials and show that the phenomenon might be exploited in both basic directions to achieve the 10-ps target: i) the reinvestigation of the response time of the conventional scintillators and optimization of their timing properties and ii) study of fast processes in radiation-hard crystals to be exploited in fast detection of ionizing radiation.

Our experiments have been carried out in pump and probe configuration. The nonequilibrium carriers have been photoexcited by 200-fs-long laser pulses in visible or UV. The change in optical absorbance induced by the excitation was probed in infrared spectral range. The results were compared with the results obtained by time-resolved photoluminescence spectroscopy using a streak camera enabling subpicosecond time resolution.

Both intrinsic ($PbWO_4$, PWO) and Ce-doped garnet-type (GAGG:Ce, YAGG:Ce) scintillators exhibited strong free carrier absorption.

In PWO, the nonlinear optical response due to free carrier absorption occurs in femtosecond domain after the short-pulse excitation. The possibility to use this fast response to provide precise timing capabilities in novel radiation detectors with optical readout is under discussion.

GAGG:Ce has been studied at predominant excitation of free holes. The response peak occurs with a delay of few picoseconds due to hole delocalization from $Gd^{3+}$ ground state to the valence band. The response in the garnet scintillator YAGG:Ce containing no Gd occurs immediately after the short-pulse excitation. The rise time of GAGG:Ce codoped by Mg is also in subpicosecond domain. The influence of carrier trapping in GAGG and applicability of the codoped crystal GAGG:Ce,Mg for fast timing are discussed.

# TIME DEPENDENCE OF THE OSL REGENERATION EFFECT IN VARIOUS TYPES OF NATURAL SODIUM CHLORIDE SAMPLES

**Magdalena Biernacka, Renata Majgier, Arkadiusz Mandowski**

Jan Dlugosz University, Częstochowa, Poland

Sodium chloride (NaCl) is a very popular material having excellent luminescence properties. For this reason the material is considered for potential application in accidental and retrospective dosimetry as well as dating of geological sediments. This is possible using thermoluminescence (TL) and optically stimulated luminescence (OSL) methods.

Properties of NaCl samples of different purity and different form of preparation, after exposure on the ionizing radiation, were discussed in recent decades. Nevertheless, most of the research was performed without considering some less known effects as fading, inverse-fading and regeneration effect. These phenomena may strongly affect dose response characteristics during storage of the material on longer time scales.

In this work radiation induced OSL properties of natural sodium chloride samples were studied. The investigations were performed for various types of the material and various forms of sample preparation. NaCl samples were irradiated prior the measurement using a beta source. Performing two subsequent OSL readouts with a fixed time delay it was possible to study the self-renewal (regeneration) phenomenon. A series of these type of measurements performed with various time delays is known as the variable delay (VD-OSL) technique. The method allows to get a full information on both fading and regeneration phenomena. The experiments were done using the custom made OSL reader 'Helios-1'. The VD-OSL measurements were performed for various storage times for each type of salt. Preliminary results indicate good stability of the regeneration effect and its dependence on the absorbed dose of ionizing radiation. Possible application to dosimetry and luminescence dating was discussed.

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# OSL AND IRSL PROPERTIES OF MICROCLINE FROM STRZEGOM GRANITES

**Robert Smyka, Arkadiusz Mandowski,**
**Magdalena Biernacka, Renata Majgier**

Institute of Physics, Jan Dlugosz University, Czestochowa, Poland

Microcline belongs to a group of minerals called potassium feldspars. The feldspars constitute more than 50% of the components of the earth's crust. Because of their prevalence, they are widely used in ionizing radiation dosimetry, especially for the purposes of dating by optically stimulated luminescence (OSL) and infrared stimulated luminescence (IRSL) methods. Microcline is a good detector of ionizing radiation. However, its luminescence depends on many factors.

In this paper the basic OSL and IRSL properties of natural microcline minerals collected from the Strzegom region (Poland) were studied. Measurements were performed using the custom made OSL readers: Helios-1 equipped with green stimulation LEDs and Helios-3 equipped with IR stimulation LEDs. In the first stage, samples were irradiated with doses ranging from ~ 1 Gy to ~ 1000 Gy. Irradiations were made using $^{90}Sr/^{90}Y$ beta source. Then the OSL and IRSL characteristics were measured for 3 series of different samples.

The measured response of irradiated microcline crystals strongly depends on the type of stimulation. At room temperature, the IRSL signal was several times higher than OSL. The dose response curves were studied for OSL and IRSL. The preliminary result shows linear dose response in this material for dose range 700 mGy to 1000 Gy for OSL and 700 mGy to 150 Gy for IRSL. The investigations of fading were carried out also.

# PHOTON RADIATION SPECTROMETER BASED ON PIN-PHOTODIODE

**Maxim Cherepnev[1,2], Stanislav Chursin[1], Eugeny Timoshenko[1], Valentina Yakovleva[1], Lev Dolgikh[1], Timofey Nikishkin[1], Aleinik Alexander[1], Zukau Valery1, Yuriy Adishchev[2]**

1 Tomsk Polytechnic University, Tomsk, Russia
2 Tomsk State University, Tomsk, Russia

The application of radiation technologies in various fields of science and technology poses the task of in-depth study of the sources of ionizing radiation. Today, the most informative for understanding the processes taking place in a particular radiation technology is photon radiation, particularly in demand detection of photon radiation in low-energy particles. Thus, we formulated the task of creating a detector with the following characteristics: high resolution, speed, miniature, counting, etc. To perform the task, model calculations were performed and a prototype device was created. As a result, it was possible to create a detecting device that meets not only the declared requirements, but an additional one for a number of parameters.

# A HIGH-DOSE IONIZATION CHAMBER FOR REAL-TIME MONITORING AT SPENT FUEL IRRADIATION STAND

**Maciej Maciak, Michał A. Gryziński**

National Centre for Nuclear Research, Otwock, Poland

Due to the high dose rates occurring in the vicinity of spent fuel elements placed in the technological pool of research reactors, underwater environment with elevated temperature and limited access, the use of traditional radiation detectors is very difficult or even impossible. At the same time, there is a great need to monitor their radiation field parameters, such as dose rate, due to the use of emitted radiation for e.g. medical sterilization or irradiation of various types of research samples. The spent nuclear fuel extracted from the reactor core is placed in a technological pool and subjected to a long-lasting process called cooling. At this time, the spent nuclear fission of the U-235 nuclei no longer occurs in the spent nuclear fuel. Nevertheless, due to the fission products created during the reactor operation and high activation of fuel elements in its surroundings, very high levels of gamma radiation occur (up to several hundred Gy/h at a distance of several dozen cm). Further degradation of the resulting fission products causes continuous heat release and additionally the formation of neutron radiation. For this reason, it is necessary to monitor the conditions prevailing in the immediate vicinity of spent nuclear fuel during scientific research or commercial irradiation of samples.

A KWD-1 cylindrical ionization chamber of 0.8 $cm^3$ has been developed for high-doses real-time radiation field monitoring during the sample irradiation at spent fuel irradiation stand.

The anode if the chamber is placed centrally, the outer electrode is the housing of the chamber, on which there is zero potential. The housing is screwed to the head containing the electrode connector. The tightness between the head and the chamber casing is not required due to the fact that it is an air chamber with a pressure of 0.1 MPa. The head construction consists of a BNT triaxial connector, which is a current outlet and at the same time a connector that applies a positive potential on the central electrode and guard ring. Both the central electrode and the chamber housing are made of aluminium. The central electrode is an aluminium bar with a diameter of 2 mm and a length of the active part equal to 25 mm. The housing is rolled out of the rod, boring the inner part first, and then the outer part on the die. The thickness of the wall is 0.5 mm. Development of the chamber was based on the Monte Carlo calculations.

The KWD-1 was tested in standard reference gamma radiation sources of $^{137}$Cs and $^{60}$Co and promising results were obtained. The next steps are testing and calibration of the chamber at high-dose medical accelerators and in the vicinity of the spent fuel elements using as reference passive detectors.

# INVESTIGATION OF LUMINESCENCE PROPERTIES OF Tm-DOPED $CaCO_3$ DOSIMETER

**Kemal Firat Oguz**

Maltepe University, İstanbul, Turkey

Thermally stimulated luminescence dosimeters (TLDs) have been an important tool in measuring the ionizing dose. Due to the some advantages of thermoluminescence materials in the field of personal, clinical, environmental and space applications, many studies have been carried out to produce more efficient TSL dosimeters in recent years.

In this study, luminescence properties and dosimetric characteristics of recently synthesized Tm doped $CaCO_3$material has been investigated using beta, UVB (312 nm) and UVC (254 nm) radiation sources. The room temperature beta irradiated Tm doped $CaCO_3$ materials when heated at a constant heating rate of 5 °C/s exhibit four glow peaks at 105 °C, 210 °C, 255 °C and 405 °C. In addition, UVB and UVC irradiated $CaCO_3$: Tm material when heated at a constant heating rate of 5 °C/s exhibit two glow peaks at about 100 °C and 360 °C by a shoulder around 150 °C. In addition, some dosimetric characteristics such as dose response, stability and sensitivity of Tm doped $CaCO_3$ material was investigated.

The results of studies showed that the $CaCO_3$:Tm material has very high sensitivity and stability, which make them potential dosimeter in low dose applications (~1-10 μGy) such as personal dosimetry and dating.

# THE ROLE AND DESIGN OF SWARM ROBOTS AND HUMAN-SWARM INTERACTION FOR RADIATION SOURCE LOCALIZATION

**Gordana Lastovicka-Medin**

University of Montenegro, Podgorica, Montenegro

This paper will investigate the role of swarm robots and multi robots in space mapping and radiation source localization. The concept of swarm robots will be compared to the concept of multiple mobile robot system. Furthermore, the features of human swarm interaction for radiation source search and localization will be explored. The literature on architecture for swarm interaction that has features suitable for swarm robotics will be overviewed too. Differences between the single point (single detector/robot) measurement versus multiple space points will be discussed from the perspective of advantages and disadvantages. Distributed algorithms for swarm robots and a simple solution towards design of swarm robots will be examined and proposed, including robotic search using hybrid techniques – fuzzy logic and swarm intelligence inspired by nature.

# DIAMOND DETECTOR TECHNOLOGY: STATUS AND PERSPECTIVES

**Dmitry Hits[1], Harris Kagan[2], William Trischuk[3]**

1 ETH Zurich, Zürich, Switzerland
2 Ohio State University, Columbus, United States
3 University of Toronto, Toronto, Canada

Beam test results of the radiation tolerance study of chemical vapour deposition (CVD) diamond against different particle species and energies will be presented. We will also present beam test results on the independence of signal size on incident particle rate in charged particle detectors based on un-irradiated and irradiated poly-crystalline CVD diamond over a range of particle fluxes from 2 kHz/cm$^2$ to 20MHz/cm$^2$. The pulse height of the sensors was measured with readout electronics with a peaking time of 6 ns. In addition functionality of poly-crystalline CVD diamond 3D devices is demonstrated in beam tests and 3D diamond detectors are shown to be a promising technology for applications in future high rate/high intensity experiments.

**Comments:** This abstract is submitted on behalf of the RD42 Collaboration.

# RADIATION CHARACTERISTICS FOR $HfO_2$ AND $SiO_2$ INCORPORATED IN ELECTRONIC COMPONENT WITH MOS STRUCTURE IN FIELDS OF GAMMA AND X-RADIATION

**Srboljub Stanković[1], Aleksandar Jakšić[2], Mirjana Radenković[1], Dragana Nikolić[1], Nikola Kržanović[1]**

1 Vinča Institute of Nuclear Sciences, Belgrade, Serbia
2 Tyndall National Institute, Cork, Ireland

The advancement of new techniques for detection of ionizing radiation requires the development of electronic components, which in their structure have new materials with improved radiation characteristics. In recent years, modern semiconductor MOS structures were designed with a silicon dioxide ($SiO_2$) as the selected material. Such Metal-$SiO_2$-Si structures have proven to be very suitable for the production of basic components for detection and dosimetry in the fields of gamma and X-radiation. In this paper we will consider the possibility of using hafnium dioxide ($HfO_2$) as a new material that could be used in semiconductor technology instead of silicon dioxide ($SiO_2$). Basic radiation characteristics for $HfO_2$ and $SiO_2$ are determined using XCOM software (NBSIR 87-3597), whereby total cross sections and attenuation coefficients as well as partial cross sections for the following processes are defined: incoherent scattering, coherent scattering, photoelectric absorption, and pair production in the field of the atomic nucleus and in the field of atomic electrons. Finally, a presentation of one type of numerical calculation of the transport of gamma and X radiation through a MOS capacitor, consisting of an aluminum electrode, $HfO_2$ gate dielectric on p-type silicon (Al /$HfO_2$/pSi) was made. The conclusions reached are of particular importance in cases where a compromise between the improvement of electrical and radiation characteristics is achieved.

# USE OF ERBIUM OXIDE LAYER AS NEW GATE DIELECTRIC IN NürFET RADIATION DOSIMETERS

**Senol Kaya, Ercan Yilmaz**

Abant Izzet Baysal University, Bolu, Turkey

High-k gate stack structures as possible candidates to replace silicon dioxide layer for nanoscale MOSFETs have been of great interest very recently due to their promise in reduction of gate current in order to reduce leakage effects on CMOS circuits and to alleviate scaling limits. However, innovations in this area have not moved yet to the size of the radiation sensors and dosimeters. High-k materials have also high potential to be use in a new dielectric layer for radiation dosimetry, due to higher effective atomic number, density and lower band gap energy than conversional $SiO_2$ gate dielectrics. Therefore in present work, Nuclear Radiation Sensing Field Effect Transistor (NürFETs) with 100 nm-thick $Er_2O_3$ gate dielectrics have been fabricated have been fabricated and variation on the device characteristics under Co-60 gamma irradiation have been inspected. The obtained results were also compared with NürFETs having conventional $SiO_2$ gate dielectrics.

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# METAL THIN-FILM DOSIMETRY TECHNOLOGY FOR THE ULTRA-HIGH PARTICLE FLUENCE ENVIRONMENT OF THE FUTURE CIRCULAR COLLIDER AT CERN

**Georgi Gorine[1], Giuseppe Pezzullo[1], Michael Moll[1], Mar Capeans[1], Katja Väyrynen2, Mikko Ritala[2], Didier Bouvet[3], Federico Ravotti[1], Jean-Michel Sallese[3]**

1 CERN, Geneva, Switzerland
2 University of Helsinki, Helsinki, Finland
3 EPFL, Lausanne, Switzerland

The Future Circular Collider (FCC) design study, aims to assess the physics potential and technical feasibility of a new synchrotron accelerator expected to reach an energy level of 100 TeV colliding proton beams (FCC-hh) circulating in a 100 km tunnel located in the Geneva area (Switzerland). Unprecedented radiation levels will presumably exceed several tens of MGy with more than $10^{17}$ particles/cm$^2$ inside the FCC detectors. Current technologies, such as silicon pin diodes, are not capable of integrating this particle fluence, thus requiring a new type of sensor to be used as dosimeter in the future irradiation facilities and, at a later stage, in the FCC accelerator.

As solution for Ultra High Fluence monitoring, we have focused our research on metal nanolayers. The technology consists of thin film resistive structures deposited on silicon wafers, where sensitivity to displacement damage, measurable in a variation of their electrical properties, can be trimmed by variating geometrical (thickness, W, L) and physical *(material)* properties of the nanolayers. The prototypes have been fabricated at EPFL Centre of Micronanotechnology, and specific high-fluence irradiation tests (with gamma, protons, neutrons) have been carried out in CERN facilities and outside CERN.

In this paper, to further describe and understand the effects of non-ionizing energy loss in metals, we present the electrical measurements performed at varying temperature, before and after irradiation, that allowed to study how the electron scattering varies and correlates to the permanent displacement damage cumulated inside the metal lattice.

# COMPARATIVE ANALYSIS OF GaN AND CdTe MATERIALS FOR RADIATION DETECTORS

**Dovile Meskauskaite[1], Eugenijus Gaubas1, Tomas Ceponis[1], Jevgenij Pavlov[1], Vytautas Rumbauskas[1], Salim Madraximovich Otajonov[2], Nodir Esonaliyevich Alimov[2]**

1 Institute of Photonics and Nanotechnology, Vilnius, Lithuania
2 Ferghana State University, Fergana, Uzbekistan

GaN and CdTe are promising materials for application of efficient radiation defectors due to their large cross-sections for interaction with ionizing radiations. The comparative analysis of the carrier recombination and of ionization cross-section spectra has been performed for polycrystalline CdTe and MOCVD GaN epi-layers. These characteristics were recorded by combining the microwave probed photoconductivity (MW-PC) and pulsed photo-ionization spectroscopy (PPIS) techniques. The inherent traps associated with growth and radiation defects, induced by proton irradiations, have been identified. Correlations of the dominant defects with radiation hardness of CdTe and GaN materials will be discussed.

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# PROPERTIES OF THE MODEL FOR RADIATION-INDUCED OPTICALLY STIMULATED LUMINESCENCE (OSL) IN SODIUM CHLORIDE AND OTHER IONIC CRYSTALS

**Renata Majgier, Magdalena Biernacka, Arkadiusz Mandowski**

Institute of Physics, Jan Dlugosz University, Częstochowa, Poland

Radiation-induced luminescence methods are commonly used in radiation dosimetry. One of the most widely applied techniques in this field is optically stimulated luminescence (OSL). The kinetic of OSL luminescence is quite complex. Recently, during the investigations of OSL in NaCl an interesting phenomenon was observed – the regeneration effect. It consists of self-renewal of the OSL signal between subsequent measurements. The regeneration mechanism cannot be explained on the basis of the simple trap model nor the model of localized transitions. To explain the effects of regeneration and fading a phenomenological model for NaCl luminescence involving both localized and delocalized (i.e. band-like) transitions was proposed. The mixed localized-delocalized (MLD) system consists of two types of trap levels and two types of recombination centers. Optically active traps (OT) are depopulated during OSL stimulation. The other traps are inactive (NOT) during optical stimulation, however they contain charge carriers' reservoir that fills emptied OT traps. The non-radiative transition W takes place from NOT to OT traps and is responsible for OSL regeneration. Recombination centers spatially connected to OTs are responsible for fading of the OSL signal. The model can be described by a set of differential equations. Testing of the model was performed by computer simulations using the numerical solutions of differential equations describing the experimentally observed physical processes.

The model of OSL regeneration in pure NaCl can be referred to similar materials, such as KCl and natural NaCl mineral (halite). The results of OSL measurements in both KCl and halite confirm the coexistence of two effects – regeneration and fading of the OSL signal after irradiation. The model allows for estimation of transition rate (W) and fading rate (Y), as well as the rate of OSL detrapping which is proportional to the stimulating light intensity (F). Theoretical results obtained by numerical simulation using the proposed OSL theoretical model correspond quite well to the experimental data.

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# 4D PARTICLE DETECTORS

**V. Cindro[1], G. Kramberger[1], I. Mandić[1], M. Zavrtanik1, M. Mikuž[2]**

1 Jožef Stefan Institute, Ljubljana, Slovenia
2 University of Ljubljana, Faculty for Mathematics and Physics, Department of Physics, Ljubljana, Slovenia

Novel silicon detectors with charge gain were designed (Low Gain Avalanche Detectors – LGAD) to be used in particle physics experiments, medical and timing applications. They are based on a n++ -p + -p structure where appropriate doping of multiplication layer (p+) is needed to achieve high fields and impact ionization. Excellent timing resolution of 27 ps has been achieved for minimum ionizing particles in thin LGADs. Segmented LGADs therefore allow precise determination of hit position and time of the particle crossing the detector. A concept of the detectors and results from first prototypes and well as examples of their application will be discussed.

# EFFECTS OF CRITICAL PROCESSING STEPS PARAMETERS ON RADFET PERFORMANCE

**Aleksandar Jaksic[1], Anne Marie McGarrigle[1], Nikola Vasovic[1], Amanda Barry[2], Russell Duane[1]**

1 Tyndall National Institute, Cork, Ireland
2 UPMC Whitfield Cancer Centre, Waterford, Ireland

Radiation Sensing Field Effect Transistors (RADFETs), also known as MOSFET dosimeters or pMOS dosimeters, have found applications in space, high-energy physics laboratories, and radiotherapy clinics. The RADFET is a discrete p-channel MOSFET with a thick gate oxide (typically from 100 nm to over 1 µm), optimised for radiation sensitivity. Radiation induces charges in the gate oxide, which cause the shift of the threshold voltage proportional to the radiation dose. The main good features of the RADFET are small size, simple/immediate/non-destructive read-out, electronic signal, and small cost when produced in volume. The main shortcoming is limited sensitivity, which precludes the use of standard RADFET designs in applications requiring minimum detectable dose lower than approx. 1 cGy.

We have investigated the effects of a Boron implant through the gate oxide on sensitivity and fading of the 400 nm gate oxide RADFETs fabricated by Tyndall National Institute, Cork, Ireland. We have found that, while the implant increases the sensitivity of the samples irradiated with zero gate bias, contrary to some previous data, sensitivity remains unchanged for +5 V bias during irradiation. We have attributed this to the surface potential at the Si-$SiO_2$ interface resulting from device design, i.e. doping levels. The implant also results in reduced fading. On the other hand, the most significant effect of the increased time/temperature of post-implant anneal is reduced fading after irradiation with zero gate bias.

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# Radiation Effects

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# DETERMINATION OF GLASS TRANSITION TEMPERATURE AND IRRADIATION RESISTANCE OF ELASTOMERIC MATERIALS BASED ON CHLORINATED NATURAL RUBBER

**Jaroslava Budinski-Simendić[1], Milena Marinović-Cincović[2], Dejan Kojić[1], Gordana Marković[3], Jelena Pavličević[1], Ayse Aroguz[4], Suzana Samaržija-Jovanović[5]**

1 Unuversity of Novi Sad, Faculty of Technology, Novi Sad, Serbia
2 University of Belgrade, Vinča Institute of Nuclear Sciences, Belgrade, Serbia
3 Tigar A.D., Pirot, Serbia
4 Istanbul University, Chemistry Department, Istanbul, Turkey
5 University of Priština, Faculty of Natural Science and Mathematics, Kosovska Mitrovica, Serbia

Synthetic rubbers have different surface structures but benefit from chlorination. In many cases their tensile strength and extensibility is lower than natural rubber and for that reason more easily mechanically damaged. Chlorination reduces the coefficient of surface friction and handling characteristics. Residual free sulfur bloom during long-term storage of elastomeric products can also be diminished. Chlorinated natural rubber (CNR) as network precursor for elastomeric materials finds application in paints, paper coatings, printing inks, adhesives, and textile finishes. An alternative way to reduce surface tackiness of powder-free latex NR medical gloves is the chlorination of the gripping side or the use of coating which may be silicone polymer, hydrogel, polymer blend or acrylic polyurethanes. Chlorination affects some of the beneficial characteristics of rubber latex, but also eliminates soluble proteins that promote allergic reactions. Chlorinated rubber has been used for restoring and excellent protecting plaster, concrete, and pool surfaces. It is a good choice for recoating previously painted surfaces. Focus of our work was to prepare elastomeric materials based on CNR and its blends with different content of chlorosulfonated polyethylene (CSM) filled with 50 phr of recycled elastomer powder (REP). The glass transition (Tg) represents the temperature above which a polymer changes from a stiff glass into a viscous fluid or a rubbery material and was evaluated using dynamic-mechanical spectroscopy. It was estimated that that the polar groups at network precursors influenced the shift of the Tg values. The effect of irradiation dose on retained hardness and tensile strength of CNR/CSM/REP elastomeric composites was determined.

# THE INFLUENCE OF CARBON BLACK ON THERMAL DEGRADATION AND GAMMA IRRADIATION RESISTANCE OF ELASTOMERIC COMPOSITES BASED ON THREE NETWORK PRECURSORS

**Slaviša Jovanović[1], Gordana Marković[2], Milena Marinović-Cincović[3], Vojislav Jovanović[4], Dejan Kojić[5], Ljiljana Korugić-Karasz[6], Jaroslava Budinski-Simendic[5]**

1 Mitas d.o.o., Ruma, Serbia
2 Tigar AD, Pirot, Serbia
3 University of Belgrade, Vinča Institute of Nuclear Sciences, Belgrade, Serbia
4 University of Priština, Faculty of Natural Science and Mathematics, Kosovska Mitrovica, Serbia
5 University of Novi Sad, Faculty of Technology, Novi Sad, Serbia
6 University of Massachusetts, Amherst, United States

The tire is an assembly of more components that are built up on a drum layer by layer and then crosslinked in a press under heat and pressure. Multi-component elastomeric materials are using for its production. The formation of polymer network creates the elasticity that permits the tire to be compressed in the area where the tire contacts the road and return back to its shape under high-frequency deformations. Some special application is for slick tires that provides more traction than grooved tires due to their greater contact area. Wet roads severely diminish the traction due to the water trapped between the contact zone and the road surface (aquaplaning). Polyisoprene (NR) is the basic network precursor used in tire fabrication. Polybutadiene (BR) is used in combination with other rubbers because of its low heat-buildup properties. The copolymer of styrene and butadiene (SBR) is often substituted in part for NR due to the comparative raw cost. The filler carbon black (CB) forms a high percentage in rubber compounds. After crosslinking this nanoparticles influence reinforcement and abrasion resistance. In elastomeric materials based on ternary blends characteristics of individual rubbers can significantly changing due to the intermolecular interactions. Focus of this work was to evaluate the irradiation resistance and thermal stability of composites based on different content of carbon black and three network precursors (BR/SBR/NR) with its mass ratio 25/50/25. The compounds were crosslinked by sulfur in hydraulic press and obtained materials were exposed to gamma irradiation at different doses up to 400 kGy. Thermogravimetric analysis confirmed that thermal stability of composites was increased with the CB content increase. The mechanical properties were determined before and after gamma irradiation of samples. It was assessed that the mechanical properties increases with increasing the irradiation dose up to 200 kGy and CB content up to 60 phr. The morphology of prepared materials was studied using scanning electron microscopy.

# DEVELOPMENT OF ACUTE LEUKEMIA IN PATIENT THROUGH 30 YEARS AFTER IRRADIATION IN ACCIDENT AT CHERNOBYL NPP

**Vladimir Nugis, Irina Galstian, Maria Kozlova, Victoria Nikitina, Catherine Dobrovolskaya**

Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency, Moscow, Russia

The development of hemoblastoses in often associated with the influence of various genotoxic unfavorable factors, in particular, with the effect of ionizing radiation. The case of development of acute leukemia in an irradiated patient thirty years after the accident at the Chernobyl nuclear power plant is considered in this communication. This patient suffered acute radiation sickness II degree of severity. The average absorbed dose was estimated from the dicentrics frequency in peripheral blood lymphocyte culture and was 4.3 Gy. At a subsequent long-term clinical observation (27 years) moderate transient instability of hematological parameters was revealed: lymphocytosis, leukopenia and thrombocytopenia, which was associated with chronic persistent B and C hepatitis viruses. Three-color FISH-staining of chromosomes of cultured peripheral blood lymphocytes through 30.1-30.5 years after irradiation demonstrated the level of translocations significantly in 42-54 times higher than background value. In 2014, the patient underwent transuretral resection of the prostate in connection with prostate cancer. In May 2015, course of radiation therapy with a total local dose of 35 Gy was conducted. In December 2015, there was a general weakness, from April 2016 three-stage cytopenia was noted in general blood test (white blood cells – $2.9\text{x}10^9$/l, platelets – $90\text{x}10^9$/, erythrocytes – $3.56\text{x}10^{12}$/l). Diagnosis: acute myeloid leukemia (AML), transformation from myelodisplastic syndrome. An abnormal complex clone was detected in 38% of metaphase cells of bone marrow by the mFISH-metod along with other chromosome rearrangements. Despite the Vidaza's chemotherapy the patient died of bilateral pneumonia in March 2017. In considering this case, naturally the question arises of the etiology and pathogenesis of developed AML. Three factors could have lead to the development of acute leukemia at this patient: 1. the emergency radiation exposure (with the induction of stable damages of chromosomes); 2. the presence of C hepatitis viruses detected by markers; 3. local gamma-therapy for prostate cancer in a total dose of 35 Gy. Therefore, we concluded that the leukemia is polyetiologic disease in this case with the undoubtedly high contribution of the transferred emergency radiation exposure.

# EFFECTS OF GAMMA-IRRADIATION DISINFESTATION WITH DIFFERENT DOSE RATES ON LEATHER MATERIALS

**Petya Kovacheva[1], Neli Boshnakova[2], Delyan Zhekov[1]**

1 University of Sofia, Sofia, Bulgaria
2 BULGAMMA, Sopharma JSC, Sofia, Bulgaria

This paper presents results from the studies on the effects of gamma-irradiation processing on the morphology, radical formation and thermal properties of leather materials. Calf leather, calf suede and pig skin patterns were selected and analysed by: SEM/EDX, EPR, DSC and TG/DTG before and after the gamma-irradiation treatment with 5 kGy, 10 kGy, 15 kGy and 25 kGy absorbed doses using low (0.006 – 0.06 Gy/s) and standard dose rates (0.6 – 6 Gy/s). The irradiation of the leather patterns was performed in the gamma-irradiation facility BULGAMMA based on JS-850 $^{60}Co$ type gamma irradiator at Sopharma. The absorbed dose distributions were measured with Ethanol Chlorobenzene routing dosimeters. No significant changes in the leather morphology or thermal decomposition were observed as a result of the gamma-irradiation treatment at both dose rates, as revealed by SEM and TG/DTG analysis. EPR analysis showed increased number of radiation-induced radicals in the calf leather samples, compared to the calf suede and pig skin patterns. This was ascribed to the presence of the non-isolated $Cr^{3+}$ ions in the chrome tanned leather patterns (calf suede and pig skin), which interact with the oxygen radicals, formed during the gamma-irradiation. The spin concentration in the samples from the three leather patterns is not influenced by the dose rate of the gamma-irradiation, except the signal in the calf leather, where higher spin concentrations were found in the samples, irradiated at low dose rate**.** The obtained results showed that gamma-irradiation treatment of calf leather, calf suede and pig skin with insecticide, fungicide and bactericide doses can be successfully applied for disinfestation and preservation without causing significant changes in their structure and morphology, even at low dose rate, where higher radiation-induced side effects are to be expected.

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# PERFORMING THE FIRST SINGLE EVENT EFFECT TESTS USING THE METU DEFOCUSING BEAM LINE IN TURKEY

**Merve Yigitoglu[1], Melahat Bilge Demirkoz[1], Pelin Uslu1, Selen Nigdelioglu[1], Cagrı Yazgan[1], Ilias Efthymiopoulos[2]**

1 Middle East Technical University, Ankara, Turkey
2 CERN, Geneva, Switzerland

METU-Defocusing Beam Line (METU-DBL) project aims to perform Single Event Effect (SEE) tests for space, nuclear and other applications. Turkish Atomic Energy Authority (TAEA) has a cyclotron which can accelerate protons up to 30 MeV of kinetic energy at Proton Accelerator Facility (PAF) mainly for radioisotope production and for R&D purposes. In the facility, the stable proton beam current is variable between 0.1μA to 1.2mA and the beam size is nearly 1 cm x 1 cm. METU-DBL pre-test setup, which has been installed in the R&D room, enlarges the beam size with two quadrupole magnets and it will reduce the proton flux with a collimator. The final beam size is about 10 cm x 10 cm and the beam flux is $10^8$ p/cm$^2$/s. The beam optics studies and particle tracking studies were performed with G4beamline and TURTLE program. The first tests for electronic cards, detectors and also commercial and experimental solar cells have been performed. These test results will be presented. Also, the final configuration of METU-DBL is now under construction and its future potential for tests according to ESA ESCC No. 25100 standard will be presented.

# THE MIXED EXTRACT OF RADIATION MUTATED PLANT ALLEVIATES DEVELOPMENT OF ARTHRITIS IN ANIMAL AND HUMAN BODY

**Chang Hyun Jin, Hyo Young Kim, Jin-Baek Kim**

Korea Atomic Energy Research Institute, Jeongeup, South Korea

In this study, the anti-arthritic effects of the mixed extract from radiation mutant Perilla frutescens var. crispa and Atractylodes ovate were determined on the development of collagen antibody-induced arthritis (CAIA) in Balb/c mice. The mixed extract was administered via oral gavage once per day for 4 days. Mice treated with the extract developed less severe arthritis than the control CAIA mice. They showed significantly improved arthritic score, paw volume, and paw thickness compared to the control CAIA mice from days 3 through 7. Furthermore, histopathological examination of ankle for inflammation showed that infiltration of inflammatory cells and edema formation were reduced by extracts treatment. In human body application test, the group taken the mixed extract showed significant improvement compared to placebo group in pain, rigidity, and joint function. Taken together, the mixed extract treatment delays the onset of the arthritis and alleviates the manifestations of arthritis in animal model and human body.

# LONG-TERM SIDE-EFFECTS OF GAMMA-IRRADIATION DISINFESTATION ON SOME PROPERTIES OF ARCHIVES

**Petya Kovacheva[1], Neli Boshnakova[2]**

1 University of Sofia, Sofia, Bulgaria
2 BULGAMMA, Sopharma JSC, Sofia, Bulgaria

Gamma-disinfestation is among the most efficient methods for preservation of biodeteriorated books and archive documents. The use of biocide effect of gamma-irradiation to stop biological aggressors has several advantages, as compared to the traditional chemical treatment, such as lack of toxic residues, higher effectiveness, reliability, applicability on large amount of objects etc. Although the recognized advantages of the gamma-irradiation processing for disinfestations of archives, this technique is not regularly well accepted and routinely used in many countries with industrial irradiators. The main hesitations of librarians, restorators and conservators are provoked by the possible degradation effects of the ionizing radiation on the paper, especially at doses, aimed to inactivate fungal and bacterial attacks. The long-term side effects of gamma-irradiation are of special interest in order to evaluate the long-lasting consequences on the properties of the archives. Therefore studies on the effects of ionizing radiation on some properties of librarian archive from Sofia University in Bulgaria were carried out. This paper presents the long-term side effects of gamma-irradiation of books and journals by focusing on the radical formation and thermal degradation 4.5 years after the gamma-irradiation. The paper samples, used in the present study were taken from six different issues, published in Germany, Russia and USA in the period from 1896 to 1962 years. Paper samples were individually packed in polypropylene bags. Each sample was gamma-irradiated with 10 kGy and 20 kGy absorbed doses, using radiation facility BULGAMMA based on JS-850 $^{60}Co$ type gamma irradiator of Sopharma JSC, Bulgaria. Analysis of non-irradiated and irradiated papers was performed by EPR, DSC and TG/DTG. Different effects were measured in the papers from the different publishers, due to differences in the material composition and production technologies.

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# HIGH PREVALENCE OF CHRONIC LYMPHOCYTIC LEUKEMIA AND B CELL LYMPHOMAS IN NUCLEAR WORKERS AFTER INCORPORATION OF ALPHA EMITTERS: CASE REPORT AND REVIEW OF THE LITERATURE

**Roland Wolff[1], Rainer Frentzel-Beyme[2], Inge Schmitz-Feuerhake[3]**

1 Expert for Radiation Protection and Medical Physics Roland Wolff (DGSV), Bremen, Germany
2 Department of Environmental Research and Technology, University of Bremen (retired), Bremen, Germany
3 Department of Physics, University of Bremen (retired), Bremen, Germany

Chronic lymphatic leukemia (CLL) was formerly considered to be a nonradiogenic form of cancer. Non-Hodgkin Lymphomas (NHL) were supposed to be very rare after radiation exposure. These historical estimations were based on early observations in the Japanese A-bomb survivors. In contrast to these, increasing rates of CLL and NHL were found in the last decades in nuclear workers and liquidators of Chernobyl, i.e. in cases of low dose chronic exposures. Estimating the dose response, the authors generally refer to the bone marrow as the corresponding target organ which often leads to surprisingly high risk figures for the radiation effect.

We recently noticed three cases suffering from illness of B lymphocyte proliferation (2 CLL and one lymphoma) who were involved in the decontamination of nuclear establishments, because Germany has decided to go out of nuclear energy, and the break up of the plants has begun to incur. The men worked in the same enterprise, were exposed to external doses of 44, 116 and 250 mSv, and had certainly inhaled alpha emitters as uranium and plutonium isotopes.

Radiation hematologists already stated in the 1980-ies that the bone marrow should not be considered as the relevant target for B cell lymphomas and CLL of B cell type, because the effect results in a proliferation of mature B lymphocytes which mainly occur outside the bone marrow. Therefore, the diseases may be induced in the whole pool of B lymphocytes including all peripheral locations also comprising lymph nodes and lymphatic organs. Our impression is that CLL and NHL are initiated predominantly at working places where the possibility of incorporation of radioactivity exists: in uranium mines, uranium and radium processing, nuclear facilities, and consequently in liquidators.

Several studies in animals and men have shown that incorporated radionuclides as uranium, thorium, and plutonium concentrate in the lymph nodes leading to higher radiation doses to the lymphocytes than are generated in other tissues. This effect is explained by the immunological reaction of macrophages functioning as scavengers of particles such as materials emitting alpha-radiation. These cells moving in the lymph vessels are stored in stationary lymph nodes.

If the target organ for dosimetry must be seen in all mature B-lymphocytes in the body, this will be valid for all kinds of external and internal exposures. Except in cases of homogeneous whole body exposure any dose estimation will be extremely unsafe or – as in our examples – in fact not be possible. These limitations must be considered in the radiation protection strategies for nuclear workers and for adequate evaluation in compensation cases.

# HERITABLE RADIATION EFFECTS IN MAN: NEGLECTED ASPECTS IN CASES OF CHRONIC EXPOSURE

**Inge Schmitz-Feuerhake[1], Sebastian Pflugbeil[2]**

1 Universität Bremen, Bremen, Germany
2 Gesellschaft für Strahlenschutz, Berlin, Germany

The International Commission on Radiological Protection (ICRP) and other international committees claim that heritable diseases after low dose exposures to ionizing radiation are virtually negligible. These organisations take into account only disorders due to dominant mutations in the first generation. They refer predominately to the Japanese atomic bomb survivors in whom significant heritable effects are missing.

The current risk estimates are therefore based on acute irradiation, e.g. the Atomic bomb explosions in Japan, which resulted in a “flash” exposure while the contribution of fallout is considered to be negligible. In such situations the most sensitive stages of the spermatogenesis and oogenesis will be affected only once per individual and not any more afterwards. This must be seen as the main difference against mutations, which lead to a cell proliferation with the endpoint of cancer, where the initial event is independent of the dose rate. The stemcells of the germ cells, which are also continuously present in the system, are well protected against external impairment. The sequels of chronic or fractionated exposures must be investigated separately in order to take into account the effects also in the short-lived stages of germ cell development.

We made a compilation of findings about early deaths, congenital malformations, Down’s syndrome and other effects, which were observed in humans after exposure of parents. Few of them are available from occupationally exposed collectives, whereas much information can be drawn from studies in populations exposed by Chernobyl fallout and from the descendants of liquidators, e.g. men who were deployed for decontamination tasks after the accident in 1986. Nearly all types of heritable defects were found, which are to be expected according to our general knowledge about. It can clearly be shown that the official risk estimates are much too low and that they should not be restricted to dominant mutations.

# EFFECT OF LOW-DOSE GAMMA-RADIATION ON LUMINOUS MARINE BACTERIA *PHOTOBACTERIUM PHOSPHOREUM*

**Alena Petrova[1], Dmitry Dementyev[2], Nadezhda Kudryasheva[2]**

1 Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia
2 Institute of Biophysics SB RAS, Krasnoyarsk, Russia

The growth of radioactive contamination of anthropogenic nature put researchers in the task of studying the effect of small and medium doses of radiation on organisms and searching for new methods of monitoring the state of the environment. Microorganisms play the fundamental role in the biosphere, and their physiological parameters are traditionally used to monitor environmental toxicity, including radiation toxicity. Marine luminous bacteria are an appropriate tool for such investigation, as they are highly sensitive to the presence of toxic compounds. The study addresses biological effects of low-dose gamma-radiation. Radioactive $^{137}$Cs-containing particles were used as model sources of gamma-radiation. Luminous marine bacterium *Photobacterium phosphoreum* was used as a bioassay with the bioluminescent intensity as the physiological parameter tested. To investigate the sensitivity of the bacteria to the low-dose gamma-radiation exposure (≤250 mGy), the irradiation conditions were varied as follows: bioluminescence intensity was measured at 5, 10, and 20°C for 175, 100, and 47 h, respectively, at different dose rates (up to 4100 mGy/h). There was no noticeable effect of gamma-radiation at 5 and 10°C, while the 20°C exposure revealed authentic bioluminescence inhibition. The 20°C results of gamma-radiation exposure were compared to those for low-dose alpha- and beta-radiation exposures studied previously under comparable experimental conditions. In contrast to ionizing radiation of alpha and beta types, gamma-emission did not initiate bacterial bioluminescence activation (adaptive response). As with alpha- and beta-radiation, gamma emission did not demonstrate monotonic dose-effect dependencies; the bioluminescence inhibition efficiency was found to be related to the exposure time, while no dose rate dependence was found. The sequence analysis of 16S ribosomal RNA gene did not reveal a mutagenic effect of low-dose gamma radiation. The exposure time that caused 50% bioluminescence inhibition was suggested as a test parameter for radiotoxicity evaluation under conditions of chronic low-dose gamma irradiation.

# CONSEQUENCES OF THE COMBINED ACTION OF IMMOBILIZATION STRESS AND THE ELECTROMAGNETIC FIELD OF THE INDUSTRIAL FREQUENCY ON THE BLOOD AND REPRODUCTIVE SYSTEM OF MALE RATS

**Grigory Goroch, Kazlou Aliaksandr, Marharyta Bakshayeva, Novikov Roman, Natalya Chueshova, Shubianok Alena**

Institute of Radiobiology of National Academy of Sciences of Belarus, Gomel, Belarus

The combined effect of immobilization stress (IS) and the electromagnetic field of the industrial frequency (EMF IF) on the blood and reproductive system in rats was studied. Animals were divided into control, EMF IF, IS groups and group of combined effects (CE). The rats belonging to the EMF IF and group CE were exposed to EMF IF (50 Hz, magnetic induction 0.4 mT) by 4 h/day for 4 days, at the same time the rats belonging to the IS and group CE were subjected to IS by 4 h/day for 4 days. The white blood cells, spermatogenesis, mature spermatozoa and their characteristics, as well as glutathione, activity glutathione peroxidase and the concentration of nitrates, nitrites and corticosterone in serum were studied. In the blood serum of animals of the EMF IF group, the levels of corticosterone and the total amount of nitrates and nitrites were decreased, while in the IS and CE groups glutathione decreased and the activity of glutathione peroxidase increased. In rats exposed IS showed a decrease in leukocytes and in particular lymphocytes, monocytes and granulocytes. In the group CE observed a similar pattern. In the same groups (IS and CE) there was a violation of spermatogenesis.

# THE IMPACT OF X-RAY IRRADIATION ON THE SPROUTING OF POTATO TUBERS

**Ulyana Bliznyuk, Vanentina Avduhina, Polina Borschegovskaya, Elena Kondratieva, Felix Studenikin, Alexander Chernyaev**

Moscow State University named after M.V. Lomonosov, Moscow, Russia

The study was carried out to observe the effect of low doses of x-ray irradiation on potato tuber sprouting for various duration of storage. All manipulations were performed on Russian grown potatoes which were harvested on 20 August 2016. Potato tubers were irradiated after 2, 3, 4 and 5 months after being harvested. The tubers were irradiated using molybdenum anode tube BSV-23 (20 mA, 50 kV). All treatments were conducted at 13-15 C. The program code GEANT 4 was used to estimate the absorbed dose in tubers. It was determined that the absorbed dose intensity in each tuber weighing 120 g was 0.01 Gy per second. The dose varied from 2.4 Gy to 30 Gy. To control the quality of irradiated tubers the concentration of reduced sugars was measured using dinitrosalycylic acid method. It was found that a complete inhibition of sprouting in tubers irradiated after 2 months of storage occurred at 15 Gy. Tubers irradiated after 3-4 months of storage required 20-25 Gy, while a complete inhibition of sprouting in tubers after 5 months of storage was at 30 Gy. Sugar concentration in non-irradiated tubers did not change until December 2016. Further a rapid increase in sugar content was observed in January 2017, which caused an active sprouting of tubers. In March the concentration dropped to the initial level. The sugar concentration in irradiated tubers increased insignificantly after 1-2 months after irradiation. However, by March 2017 the sugar content in each irradiated tuber stabilized.

# DIELECTROPHORETIC STUDY OF RADIATION PROTECTION ABILITY OF NANODIAMONDS

**Natalya Kizilova[1], Liliya Batyuk[2]**

1 Warsaw University of Technology, Warsaw, Poland
2 Kharkiv National Medical University, Kharkiv, Ukraine

Recently nanodiamonds (ND) were found useful in regenerative medicine, cancer treatment, activation of the intracellular activity and other medical applications. This paper is dedicated to experimental study of influence of ultradispersed ND on red blood cell (RBC) damage in rats exposed to X-ray radiation. The experimental group of 20 rats received 1.0 ml of a diluted suspension of ND once per day with food during 5 days prior to the radiation treatment. The suspension has C=0.01 % of dry weight of ND in saline. The control group of 20 rats has not received ND with food. Therefore, four groups of 10 rats have been studied: with both ND and X-ray (I); with ND without X-ray (II); without ND with X-ray (III); with neither ND nor X-ray (IV). In that way, 20 rats from the groups I and III were treated by X-ray with a dose of 5.8 Gy. Blood samples were collected in 30 days after the irradiation.

The RBC were washed out from blood plasma with saline and then diluted to the standard concentration 35%. The dielectric properties of the RBC have been studied by microwave-dielectrometry at the frequency f=9.2 GHz. This frequency corresponds to the gamma-dispersion range which is determined by mobility of water molecules. Molecules of free water have higher rotational mobility while the water molecules bound by the RBC membranes are bound and form hydration shell over the membrane. The RBC suspension has been placed in a capillary (d=0.4 mm) and located in the resonator of the dielectrometer at a fixed temperature. The real and imaginary parts of the dielectric permittivity of the suspension have been measured. The first value corresponds to physical dielectric permittivity determined by the thickness of the hydration shell and dielectric permittivity of the membrane. The second value is the loss factor, a measure of the dissipative loss associated with the polarizable charges moving in the electric field. The temperatures ranged from T=0 to 50C (T=54C is denaturation temperature for the RBC proteins).

It was shown, X-ray radiation leads to an increase in the static permittivity and decrease in the frequency of the dielectric relaxation of the RBC suspension by 37% with respect to those in intact rats. ND plays a protective role by decreasing the level of dehydration of the RBC membranes produced by X-rays relative to control. Similar changes in the dielectric properties of RBC of patients with different types of cancer before and after treatment have been detected in our previous study. Dielectric properties of suspensions of ND have also been studied at the same frequency. The results indicate that ND can decrease the pathological RBC dehydratation produced by in vivo X-ray radiation.

# INFLUENCE OF MICROWAVE IRRADIATION ON PROTEOMIC PROFILE OF AN ADDER

**Kristina Gopcevic[1], Dragomir Stanisavljev[2], Amela Hozic[3], Mario Cindric[3]**

1 Faculty of Medicine, Belgrade, Serbia
2 Faculty of Physical Chemistry, Belgrade, Serbia
3 Institute Rudjer Boskovic, Zagreb, Croatia

*Vipera ammodytes* the long-nosed viper (also known as the Western sand viper, horned viper, nose-horned viper, or rhinoceros viper), is largely confined to the Balkans. The subspecies *V. ammodytes ammodytes* (*Vaa*) is the most common viper snake in the Balkans. *Vaa* snake venom proteome comprises more than 100 different proteins that can be grouped into nine protein families.

The purpose of this study was to analyze *Vaa* proteome and changes caused by microwaves irradiation. Venom of *Vaa* (Institute of Virology and Immunology, Torlak, Belgrade, Serbia) in concentration 1 mg/mL dissolved in phosphate buffer 0.05 M, pH 7.40 was used in experiments Microwaves irradiation was performed using CEM focused microwave (MW) reactor Discover. All samples (V=10 ml) are irradiated with the output MW power of P=110 W. After the Trypsin digestion, peptides were analyzed on nano-UPLC-ESI-qTOF. Data were recorded in TIC (Total Ion Current) mode, and chromatograms were obtained in MSe mode. Spectra were recorded on lower followed higher collision energy. Sensitivity was $1 \times 10^8$.

By comparing tryptic peptides of *Vaa* with data in Serpentes protein data base (www.Expasy.org, UniProt.KB) it was revealed 56 proteins in control sample homologous to four classes of enzymatic proteins: L-aminoacid oxidases (LAAOs-14, metalloproteinases (MP)-2, Phospholipases A2 (PLA2)-5 and Serine Proteases (SPs)-16 members, and four classes of nonenzymatic proteins: Cysteine Rich Secretory Proteins (CRISPs)-8, C-Type Lectins (SNACLECs)-9, Serine Proteases Inhibitors (SPIs)-2 and Vascular Endothelial Growth factors (VEGF)-1 member. Additionally, it was identified 1 protein of Unknown function (UF). In irradiated sample it has been revealed 74 enzymatic proteins: LAAOs-15, MPs-16, PLA2s-3 and SPs-14 members, and nonenzymatic: CRISPs-9, SNACLECs-9, SPIs-2, VEGFs-5 and UF-1.

LAAOs in control sample are homologous to proteins belonging to two families and 12 snake genus. Only LAAO AC PODI84 is from *Vaa* proteome. Proteome of *Vaa* contains 5 MPs, belonging to two snake families and 3 snake genus. Only one PLA2 was detected. SP are most abundant in *Vaa* proteome, represented by 16 members. The following was identified: 8 CRISPs, 9 SNACLECs, two SPIs, both from *Viperidae* family. Only 1 member of VEGFs was identified, vammin, from *Vaa* proteome.

Irradiated sample contained 15 LAAOs, 16 MPs, 3 PLA2s and 14 SPs. Among nonenzymatic compounds, the following were identified: CRISPs-9; SNACLECs-9; SPIs-2; VEGF-1 and UF-a member.

Microwave irradiation caused qualitative and quantitative changes in *Vaa* proteome.

# EFFECTS OF MICROWAVE IRRADIATION ON PROTEOLYTIC AND CYTOTOXIC ACTIVITY OF AN ADDER

**Kristina Gopcevic[1], Dragomir Stanisavljev[2], Lidija Izrael-Zivkovic[1], Ana Medic[1], Aleksandra Isakovic[1]**

1 Faculty of Medicine, Belgrade, Serbia
2 Faculty of Physical Chemistry, Belgrade, Serbia

Snake venoms contain a large number of biologically active proteins and peptides with wide range of biological activities. Key enzymes in venoms are serine-proteases, hemorrhagins, fibrinolytic activators, metalloproteases and group II PLA2 isoenzymes. There is different approach in treatment of snake bite injuries including local application of high-voltage low-amperage direct electric current reported by different authors. The aim of the present paper was to investigate the effect of microwaves irradiation on Vipera ammodytes ammodytes (adder) (Vaa) snake venom proteolytic and cytotoxic activity.

range from 250 to 320 nm. Proteolytic activity was determined as a general (GPA) or metalloproteases activity (MPA). Electrophoretic profile of proteins in Vaa venom was analyzed by native, sodium-dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) and reverse electrophoretic zymography. Cell cultures of mouse melanoma B16 cell line and rat glioma C6 were maintained at 370C in a humidified atmosphere with 5% $CO_2$. Cells were rested for 24 hours and then treated with snake venom solution in appropriate serial dilutions. Cell viability was measured by using phosphatase assay. The results were presented as percent of the control value (untreated cells) which was arbitrarily set at 100 %.λVenom of Vaa (Institute of Virology and Immunology, Torlak, Belgrade, Serbia) in concentration 1 mg/mL dissolved in phosphate buffer 0.05 M, pH 7.40 was used in experiments. Microwaves irradiation was performed using CEM focused microwave (MW) reactor Discover. All samples (V=6 ml) are irradiated with the output MW power of P=110 W. UV spectra were recorded in

GPA of irradiated venom increases, while metaloproteases activity decreases. Native PAGE electrophoregram of control sample contains 11 fractions of proteins with different molecular masses and different electrophoretic mobility. Protein profile of MW treated venom on SDS PAGE electrophoregram shows different composition of venom in molecular masses. Zymogram of control shows presence of several enzymes with metalloproteases activity while they are absent in MW treated snake venom. $IC_{50}$ values of control sample were 1.41 and 12.5 µg/L, for mouse melanoma B16 cell line and rat glioma C6 cell line, respectively. After microwaves irradiation are obtained next $IC_{50}$ values: 38.5 and 42.8 µg/L for B16 and C6 cell lines, respectively.

Microwave irradiation causes changes in proteolytic activity and electrophoretic profile of venom and could be efficient in treatment of cytotoxic activity of snake venom.

# PROTON IRRADIATION EFFECTS ON SINGLE-PHOTON AVALANCHE DIODES

**Francesco Di Capua[1], Marcello Campajola[1], Ettore Sarnelli[2], Ciro Nappi[2], Daniela Fiore[3]**

1 Università Federico II and INFN, Napoli, Italy
2 CNR SPIN, Napoli, Italy
3 Università della Calabria, Cosenza, Italy

Single Photon Avalanche Diodes (SPAD) sensors are of particular interest for future high-energy experiments for their excellent timing resolution reaching few tens of picoseconds and an internal gain of the order of $10^6$. Starting from 2003, SPAD-based pixel arrays have been fabricated in CMOS technology. This technology has allowed the additional circuitry, which is necessary for SPAD quenching, data storage and signal processing, to be integrated adjacent to the pixel. Nowadays, small-area CMOS SPADs can be fabricated in deep-submicron processes to create dense high resolution arrays. In spite of all their advantages, CMOS SPADs suffer from high level of spurious pulses whose mean frequency is indicated as Dark Count Rate (DCR). The high doping levels in CMOS fabrication steps increase the intrinsic DCR level. This is due to the presence of trap centres both in silicon and oxides, which trigger Shockley-Read-Hall generation-recombination and trap assisted tunnelling mechanism.

In the present work, we investigate the functionality of SPADs in presence of radiation. We measured the behaviour of different SPAD layouts, designed and implemented in a CMOS 150 nm process, before and after proton irradiation. Chip samples containing several SPAD arrays with different dimensions and layouts have been irradiated at different fluences and energies: 21 MeV proton beam from Tandem accelerator, 60 MeV protons from cyclotron. Both tests have been performed at Laboratori Nazionali del Sud of Istituto Nazionale di Fisica Nucleare (Catania, Italy). We characterized the DCR as a function of the delivered proton fluence and provided the limits of operability of such devices in radiation environments, like in collider high-energy experiments or in space missions. At proton fluence of $6 \times 10^{10}$ p/cm$^2$, a significant increase in DCR of about one order of magnitude has been measured. In addition, by studying the DCR as function of temperature and bias voltage, we will derive information about principal mechanisms at the basis of such effects. For a large fraction of irradiated SPAD pixels (more than 50%), DCR discrete fluctuations between two or more values have been observed. This phenomenon, known as Random Telegraph Signal (RTS), has been investigated. The influence of the proton energy, fluence, operating temperature and bias on the RTS amplitude, time constants and occurrence probability is studied and discussed.

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# INFLUENCE OF RADIATION ON HEART RATE VARIABILITY (HRV) OF RATS AT DIFFERENT TERMS OF POST-RADIATION PERIOD

**Iryna Kovalchuk, Mechyslav Gzhegotskyi**

Lviv National Medical University, Lviv, Ukraine

In recent years, there is an increasing interest in evaluating possibilities of post-radiation myocardial adaptation, which until recently was considered one of the most radio-resistant organs. In this regard, it is promising to use the HRV analysis, which not only reflects the state of autonomous regulation of the cardiovascular system, but also allows to evaluate changes in different levels of oxygen dependent metabolism. The aim was to investigate HRV in different terms after exposure to radiation.

**Methods:** All experiments were performed in accordance with the current requirements for humane treatment of animals. The rats were irradiated at 2 Gy single fraction dose. The activity of various parts of the regulatory systems was evaluated based on spectral, statistical methods and variation pulsometry of HRV. We used photoplethysmogram transducer for 5-minute recording of peripheral pulse and assessing of HRV. HRV parameters were determined before irradiation (control) and after 1, 2, 3 and 5 days after irradiation.

**Results:** Statistically significant reduction of TP in 2 times compared to baseline was found 1 day after irradiation. The decrease of power in all spectrum ranges was recorded: LF and MF on 54% and 52%, respectively, HF – on 40%. This indicates a significant inhibition of the activity of all parts of regulatory systems. The reduction of the statistical parameters of HRV (SDNN, CV, RMSSD) is noted on average 20%, which characterizes the decrease of activity of the parasympathetic nervous system. Two days after irradiation, an even more pronounced decrease in the spectral and statistical parameters of HRV was established. Thus, the TP decreased on 82% in terms of control, and compared with the previous period of the post-radiation period on 66%. In this case, the sympathetic vagal index of MF/HF increased, the MF fraction increased in the internal structure of the spectrum, the AMO value increased in comparison with the control and with the 1$^{st}$ day, indicating the predominant effect of the sympathetic nervous system at the suppressing of total regulatory activity. After 3 days, there was an increase in the level of spectral and statistical indicators of HRV compared to the 2nd day, but their values remained lower compared with control and indicators of the 1st day. Thus, TP was twice as high as in the 2nd day, but lower than control and 1st day on 62% and 26%, respectively. Restoration of HRV indexes to control level was observed at the 5th day.

**Conclusions:** Thus, the reduction of the total effect of vegetative regulation by the rates of SDNN, RMSSD, CV correlates with the reducing of total activity of regulatory processes by the spectral rate of TP and indicates the tension of regulatory systems in a day after exposure to radiation at a dose of 2 Gy. These changes are exacerbated (worsening) on the 2nd day of the post-radiation period. Restoration of the activity of regulatory processes of all units began with the 3rd day and reached the level of control on the 5th day after exposure to radiation.

**Key words:** Radiation, heart rate variability, activity of regulatory systems, experimental animals.

# INCREASING OF ION FLUX IN CELLULAR MEMBRANE CHANNELS CAN BE INDUCED BY EXPOSURE TO ELECTROMAGNETIC FIELDS

**Emanuele Calabrò, Salvatore Magazù**

Department of Mathematical and Informatics Sciences, Physical Sciences and Earth Sciences, University of Messina, Messina, Italy

In this paper, we described the effects of applied electromagnetic fields (EMFs) on cellular membrane channels.

It was shown that proteins dipole moment increases with increasing of an applied high frequency electromagnetic field (HF-EMF) (*Bioelectromagnetics* 37:99-107), so that it was assumed that exposure to HF-EMFs causes the orientation of α-helices along the direction of the applied field (*Int. J. of Radiation Biology* 92(7):395-403, *Electromagnetic Biology and Medicine* 36(3):279-288). As cells membrane channels are formed by proteins, α-helix structure is present in all types of cells membranes channels (*J Mol Biol* 353:1011–10204-6, *Physiol Rev* 94:519–608, *Proc Natl Acad Sci USA*. 107:22546–22551). As a result, the rotation of α-helices towards the direction of an applied EMF should cause an enlargement in the diameter of cellular membrane channels, inducing an increase of ion transport across the channels, altering the equilibrium of cellular functions.

Indeed, cells ions channels are membrane proteins that possess several features of typical proteins (*J Mol Biol* 353:1011–10204-6, *Physiol Rev* 94:519–608, *Proc Natl Acad Sci USA*. 107:22546–22551) and can be opened by changes in cellular membrane potential, allowing quick ions movement (*Ion Channels of Excitable Membranes*. 3rd Ed. Sinauer Associates, Sunderland, Mass.). Furthermore, the differences in ions concentrations in the cytoplasm and in the exterior environment create an electrochemical gradient, leading to a large influx of positive and negative charges until the balance is reached (*Biochim. Biophys. Acta* 1565:267-286).

This delicate balance can be changed also by a low intensity EMF. Indeed, a decrease of the mitochondrial transmembrane potential under exposure to a static magnetic field at 2 mT was observed in neuronal-like cells, leading us to assume that an increasing of the flux of ions across the channels occurred after EMF exposure, changing cellular functions (*Bioelectromagnetics* 34: 618-629). This effect was also observed after exposure to a 50 Hz EMF, as both a decrease of transmembrane potential and a significant reduction of cell viability occurred after exposure (*Oxidative Medicine and Cellular Longevity* 2013. Article ID 414393). Hence, this phenomenon could be used to destroy damaged cells.

# DIAMAGNETIC EFFECTS IN A METHYLENE GROUP INDUCED BY LOW INTENSITY EXPOSURE TO A STATIC MAGNETIC FIELD

**Emanuele Calabrò, Salvatore Magazù**

Department of Mathematical and Informatics Sciences, Physical Sciences and Earth Sciences, University of Messina, Messina, Italy

We report the effects of 2 h exposure to a static magnetic field (SMF) at 100 mt of $CH_2$ group in gasoline fuel and polymers (polyethylene oxide), studied by means of Fourier Transform Infrared (FTIR) spectroscopy.

The asymmetric and symmetric vibrations of $CH_2$ at 2963 $cm^{-1}$ and 2922 $cm^{-1}$, respectively, did not change significantly after exposure, whilst both the bending vibration of $CH_2$ group at 1465 $cm^{-1}$ and the out of plane twisting of $CH_2$ group at 1230 $cm^{-1}$ decreased in intensity significantly after exposure.

We can explain the change in intensity of $CH_2$ vibrations, observed after exposure to SMF, using the classical theory of diamagnetism. Diamagnetism consists of a magnetic field created in diamagnetic materials which opposes to the applied magnetic field.

In fact, aliphatic hydrocarbons are diamagnetic substances with diamagnetic susceptibility, whose intensity increases with increasing of the number *n* of carbon atoms in the chain $C_nH_{2n+2}$ (Theory and Applications of Molecular Diamagnetism, Wiley-Interscience). Hence, a SMF applied to gasoline fuel should induce a magnetic field in the fuel which opposes to the applied field, inducing the alignment of $CH_2$ chains with their axes parallel to the field and opposing to it (*Spectroscopy Letters: An International Journal for Rapid Communication* 48(8):593-599, *Petroleum Science and Technology* 33:1676-1684).

This phenomenon was observed also in polymers, for instance in polyethylene oxide, in which an applied SMF induced the reorientation of the polyethylene $CH_2$ chains towards the direction of the field (*Polymer* 34 (16): 3347–3357, *Physica B* 346-347 (1-4): 255–261, *Adv. in Phys. Chem.* 2013, ID 485865).

The decrease in intensity of $CH_2$ vibrations observed after exposure to SMF can be explained assuming that $CH_2$chains begin their motion aligning with the applied field and opposing to it, causing that the angle bends become larger than in the absence of a magnetic field.

As a result, the dipole moment of $CH_2$ molecule reduced, causing that $CH_2$ vibrations decrease in intensity because the reorientation of the chains.

# ASPECTS OF IONIZING RADIATION EFFECTS ON PURINE METABOLISM IN SPLEEN LYMPHOCYTES UPON INJECTION OF INOSINE

**Tetiana Andriichuk[1], Nataliia Raksha[1], Sergii Vakal[2], Ludmyla Ostapchenko[1]**

1 ESC 'Institute of Biology and Medicine', Taras Shevchenko National University of Kyiv, Kyiv, Ukraine
2 The Affiliated Eye Hospital of WMU, Wenzhou Medical University, Wenzhou, China

**Introduction.** One of the key consequences of exposure to ionizing radiation (IR) is a suppression of immune system, as evidenced by induction of apoptosis of radiosensitive lymphoid cells. Thus, study of biochemical aspects of radiation-induced impairment of lymphocytes function could lead to better understanding of immune depression mechanisms and development of novel approaches to restore human immunity. Close association of purine metabolism with functional activity of immune competent cells is well established. Dysfunction of adenosine deaminase (AD), purine nucleoside phosphorylase (PNP) and xanthine oxidase (XO) leads to impairment of T- and B-cellular immunity. Moreover, depletion of adenine nucleotides following activation of purine catabolism is currently suggested to be a probable cause of apoptosis of lymphocytes.

**Goal.** To assess the activity of AD, PNP and XO in rat spleen lymphocytes after exposure to 1.0 Gy of IR upon injection of inosine.

**Methods.** The experiment was carried out with white adult male rats with average mass 150-170 g. IR was generated by X-ray apparatus RUM-17 (total dose of 1.0 Gy). Inosine was injected abdominally 15 min before IR-treatment. Rats treated with vehicle only were used as the control group. Animals were sacrificed 3 hrs after the exposure, and spleen lymphocytes were isolated in Ficoll-Paque density gradient. AD, PNP and XO activities were determined by standard assays. Statistical processing was performed with IBM SPSS 22.0; data expressed as M ± SD.

**Results.** A significant decrease of AD activity 3 hrs after exposure to IR has been established. Thus, adenosine accumulation took place under these conditions. It can lead to disturbance of dNTP pool, suppression of DNA synthesis and, as a consequence, to impairment of immune proliferative reactions. However, injection of inosine before irradiation prevented the radiaton-induced changes of AD activity. Our study revealed 1.3-fold increase of PNP activity in rat spleen cells after exposure to IR, suggesting the hypoxanthine accumulation. High levels of hypoxanthine, both directly and indirectly (through stimulation of prooxidant form of xanthine oxidase), cause deep changes of cellular metabolic state. Preliminary injection of IR-treated animals with inosine was associated with 32% lower activity of PNP. XO activity after IR-exposure were 1.2 times higher than the control, and 1.5 times higher after joint treatment with inosine and IR, which can be caused by increase of XO-substrates after injection of inosine. The observed effects of inosine could be explained by its modifying impact on cellular energetic metabolism that leads to alleviation of primary radiation processes intensity.

**Conclusions.** Thus, significant impairment of AD, PNP and XO activities in rat spleen lymphocytes after exposure to 1.0 Gy of IR has been established, whereas injection of inosine before IR-treatment has been shown to prevent most of the changes in purine metabolism.

# THE EVOLUTION OF THE PHYSICAL, CHEMICAL AND ELECTRICAL CHARACTERISTICS OF $SnO_2$/Si INTERFACE UNDER GAMMA IRRADIATION

**Senol Kaya, Saleh Abubakar, Ramazan Lok,**
**Huseyin Karacali, Aliekber Aktag, Ercan Yilmaz**

Abant Izzet Baysal University, Bolu, Turkey

A great interest exists to understanding radiation responses of the devices in harsh radiation environment for advances materials industry. Hence, we aim to study possible radiation influences on the promising $SnO_2$ gate dielectrics in details. The irradiations effects on the structural, morphological and electrical characteristics have been investigated incorporating the radiation degradation on the electrochemical characteristics of the $SnO_2$/Si stacked. The results demonstrate that the crystallinity of the dielectric layer and surface roughness slightly change with increasing the irradiation exposure. The variations on the oxidations states of $SnO_2$ demonstrate that radiation breaks the chemical bonds and creates possible new defect sites. In addition, passivation of the gate stack for some doses can be also observed during the radiation exposure. Slight changes on the capacitance and conductance characteristics has been observed after radiation exposure which is connected to variations in structural and the electrochemical characteristics of the thin films under radiation exposures.

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# INTERFACE AND OXIDE TRAPPED CHARGES AND GAMMA-RAY IRRADIATION EFFECTS ON Al/HfSiO$_4$/P-Si/Al MOS CAPACITORS

**Ramazan Lok, Senol Kaya, Aliekber Aktağ, Ercan Yılmaz**

Abant Izzet Baysal University, Bolu, Turkey

In this study, the electrical characteristics of the Al/HfSiO4/p-Si/Al MOS capacitors were determined by using C–V and G/ω–V measurements for several frequencies from 30 kHz to 2 MHz. The MOS capacitors were irradiated, the initial interface trap density ($N_{it}$) was evaluated from 2MHz frequency (HF) and 30 kHz frequency (LF) capacitance method and the $N_{it}$ was calculated as $10.78 \times 10^{11}$ $cm^{-2}$. The results show that $HfSiO_4$/p-Si interface quality is convenient for microelectronics applications. The Co-60 gamma irradiation responses of $HfSiO_4$ (MOS) capacitors were examined in various radiation doses. The 2 MHz C-V measurements of the samples were taken at each irradiation step and the radiation sensitivities of the devices were examined using flat band and midgap voltage shifts. Simple equivalent circuit model have been proposed for the MOS capacitor to determine interface and oxide the trapped charges. The radiation sensitivity of the $HfSiO_4$ MOS capacitors was found to be 4.41 mV/Gy for 300 nm-thick $HfSiO_4$ gate dielectric. Because Hafnium silicate is not sensitive to radiation as much as $SiO_2$, it will saturate at very high radiation doses. Hence it may have important usage in high radiation field areas.

**Key words:** $HfSiO_4$ MOS capacitors; irradiation hard materials, interface states, oxide trapped

**Acknowledgements:** This work is supported Ministry of Development of Turkey under the contract number 2016K121110.

# THE RADIATION RESPONSE AND ELECTRICAL CHARACTERIZATION OF NEODYMIUM OXIDE MOS CAPACITORS BY SOL/GEL DIP COATING TECHNIQUE

**Ramazan Lok, Erhan Budak, Saleh Abubakar, Ercan Yılmaz**

Abant Izzet Baysal University, Bolu, Turkey

The neodymium oxide MOS capacitors, which are produced by Sol–Gel Dip Coating Technique, have studied structural features. Fourier transforms infrared spectroscopy (FTIR) and energy-dispersive x-ray spectroscopy (EDX) measurements were taken to describe the structural properties. The electrical characteristics of the Al/$Nd_2O_3$/p-Si/Al MOS capacitors were determined by using C–V and G/ω–V measurements for several frequencies from 50 kHz to 1 MHz. The initial interface trap density (Nit) was evaluated from 1 MHz frequency (HF) and 50 kHz frequency (LF) capacitance method and the Nit was calculated order of $10^{11}$ $cm^{-2}$. The results show that $Nd_2O_3$/p-Si interface quality is convenient for microelectronics applications. The Co-60 gamma irradiation responses of $Nd_2O_3$ (MOS) capacitors were examined in various radiation doses. The 1 MHz C-V measurements of the samples were taken at each irradiation step and the radiation sensitivities of the devices were examined using flat band and mid-gap voltage shifts.

**Key words:** $Nd_2O_3$ MOS capacitors, interface states, oxide trapped, radiation response

**Acknowledgements:** This work is supported Ministry of Development of Turkey under the contract number 2016K121110.

# SUB-LETHAL UVA AND UVB RADIATION DURING EARLY LIFE STAGES ALTERS BEHAVIOUR AND HEART RATE IN THE ZEBRAFISH *(DANIO RERIO)*

**Selma Hurem[1,2], Thomas Fraser2, Julia Ortman[3], Ian Mayer[1], Terje Christensen4**

1 Centre for Environmental Radioactivity (CERAD CoE), Ås, Norway
2 Norwegian University of Life Sciences, Faculty of Veterinary Medicine and Biosciences, Oslo, Norway
3 Helmholtz centre for Environmental research, Department of Bioanalytical Ecotoxicology (UFZ), Leipzig, Germany
4 Centre for Environmental Radioactivity (CERAD CoE), Norwegian Radiation Protection Authority, Ås, Norway

Environmental UV radiation in sufficient doses is potent enough to affect living organisms. For fish that breed at a shallow water depth, the embryonic stage is the most susceptible to the biologically damaging effects of UV radiation.

The aim of this project was to evaluate the potential toxic effects of early life stage (4.5 – 5.5 hours post fertilization) exposure to sub-lethal and environmentally relevant doses of broadband UVA (Control, 9.3, 18.6 min, 37.2 J/cm$^2$) and UVB radiation (Control, 0.013, 0.026, 0.078 J/cm$^2$) on the development and behaviour in the zebrafish (*Danio rerio*).

The doses used caused no significant difference in survival, deformities, or hatching between the exposed groups and non-exposed controls. The heart rate was found to be significantly reduced at 60 hpf in all groups of UVB and UVA compared to controls, except for the lowest UVA dose.

Exposure to the two highest doses of UVA led to a significant reduction in the time spent active and the total distance moved compared to controls at 100 hpf, while no effect on the swimming speed was observed. The lowest dose of UVA dose had no effect on behaviour.

Exposure to the highest dose of UVB led to an increase in the time spent active and a slower average swimming speed although these effects were not significant. Neither of these tendencies was observed at lower UVB doses.

The obtained results indicate that UV doses below the LD50 levels are able to cause changes in behaviour and physiological parameters; however, further testing is necessary to assess how this type of radiation and the effects observed might be affecting fish populations.

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# ESTABLISHMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS FOR CT LOCALISATION PROCEDURES IN RADIATION THERAPY AT UNIVERSITY HOSPITAL RIJEKA

**Ana Diklić[1], Doris Šegota[1], Ingrid Belac-Lovasić[2], Slaven Jurković[1]**

1 Medical Physics Department, University Hospital Rijeka, Rijeka, Croatia
2 Clinic for Radiotherapy and Oncology, University Hospital Rijeka, Rijeka, Croatia

Computed tomography (CT) has become a standard tool in radiation therapy (RT) treatment planning. However, there is a growing awareness of the dose delivered to the part of the body outside the target volume. Ionizing radiation carries a stochastic risk of malignancy, therefore doses for any medical exposure should be kept as low as reasonably achievable in order to provide an adequate diagnostic information, in this case information needed for radiotherapy planning.

To quantify the doses from CT localization scans at University Hospital Rijeka, local DRL (Diagnostic Reference Level) values were established for five most common procedures of different anatomical regions; head, head and neck, pelvis, breast and thorax. An retrospective analysis was performed on Siemens Sensation Open, a 16-slice CT simulator installed at the radiotherapy department. The scanner is used only for radiotherapy planning. Data was collected using a dose tracking software, Care Analytics. CTDIvol (Computed Tomography Dose Index volumetric) and DLP (Dose Length Product) were used as dose indicators and scanning parameters were also recorded. Since the aim of this study was to start the optimization process, image quality assessment was performed for each set of images. For each body region, two oncologists were asked to score the image quality using a four level scale; 1 = not acceptable for contouring, 2 = acceptable for contouring, but requires improvement, 3 = fully acceptable for contouring and 4 = image quality more than needed for contouring. The median scan length, DLP and CTDIvol and average image quality score were found for each acquisition protocol.

National DRLs for radiotherapy planning CT scans do not exist at this moment. Results were compared to the rarely published data in order to compare clinical practice. Image quality for almost all of the body regions are scored in average as acceptable, but require improvement. This clearly indicates that scanning and reconstruction parameters need to be revised in order to achieve optimal image quality.

The results of this survey were used to set up local DRL values in radiotherapy at University Hospital Rijeka. Also, it is shown that the optimization of RT protocols is required therefore these results will be used as a guideline for that process. The establishment of the national DRLs for CT localization procedures in radiation therapy in Croatia is the next step and is currently an ongoing process.

# *In vivo* verification of entrance dose for head and neck treatments

**Dragan Ćirić[1], Dragoslav Otašević[1], Bojan Radojičić[1], Dejan Jovanović[1], Gordan Nišević[2]**

1 Military Medical Academy, Belgrade, Serbia
2 Orthoaid, Belgrade, Serbia

3DCFRT is a classic method of Head&Neck radiotherapy planning. With ours TPS as well as MLC system we are achieving full coverage of planning tumor volume where minimum of dose is at 95% and maximum is at 107%, by adequate protection Organs at Risk. Slanting fields make ours plan better and make more safe Organs at Risk. In radiation treatments skin dose is one of the main issues. With in vivo detectors we are checking prescribed, according to an internal protocol, dose by TPS. The 3G patient detectors are based on the high doped p-type silicon diode chip, specifically designed for radiation therapy applications. No bias voltage is used, and the diode works in photovoltaic mode. Two type of detectors are used, EDP-10$^{3G}$ (Approximately 10mm water equivalent build-up, green) and EDP-20$^{3G}$ (Approximately 20mm water equivalent build-up, yellow). The credibility of these detectors was confirmed by comparison wit Farmer NE2571 ionization chamber. Three energies of our linac are used so detectors for in vivo dosimetry are calibrated to detect and measure dose for 4MV, 10MV and 18MV.

# EXPERIENCE OF UKRAINE IN EDUCATION AND REFRESHER TRAINING OF MEDICAL PHYSICISTS AS QUALITY ASSURANCE OF MEDICAL IRRADIATION SERVICES

**Liudmyla Aslamova, Ielyzaveta Kulich, Nadiia Melenevska**

Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

Medical physicist and doctor together are responsible for quality assurance of medical serving. It is increasingly recognized that national education system interconnected with formal certification schemes for the recognition of the expertise and competence is an important contribution to ensuring the professionalism of individual practitioners in medical physics. Such a certification scheme could either be directly under the control of the regulatory body, or operated by a non-governmental not-for-profit organization. For example, it can be an associate society, under an approval from the regulatory body, or its activity is regulated by appropriate national legislation.

Development of certification scheme becomes topical in Ukraine because of:

• high technologies are used and implemented. There are 24 linear accelerators and 2 PET centers. However, if population is more then 42 million people, country needs 84 linear accelerators in correspondence with international standards. First and foremost, quality assurance is performed by certified personal;

• Ukraine selected one of ten principles of "Further generations protection", namely not to accumulate radioactive waste. In particular, equipment with radionuclides should be replaced by the one with generating ionizing radiation sources;

• today, the definition of "medical physicist" is absent in Ukrainian legislation base as well as his/her duties and functions. However, a certain part of medical personal is performing medical physicist's functions in part;

• national system regulated for registration and tracing of patient's exposure dose is absent.

International standards stated in the International Atomic Energy Agency Basic Safety Standards are progressively implemented in Ukraine. In particular, the Radiation Protection Officer and the Qualified Expert (radiation protection expert) are defined in the document; also, recommendations for their functions, duties and responsibility area are given.

Successful experience of cooperation with Swedish regulatory authority in the frames of project "Quality Assurance and Quality Control in medical radiology in Ukraine" was used for education and training of medical physicists.

Faculty of Radio Physics, Electronics and Computer Systems of Taras Shevchenko National University of Kyiv is educating magisters on specialties "medical physics", "biomedical physics, engineering and informatics".

Moreover, Training and Research Center for Radiation Safety of the university successfully carries out refresher courses and examination on "Radiation safety in performing selected types activity in area with using nuclear energy" more then 14 years. The center has certificate ISO 9001:2008 of International standards for quality management. Base on long years experience, the university together with Ukrainian Association of Medical Physicists and Engineers looking for a possibility to introduce certification scheme for radiation protection and medical physics experts.

# INTRODUCING COMPUTED TOMOGRAPHY LOW DOSE PROTOCOL FOR SINUSES AT UNIVERSITY HOSPITAL RIJEKA

**Doris Šegota, Ana Diklić, Petra Valković Zujić, Goran Banušić, Slaven Jurković**

University Hospital Rijeka, Rijeka, Croatia

Computed tomography (CT) is considered to be a high dose radiological procedure. The speed and ease of performing this imaging procedure has resulted in over-stretching the use of this modality. According to published data, CT contributes most of the collective effective dose from diagnostic X-ray examinations in the world. A lot of effort has been made to create a „so called" low dose protocols in order to individually adapt the dose to the clinical indication.

CT of paranasal sinuses is frequently performed at University Hospital Rijeka. Thin axial CT images have become an essential aid in the treatment of sinus disease as a mandatory preoperative diagnostic tool used for the navigation during the functional endoscopic sinus surgeries (FESS). The population undergoing this exam is usually relatively young and requires follow-up exam. Special attention must be paid to the eye lens and thyroid gland because these radiosensitive organs are exposed to direct or scattered radiation. Therefore, we decided to implement a low dose protocol in our clinical practice dedicated to the given indication.

Up to the time of this research a standard protocol for sinuses (120 ref. kV, 50 ref. mAs, kV and tube current modulation turned on) was used regardless of the indication. Low dose protocols for paranasal sinuses have already been published with different dose reduction strategies. In order to decide on the protocol to be used, several measurements were made. For the initial evaluation of the image quality anthropomorphic phantom was used. It was scanned with our standard protocol and four other scanning protocols with dose reduction on the 256-slice Siemens Definition Flash. Dose indicator values CTDIvol and DLP were recorded. These images were evaluated by two independent radiologists. Average image quality score was assigned to every protocol. Signal to Noise Ratio (SNR) was measured in three different regions of interest (ROI): maxillary sinus, zygomatic bone and bulbus oculi. Catphan image quality phantom was scanned with the same five protocols to obtain the technical quality of the images. Following the phantom evaluation, clinical trial was performed and clinical images were evaluated using the same image quality score scale.

After the overall evaluation, the standard helical protocol was replaced with a low dose protocol (80 kV, 40 mAs, kV and tube current modulation turned off, axial mode). It resulted with a reduction of CTDIvol from 5.4 mGy to 2.2 mGy. SNR and image quality were consequently decreased but to an acceptable level for the given indication. Regarding the localization of structures used for FESS, a new low dose protocol indicates sufficient accuracy at a lower dosage level.

# IMPACT OF EXTENDED CT DENSITY RANGE ON ECLIPSE ACUROS XB

**Silvia Vargas Castrillon, Francisco Cutanda Henriquez**

Edinburgh Cancer Centre, Edinburgh, United Kingdom

**Introduction.** Philips Brilliance Big Bore CT offers the options of 12 bit-depth (4096 HU range) or a 16 bit-depth (65536 HU range) configuration, the implementation of the latter leads to an extended CT density range. When using 12 bit-depth, HU saturate at 3071 in Varian Eclipse radiotherapy treatment planning system whereas for the 16 bit-depth configuration HU saturate at a such high value that all clinically relevant materials would be included.

Varian Eclipse Acuros XB algorithm was designed to more accurately take into account heterogeneities in radiotherapy treatment planning. It solves the linear Boltzmann transport equation what allows to consider the effects of different heterogeneities in patient dose calculations. Hence, obtaining an accurate representation of any material in a patient is especially important for this algorithm; otherwise it will not be used to its full capability and optimal accuracy will not be obtained. The clinical impact of using a 12 bit-depth versus a 16 bit-depth configuration has been assessed.

**Methods.** A standard Sun Nuclear RMI phantom plus three metal inserts, aluminum, titanium and stainless steel were used for this study; water like density material was added in order to ensure full scatter conditions. The phantom was scanned using different standard clinical protocols for both, 12 bit-depth and 16 bit-depth configurations, OMAR correction was applied for all CT scans. All CT acquisitions were then imported to Eclipse and HU were checked for all acquisitions and inserts.

Different plans for a Varian TrueBeam linac, all including the metal inserts, were studied: a single field with different field sizes ranging from 3x3 to 15x15 $cm^2$ and two opposed fields ranging from 5x5 to 15x15 $cm^2$, with gantry angles were chosen to ensure that the inserts were encompassed by the beams. Two more plans were considered, one single conformal arc and two conformal arcs, field sizes from 2x2 to 15x15 $cm^2$. All setups were isocentric with the same dose prescribed to the isocentre and beam qualities were 6MV, 6FFF, 10MV, 10FFF and 15MV.

**Results and discussion.** All plans were calculated and Monitor Units (MU) obtained using Acuros XB algorithm (v 13.6) for both, 12 bit-depth and 16 bit-depth scans. The difference in MU between 12 bit and 16 bit images was not significant for any of the plans. However, isodose maps differ from one configuration to another in regions behind the titanium and stainless steel metal inserts, with a shift of isodoses that may have clinical consequences (for organs at risk and PTV coverage). This effect is expected to be more relevant for hip prostesis since their volume is larger than the inserts'. Therefore, the use of a CT extended range is recommended.

# PARAMETRIC STOCHASTIC MODEL OF BONE STRUCTURES TO BE USED IN COMPUTATIONAL DOSIMETRIC PHANTOMS OF HUMAN SKELETON

**Elena Shishkina[1,3], Vladimir Zalyapin[2], Yurii Timofeev[1], Marina Degteva[1], Bruce Napier[4]**

1 Urals Research Center for Radiation Medicine, URCRM, Chelyabinsk, Russia
2 South Ural State University, Chelyabinsk, Russia
3 Chelyabinsk State University, ChelSU, Chelyabinsk, Russia
4 Pacific Northwest National Laboratory, Richland, W, United States

Estimation of dose factors for active marrow exposed to bone-seeking beta-emitters, such as $^{89}$Sr and $^{90}$Sr/$^{90}$Y (0 – 1.5 MeV and 0 – 2.4 MeV, respectively), is an important task of bone dosimetry. Monte Carlo simulations of electron – photon transport to calculate the active marrow doses are based on the geometrical modeling of bone structures. The model geometry should consist of accurate descriptions of spongiosa fine structure and cortical bone thickness (because of the high probability of low energy electron emission) as well as descriptions of bone macro-dimensions (because the maximum electron path length in spongiosa is about 5-9 mm). New computer tomography (CT) -based methods are widely applied to develop computational dosimetric phantoms. The advantage of the CT-based method is in high realism of the description of complex bone shape as well as in the possibility of an adequate description of bone microstructure with µCT. However, the method has a number of disadvantages, viz.: (1) the method is laborious and expensive; (2) the use of cadavers is associated with organizational difficulties; (3) one cadaver –based model can be non-representative and does not allow estimation of the uncertainties associated with individual variability of human anatomy; (4) cortical bone thickness is fixed based on the CT, for which resolution is worse than the measured; (5) in practice, the limitation in voxel resolution of the computational phantom often results in narrowing down the strong points given by µCT because of inadequate representation of the microstructure. Moreover, high individual variability of bone shapes and macro-dimensions negates the advantages of the above-mentioned high realism. The aim of the presented study is to elaborate the algorithm of parametric bone modeling, which allows generation of phantoms of hematopoietic bone segments based on known micro- and macro dimensions. We propose an approach that permits easy subdivision of bones into small segments, which may be described by simple-shape geometric figures with appropriate voxel resolution. Spongiosa structure (presented by a stochastic rod-like model and calibrated by literature-derived bone volume-to-total volume ratio) is covered by homogenous cortical layer. All parameters of the proposed cadaver-free model can be obtained from literature on morphometry and hystomorphometry. Moreover, the parametric modeling allows simulation of individual variability of bone-specific dimensions.

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# SEGMENTATION OF HEMATOPOIETIC SITES OF HUMAN SKELETON FOR CALCULATIONS OF DOSE TO ACTIVE MARROW EXPOSED TO BONE-SEEKING RADIONUCLIDES

**Pavel Sharagin[1], Elena Shishkina[1], Evgenia Tolstykh[1], Aleksandra Volchkova[1], Michael Smith[2], Marina Degteva[1]**

1 URCRM, Chelyabinsk, Russia
2 PNNL, Richland, United States

The Techa River (Urals, Russia) was heavily contaminated due to the release of radionuclides from the Mayak Production Association from 1949 to 1956 that was the result of insufficient controls in place during the early years of operation at the USSR's first plutonium production facility. The radioactive releases included bone-seeking beta-emitters such as $^{90}Sr$ and $^{89}Sr$ that contribute to doses to bone marrow. Moreover, $^{90}Sr$ is a long-lived isotope, the uptake of which leads to chronic bone marrow exposure known to result in an increased risk of leukemias. Ongoing epidemiological studies of the long-term effects of chronic radiation exposure are being performed for the Techa River Cohort members. Radiation dosimetry is a part of this study, of which, the internal dose estimates for active bone marrow exposed to beta emission of Sr isotopes incorporated in calcified tissue is an important component. Internal dose calculations, which are based on electron-photon transport simulations, require geometrical descriptions of bone shapes and bone microstructures of the main hematopoietic sites of the human skeleton (ribs, vertebrae, pelvic bones, femur, humerus, bones of the skull, sternum, clavicle and scapula). For this purpose, the parametric approach for modeling bone geometry was elaborated. The proposed approach is to segment and define each of the bone sites as simple geometric shapes for which parameters can be derived.

The aim of the paper is to present the principles of bone segmentation. As an example, the segmentation of a lumbar vertebra, which is characterized by a complex geometric shape, is shown. The segments of the vertebra are represented as simple shapes such as elliptic cylinders and boxes. Dose factors that convert the activity concentration of bone-seeking radionuclides into a corresponding bone marrow dose rate were calculated for each segment. The calculations were done with MCNP 6.1. A comparison of dose factors calculated for different segments demonstrates the influence of bone geometry on the results.

**Acknowledgments:** This work was funded by the Russian Health Studies Program of US DOE and by FMBA of Russia.

# GEOMETRIC MODEL OF HEMATOPOIETIC SITES OF HUMAN SKELETON TO BE USED IN BONE DOSIMETRY: PARAMETER ESTIMATION

**Darya Parshkova[1], Elena Shishkina[1,2], Evgenia Tolstykh[2], Alexandra Volchkova[2], Pavel Sharagin[2], Michael Smith3, Marina Degteva[2]**

1 Chelyabinsk State University, CelSU, Chelyabinsk, Russia
2 Urals Research Center for Radiation Medicine, URCRM, Chelyabinsk, Russia
3 Pacific Northwest National Laboratory, PNNL, Richland, Washington, United States

The Techa River (Urals, Russia) was contaminated due to liquid radioactive waste releases in 1949-1954. Radioactive releases included long-lived bone-seeking 90Sr. That is why epidemiological studies of the riverside population (about 30,000 people) pay special attention to the effects of radiation exposure of active marrow. Bone dosimetry is an important component of the Techa River studies as it allows for the estimation of active bone marrow doses due to beta-emitting strontium isotopes accumulated in the bone structures, viz., trabeculae and cortical bone layer. This task was accomplished using geometric modeling of hematopoietic sites of the human skeleton. A new parametric method of bone modeling was developed in the Urals Research Center for Radiation Medicine (URCRM). The method is based on stylized phantoms with bone-specific linear dimensions and cortical thickness. Spongiosa microstructure is described by a stochastic rod-like model with bone-specific trabecular thickness and bone volume-to-total volume ratio. Model parameters are derived based on extensive literature available on morphometry and histomorphometry. Existing methods of bone modeling, based on CT image processing, make it possible to obtain true-to-life bone shapes. However, a limitation of these methods is the low number of scanned cadavers. An advantage of the proposed parametric approach is the possibility of elaborating a statistically representative model (based on a large number of measurements presented in literature) to estimate the influence of individual variability of bone dimensions (model parameters) on the dose calculation. The purpose of the present study is to describe a method of parameter estimation for the geometric modeling of hematopoietic sites of the human skeleton.

The paper includes a description of: (1) principles of data search, (2) criteria of data inclusion into analysis, and (3) method of data averaging. Examples of the application of the approach are shown for proximal femur and proximal humerus of an adult man. Mean and coefficient variations of model parameters are shown as well as the obtained mean dose factors (converting 90Sr activity concentration in bone tissue into active marrow dose rate) and corresponding coefficients of variations.

**Acknowledgments:** This work was funded by the Russian Health Studies Program of US DOE and by FMBA of Russia.

# MONTE CARLO MCNP CODE IN BORON NEUTRON CAPTURE THERAPY FOR SEVERAL ORGANS OF THE ORNL VOXEL PHANTOM

**Dragana Krstic[1], Dragoslav Nikezic[1], Marija Jeremic[2], Milovan Matovic[2]**

1 University of Kragujevac, Faculty of Science, Kragujevac, Serbia
2 Clinical Centre, Kragujevac, Kragujevac, Serbia

BNCT – Boron Neutron Capture Therapy is a special kind of radiation therapy where each cell of tumour is target. The stable B-10 isotope has large affinity to bind to tumour tissue. After an intravenous stable boron application, it is necessary to apply flux of thermal neutrons, which, in interaction with B-10, create alpha particles and Li-7 ions. The resulting products have a range similar to cell-size and effectively kill tumor tissue, without causing harmful effects to healthy tissue. Therefore, this type of therapy has a significant advantage over other therapies. The real problem is the requirement for a small nuclear reactor near the hospital and in the construction of a column for the direction of the neutron beam. In recent times, linear accelerators of very high energies, usually about 18 MeV, are used, to obtain neutrons after in interaction of with heavy target.

BNCT therapy can be applied in the treatment of malignant diseases involving various organs such as: liver, lung, brain, pancreas, and others, especially with metastases.

In this study Monte Carlo MCNP software is used for calculation of neutron absorbed dose in various organs human body of computational ORNL (Oak Ridge National Laboratory) voxel phantom (http://ordose.ornl.gov/resources/Mird.pdf) for BNCT therapy. Theoretical results have shown that BNCT therapy is suitable for use in metastasis or cancer of whole organ or tissue in the human body.

# IN-BEAM PET MONITORING TECHNIQUE FOR PROTON THERAPY: EXPERIMENTAL DATA AND MONTE CARLO PREDICTION

**Albana Topi[1,3], Silvia Muraro[2,3], Giuseppe Battistoni[3], Aafke Christine Kraan[2,3], Nicola Belcari[2,3], Maria Giuseppina Bisogni[2,3], Niccolò Camarlinghi[2,3], Luca Cristoforetti[4], Alberto Del Guerra[2,3], Alfredo Ferrari[5], Francesco Fracchiolla[4], Matteo Morrocchi[2,3], Roberto Righetto[4], Paola Sala[3], Marco Schwarz[6], Giancarlo Sportelli[2,3], Diego Barbosa[2,3], Valeria Rosso[2,3]**

1 Department of Physical Sciences, Earth and Environment, University of Siena, Pisa, Italy
2 Department of Physics, University of Pisa, Pisa, Italy
3 INFN, Milano, Italy
4 Proton Therapy Department, Trento Hospital, Trento, Italy
5 CERN, Geneva, Switzerland
6 Proton Therapy department, Trento Hospital and TIFPA INFN, Trento, Italy

Charged particle therapy is a precise radiotherapy method for treatment of solid tumors. This method can deliver conformal dose distributions minimizing damage to healthy tissues thanks to its characteristic dose profile. However, the steep dose profile of charged particle beams (due to the Bragg peak) can result in radiation over- or under-dosage. Monitoring the range of the charged particles is therefore highly desirable.

In this study we use a planar in-beam PET system for range verification of pencil beams in proton therapy. The planar geometry of DoPET system is advantageous because it can be used online, i.e., during treatment. In the particle therapy community, the Monte Carlo (MC) codes are widely used to evaluate the radiation transport and interaction with matter. For this reason, the FLUKA MC code was used to simulate the experimental conditions of irradiations performed at the Proton Therapy Center in Trento (IT).

Several mono-energetic pencil beams were delivered on phantoms mimicking human tissues. Different acquisitions are analyzed and compared with the MC predictions. The image reconstruction for experimental data and simulation is based on the Maximum Likelihood Estimation Method (MLEM) algorithm. A special focus on validating the PET detectors response for activity range verification will be presented.

# MONTE-CARLO SIMULATION OF COMBINED EFFECT OF GOLD NANOPARTICLES AND PROTON RADIATION BEAMS

**Vladimir Morozov[1], Vladimir Morozov[2], Alexander Belousov[2], Grigorii Krusanov[3], Maria Kolyvanova[1], Alexander Chernyaev[2], Alexander Chernyaev[3], Vladimir Klimanov[1], Vladimir Klimanov[4], Alexander Shtil[5], Alexander Samoilov[1]**

1 A.I. Burnazyan Federal Medical Biophysical Center, Moscow, Russia
2 Department of Physics, M.V. Lomonosov Moscow State University, Moscow, Russia
3 Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia
4 National Research Nuclear University MEPhI, Moscow, Russia
5 N.N. Blokhin National Medical Center of Oncology, Moscow, Russia

**Introduction.** Proton radiation therapy of malignant tumors is an evolving hopeful approach in radiation oncology. The main advantage of proton radiotherapy is a less severe damage to the perifocal tissues, since the main ionization takes place in the Bragg peak area. In addition, proton radiotherapy gives a possibility of treating deeply located and radioresistant neoplasms. Modern capabilities of nanotechnology allow us to hope to produce new inorganic nanoradiosensitizers to increase the effectiveness of proton radiotherapy. In the present work Monte-Carlo simulation was used to evaluate the radiosensitizing effect of gold nanoparticles in combination with clinical proton beams.

**Materials and Methods.** To determine the dose enhancement factor (DEF) in proton absorption, proton beam passage through a phantom was simulated. In this paper we used the Monte Carlo method, implemented in the program code based on the Geant4 libraries. The tumor modeling target containing gold nanoparticles (5 mg/ml) and, was in different sections of the Bragg curve, including the peak. We assumed that the gold nanoparticles were evenly distributed throughout the entire volume of the target, and their presence was modeled by a change in the target elemental composition. Dose distributions of proton beams with energies of 100, 150, 200 and 250 MeV were investigated.

**Results.** When a proton beam passed through the phantom, a dose increasing in the region of localization of nanoparticles due to increased interaction with radiation was expected. In different parts of the Bragg curve, excluding the peak, the dose intensifications were insignificant. The regions of the Bragg peak for protons with energies of 100, 150, 200 and 250 MeV were located at the depths of the tumor model of 7.5, 15, 25 and 40 cm, respectively. The effect of dose enhancement depended on the energy of the proton beam. The smallest DEF value 1.05 was obtained at a proton energy of 250 MeV. At proton energies of 100, 150 and 200 MeV, the DEF values were 1.2, 1.3, and 1.18, respectively.

**Conclusion.** In a model combination with proton radiation, gold nanoparticles showed a radiosensitizing effect when localized in the region of the Bragg peak. The DEF values were 1.2, 1.3, 1.18 and 1.05 at a concentration of gold nanoparticles of 5 mg/ml for proton energies of 100, 150, 200 and 250 MeV, respectively. The presented results demonstrate the possibility of using gold nanoparticles as potential enhancers of the efficacy of the antitumor effect of proton radiation.

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# THORACO-ABDOMINAL TRIPHASIC CT IN ONCOLOGIC FOLLOW-UP: ASSESSMENT AND ADVANTAGES OF LOW DOSE PROTOCOL

**Andrea Bonfanti, Elena Ciortan, Ruggero Baroni, Luciano Abate, Serena Padelli, Riccardo Buffa, Roberto Moltrasi**

CdC IGEA, Milano, Italy

**Introduction.** Oncologic follow-up often requires close monitoring with imaging, whereby patients are exposed to an overall high radiation dose. As a result, it seems important not only to be aware of modern technologies, but also to give consideration to the radiation dose delivered to patients.

**Objectives.** To compare the contrast enhanced computed tomography (CT) "LOW DOSE" protocol for thoraco-abdominal scans, with the standard CT protocol for oncologic follow up. We analyzed the two different imaging techniques and the overall radiation dose in order to determine benefits in terms of diagnosis.

**Methods.** Eligibility criteria were the medical indication to a contrast enhanced thoraco-abdominal CT as part of an oncologic follow up (breast cancer, hepatocarcinoma, neuroendocrine tumors, kidney cancer and prostatic cancer) and the availability of previous enhanced CT scans performed in the last year of follow up.

An analysis of prospectively collected data was performed from January to May 2017 in 50 patients in which oncologic follow up included a triphasic thoraco-abdominal CT for staging of liver disease. All scans were performed with 128 x 2 channel multidetector CT system dual source (SOMATOM Definition Flash, Siemens medical solution). All patients were divided into two groups according to a normal (15-30 $kg/m^2$) or high (> 30 $kg/m^2$) body mass index (BMI).

The standard triphasic CT protocol provides for CT arterial phase of the upper abdomen and the thorax volumes separately; with the aim of optimize the radiation exposure we designed a "LOW DOSE" CT protocol in which the arterial phase of liver and the thorax venous phase are performed in a single caudo-cranial volume.

We collected data on radiation exposure. The effective dose was calculated from the product of Dose Length Product (DLP) value and the normalized value of the conversion factor (EDLP); in the standard protocol the thorax conversion factor was 0,014 and the abdominal one was 0.015. In the LOW DOSE protocol the conversion factor was 0,0145.

**Results and conclusions.** The LOW DOSE protocol for triphasic CT in oncologic follow up permits saving of effective dose up to 50% (27% on average) for each scan and an overall saving up to 40% (15% on average) for complete procedure in the normal BMI group. The LOW DOSE protocol was efficient also in diagnosis of thromboembolic disease.

All the scans from LOW DOSE CT protocol were analyzed from radiologists unaware of introduction of the protocol, with at least 10 years of experience; there weren't reported any differences or difficulties in diagnosis compared to the standard CT protocol.

# PULMONARY DUST DISEASES IN BULGARIA

**Elisaveta Petrova**

ACIBADEM City Clinic, Tokuda Medical Center, Sofia State University Saint Kliment Ohridski, Sofia, Bulgaria

**The Aim** of the study was to present the epidemiological characteristics, new diagnostics trends and prevention of pulmonary diseases related to dust (PDD) in Bulgaria.

**Materials and Methods:** Retrospective epidemiological study, case control study and case reports for different dust diseases in Bulgaria during 1980-2003 y. were done. A SPSS statistical package was used.

**Results:** Epidemiological trends of different types of pneumoconioses and malignant mesothelioma were analyzed. A prognosis of appearance of PDD during future 10 – 30 y was done. A comparison between chest radiographic images and chest HRCT amongst pneumoconiotic patients were done. Image/functional constellations for medical prevention purposes were created.

**Conclusions:** 1. PDD play a leading epidemiological role amongst occupational diseases in Bulgaria. 2. An appearance of pneumoconiosis and asbestos related malignant mesothelioma in next 10 – 20 y were expected. 3. HRCT, as well as constellation HRCT/VC, FVC and FEF50% could be early diagnostics methods for pneumoconioses.

# ULTRASOUND-GUIDED PERCUTANEOUS SCLEROTHERAPY OF SIMPLE RENAL CYSTS: PRIMARY SUCCESS AND PROCEDURE SAFETY

**Dragica Obad Kovačević, Jelena Popić, Vinko Vidjak**

University Hospital Merkur, Zagreb, Croatia

**Objective:** To evaluate primary (technical) success and procedure safety in ultrasound (US)-guided percutaneous sclerotherapy of simple renal cysts, using 96% ethanol.

**Patients:** 17 patients with symptomatic simple renal cysts referred by nephrologists or urologists.

**Methods:** US-guided percutaneous puncture of the cyst with an 18G (gauge) needle and a "pigtail" 5F (French) catheter, drainage and inspection of the cyst content, and injection of ethanol.

**Results:** Puncture was rejected in two referred patients because of Bosniak II cyst and renal hilum proximity. 15 patients underwent puncture and drainage of the cyst content. In 4 patients ethanol was not injected because: thick or bloody cyst, proximity of renal hilum and severe pain during injection of ethanol. 11 patients underwent sclerotherapy of the cyst. The average size of sclerosed cyst was 8 cm (range 6-12 cm). There were no significant complications.

**Conclusion**: US-guided percutaneous sclerotherapy of simple renal cysts is easy to perform and safe procedure, with the previous good selection of cysts that are suitable for the sclerotherapy.

# THE POSSIBILITIES AND LIMITATIONS OF DIRECT DIGITAL RADIOGRAPHY, ULTRASOUND AND COMPUTED TOMOGRAPHY IN DIAGNOSING PLEURAL MESOTELIOMA

**Jelena Popić[1,2], Dragica Obad Kovačević[2], Đurđica Milković[3], Verica Garay Vrhovac[4], Vinko Vidjak[1,2]**

1 Medical School, University of Zagreb, Zagreb, Croatia
2 University Hospital Merkur, Zagreb, Croatia
3 Childrens Hospital Srebrnjak, Zagreb, Croatia
4 Institute for Medical Research and Occupational Health, Zagreb, Croatia

The goal of this study was to compare the possibilities and limitations of direct digital radiography of the chest (DDR), the use of ultrasound of the chest (US) and single slice computed tomography of the chest (CT) in diagnosing pleural mesothelioma. The study was conducted during the course of one year, on 80 patients who were successively referred to a specialized institution, under clinical suspicion of mesothelioma. The method of investigation was the comparison of findings, obtained by the reviewed methods of examination, with the pathohistologic results of a biopsy performed on each patient. The findings that were obtained by the enumerated methods were classified according to the radiologic signs that were found in each individual patient. We evaluated following radiological findings (signs), on each of the investigated methods: plaques, localized and generalized pleural thickenings, calcifications of the pleura, pleural effusions, parapneumonic effusions, pleural empyema, (round) atelectasis, pneumothorax, tumor mass or node, inflammatory infiltrate, elevation of the hemidiaphragm and osteolysis. The results of these were compared with pathohistologic findings and analyzed by means of standard statistical methods. The highest sensitivity was found for CT (94.4%), followed by US (92.6%), and by DDR (90.7%). The highest specificity was obtained with DDR (46.2%), followed by CT (35.5%) and US (23.8%). The comparison of these methods showed 90% diagnostic accuracy for DDR in relation to CT CT as an individual method best satisfied most of the criteria for diagnosing mesothelioma. No pathognomonic radiologic sign for mesothelioma was found.

# EVALUATION OF SKIN-ABSORBED DOSES IN RADIOGRAPHY FOR THREE PROCEDURES- SKULL, THORAX AND LUMBAR SPINE

**Florentin Niculescu[1], Corina Mariana Pera[2], Daniela Mossang[1], Elena Dadulescu[1], Elisabeta Antonescu[3]**

1 Laboratory for the Hygiene of Radiations, Public Health Authority of Dolj County, Craiova, Romania
2 County Emergency Hospital Resita, Resita, Romania
3 Lucian Blaga University Sibiu, Sibiu, Romania

**Introduction.** The ionizing radiations are used more and more often for diagnosis and for the treatment of different illnesses so the patients receive a significant dose, although this is for their own medical benefit. Medical exposure at ionizing radiations is the main source to receive radiations compared with other equipment created by humankind. The aim of this study is to know the received doses by the patient during diagnostic procedures so in the end certain procedures can be applied to minimize as low as reasonable achievable doses (ALARA).

**Evaluation method.** The study was conducted in 2 hospitals (A and B) from 2 regions of the south – west of Romania, using 2 types of equipment (two Eltex 400 and two Multix Compact – all without DAP-meters) on 30 patients for each procedure. It was calculated the surface skin absorbed doses for three procedures like skull, thorax and lumbar spine, using tube efficiency, current intensity and time of exposure (mAs), distance source film, distance source dosimeter (the measurements were obtained with a multifunctional instrument for testing system radiology quality RMI-242, with a flat ionizing chamber), patient thickness and backscatter factor (it was used a perspex phantom).

**Results.** The estimated doses for skull, using Eltex 400 equipment, varied between 4.877±0.144 mGy for hospital A and 0.541±0.056 mGy for hospital B (differences between these two hospitals were significant, $p<0.001$). For thorax and lumbar spine we had 0.663±0.042 mGy and 0.536±0.015 mGy (thorax) respectively 6.302±0.852 mGy and 5.904±0.631 mGy (lumbar spine). For Multix Compact equipment, doses were for skull between: 4.055±0.173 mGy in hospital A and 1.166±0.031 mGy in hospital B (differences between these two hospitals were significant, $p<0.001$), for thorax calculated values were 1.881±0.275 mGy in hospital A and 0.853±0.070 mGy in hospital B, and for lumbar spine 6.761±2.331 mGy and 5.342±0.127 mGy.

**Conclusions.** A significant dose variation between the two hospitals for skull procedures could be observed, for these two types of equipment. By comparison with the recommended reference values of the International Commission on Radiological Protection (Diagnostic Reference Levels in Medical Imaging – ICRP 2001), the calculated values of dose for these two hospitals and for these two types of equipment for lumbar spine were much smaller ($p<0.001$). Optimization is required by making work protocols for medical examinations with ionizing radiation that allow for the correct diagnosis of the patient at a radiation dose as low as possible for a reasonably good radiographic image.

# RADIATION PREDICTORS OF OUTCOMES OF ISCHEMIC STROKE

**Vladimir Shchedrenok[1], Maxim Kotov[2], Tatjana Zakhmatova[2], Olga Moguchaya[2]**

1 National Medical Research Center named after V.A. Almazov, Saint Petersburg, Russia
2 Northwestern State Medical University named after I.I. Mechnikov, Saint Petersburg, Russia

The purpose of this study estimate predictors that determine prognosis of outcomes of acute disorders of cerebral circulation by ischemic type.

**Materials and methods.** A comprehensive examination of 140 patients with acute violation of cerebral circulation (main group) and 30 people without any pathological changes (control group or comparison group) was performed.

The examination included native spiral computed tomography with the definition of the density of stem structures of the brain, CT-perfusion with quantification of blood flow in the brain stem and duplex scanning extra- and intracranial segments of the vertebral and basilar arteries.

**Results.** The mortality rate was 7.1%. Prognostic parameters in the patients who died were characterized by the following. Reducing density of the brain stem at the level of the tentorial and occipital hole up to +28.5±0.9 HU, reducing blood flow to the brain stem below 30 ml/100g brain matter minute (according to CT-perfusion). In duplex scanning revealed a pattern of "poor perfusion": decreased speed performance and a marked increase in the indexes of peripheral resistance (diastolic velocity equal or close to 0, the resistance index Purcelo equal to 1.0, the index of positively Gosling more than 1.8). Diagnostic informativeness of the identified techniques has reached 89-93% (patent № 2598459 RU).

**Conclusions.** Native spiral CT with the investigation of the density of the brain stem at the level of the tentorial and occipital hole, CT-perfusion measurement of blood flow in the brain stem and the basilar and vertebral arteries using Doppler sonography allows a high degree of reliability to determine the prognosis of ischemic stroke.

**Key words:** Spiral CT, CT-perfusion, duplex scanning, ischemic stroke, outcomes

# APPLICATION OF CONTRAST DRUGS IN ULTRASOUND DIAGNOSTICS

**Živorad N. Savić[1], Katarina Ž. Savić[1], Sofija Ž. Savić[2], Mirjana M. Petrović[1], Vladimir S. Radak[1], Srđan Z. Marković[1], Dragana A. Kastratović[1]**

1 Clinical Centre of Serbia, Belgrade, Serbia
2 Medical Faculty, University of Belgrade, Belgrade, Serbia

Ultrasound contrast agents work on the principle of enhanced refractivity of ultrasonic waves. The main components of the ultrasound contrast medium (UCA) are micro bubbles filled with gas. On average, UCA contains billions of bubbles per ml. [1]

Ultrasound molecular image is a powerful diagnostic modality using micro-bubbles coated with a target ligand specific for endothelial biomarkers. The display of circulating ligand-containing contrast media represents a targeted and crucial determinant in contrast enhancement, demonstrated the importance of surface architecture in the design of targeted micro-chemicals for ultrasound molecular image.[2]

Micro-histories as ultrasound contrast agents have been in clinical use for more than two decades, over time, their application has been increased to include echocardiography, Doppler Reinforcement, perfusion studies and molecular image, as well as a range of therapeutic applications including drug delivery, gene therapy, ultrasonic treatments of high intensity and sonotrombolysis.[3] Contrast-enhanced ultrasonography (CEUS) has been shown to be reliable in the detection of metastases in the liver in patients with known extrahepatic primary tumor and suspicious lesions of the liver.[4] Sonazoid ultrasonography-enhanced in the study demonstrated a higher sensitivity and accuracy for the diagnosis of malignancies of the liver than with CT kontrastom.[5-7]

**Contrast resources in neurosonology:**

- Extracranial tests allow us to improve the visualization of stenotic segments, residual lumen, pseudo-occlusion, dissection, vertebral artery.
- Cerebral macrocirculation gives us an enhancement of the transcendental and foraminal support
- Cerebral microcirculation allows examination of parenchyma.
- Cardiopulmonary detection of ovale shunt-foramen.
- Therapeutic application: improvement of thrombolysis, release of targeted drugs (new contrast agents).

**Conclusion:** Ultrasound with contrast is a relatively new diagnostic method with advantages: no ionizing radiation, harmless, affordable and cheap; Disadvantages: however contrast is given and it is not able to be a definitive diagnostic method due to the existence of atypical cases.

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# MICRONUCLEI FREQUENCY IN PATIENTS TREATED WITH J-131 FOR THERAPEUTIC CAUSES

**Mirela Mačkić-Đurović[1], Dunja Rukavina[2], Izeta Aganović-Mušinović[1]**

1 Center for Genetic, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
2 Veterinary Faculty, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

Patients with thyroid diseases have been treated with different doses of J-131 in therapeutic causes. Using standard method (cultivation 48 hours) 12 patients have been cytogenetically analyzed two times. First culture was set before treatment with J-131, and another was set 7 days after application of J-.131. We were analyzed – 1000 cells per patient for micronuclei frequency (MN). Micronuclei appear during cell division as result of acentric fragment or whole chromosomes condensation left in anaphases (it is considered as marker of structural or/and numerical chromosomal aberrations existence).

Applied doses of J-131 were 10mCi; 15 mCi and 20 mCi for 4 patients per each dose. At first set of analyzes as initial no significant MN's were found. At second set of analyzes for patients who received doses of 10 mCi and 15 mCi it is apparent slow increase of MN frequency (small aberrations); while for those who received dose of 20 mCi there is apparent increase of MN's frequency alone or with 2 micronuclei per cell. There was also an increase in number of nucleoplasmic bridges (NPBs) and nuclear buds (NBUDs)

This is initial phase of research that is going to be further investigated on a large number of patients.

# DIAGNOSTIC CONTRIBUTION OF POSITRON EMISSION TOMOGRAPHY WITH [$^{18}$F] FLUORODEOXYGLUCOSE IN HEPATOSPLENIC CANDIDIASIS

**Nataša Čolović[1], Danijela Leković[1], Mila Tirnanić[2], Vladimir Jurišić[3]**

1 University of Belgrade, School of Medicine; Clinic of Hematology, Clinical Center of Serbia, Belgrade, Serbia
2 University of Belgrade, School of Medicine; Center of Nuclear Medicine, Clinical Center of Serbia, Belgrade, Serbia
3 University of Kragujevac, Faculty of Medical Sciences, Kragujevac, Serbia

**Introduction.** Patients with acute leukemia are considered a population at high risk for developing an invasive fungal infection (FI). *Candida* and *Aspergillus* are the most common causes of FI in these patients. The treatment of AL requires strong chemotherapy after which it is expected that the patients will develop bone marrow aplasia, thus becoming liable to bacterial and fungal infections. Hepatosplenic candidiasis (HSC) is a frequent complication of neutropenia in hematologic malignant diseases which is clinically presented with prolonged febrility unresponsive to antibiotics.

**Case Outline.** A 53-year-old patient with acute myeloid leukemia (AML) was submitted to standard chemotherapy “3+7” regimen (daunoblastine 80 mg i.v. on days 1 to 3, cytarabine 2×170 mg i.v. during 7 days) and achieved complete remission. However, during remission he developed febrility unresponsive to antibiotics. Computerised tomography (CT) of the abdomen showed multiple hypodense lesions within the liver and spleen. Haemocultures on fungi were negative. However, seroconversion of biomarkers for invasive fungal infection (IFI) (Candida and Aspergillus antigen/Ag and antibody/Ab) indicated possible HSC. High positivity of anti-Candida IgG antibodies and mannan, accompanied by CT finding was regarded sufficient for the diagnosis and initiation of antimycotic therapy. Control MSCT after three months was normal but febrility still remaind. [$^{18}$F]fluorodeoxyglucose positron tomography showed presence of diffuse focal hypermetabolic lesions in liver and spleen confirming the activity of fungal infection and antimycotic therapy which was prolonged during next two months.

**Conclusion.** In patients with prolonged febrile neutropenia and leukemia FI has to be strongly clinically suspected. If imaging techniques show multiple hypodense lesions within liver and spleen, HSC has to be seriously taken into consideration. Optimal staging and evaluation of residual lesions of invasive fungal infections (IFIs) are major challenges in the immunocompromised host. Preliminary data have suggested that [$^{18}$F]fluorodeoxyglucose ([$^{18}$F]FDG) uptake may be observed in the course of active invasive fungal infections.

# IMPACT OF THE ATTENUATION CORRECTION ON THE SPECT/CT IMAGE QUALITY AND PATIENT EXPOSURE IN BONE SCINTIGRAPHY

**Monika Tulik[1], Piotr Tulik[2], Dominika Banasiewicz[2], Damian Kabat[1], Teresa Kowalska[1]**

1 Maria Sklodowska-Curie Memorial, Cancer Center and Institute of Oncology, Krakow Branch, Kraków, Poland

2 Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, Warsaw University of Technology, Warsaw, Poland

Single-photon emission computed tomography/computed tomography SPECT/CT of bones is a well-known study performed to evaluate metabolic activity of the skeleton. Additional advantage of attaching CT to SPECT is possibility to carry out an attenuation correction (AC) of SPECT data based on CT data. However reconstruction of SPECT images implementing CT data collected for AC may be biased especially in the case of dense structures. Low quality of CT images (associated i.a. with image noise, beam hardening effect and photon starvation from highly attenuating materials like bones) could affect the quality of SPECT images. On the other hand improved CT image quality is related to higher exposure of the patient. In case of bone scintigraphy after administration of $^{99m}$Tc-MDP, SPECT/CT examination performed even with reduced CT parameters may increase the total effective dose in range of 60-83% compared to the SPECT study without CT component (*Int J Mol Imaging* 2011:897202).

The aim of this study was to present the process of CT parameters optimization in terms of reducing patient exposure to ionizing radiation during SPECT/CT examination without adversely affecting the quality of obtained SPECT images with AC in the specific case of bone scintigraphy.

The study was performed using AnyScan SC device (Mediso). We designed and developed a new phantom, reflecting clinical situation of bone scintigraphy. The phantom consisted of the cylinder with flanged top and bottom containing 5 cylindrical containers simulating long bones of various sizes. The phantom body was filled with $Na^{99m}TcO_4$ sodium pertechnetate solution ("warm" background). Containers were filled with a $K_2HPO_4$ solution mixed with $Na^{99m}TcO_4$, simulating radiopharmaceutical accumulation in bones. The use of such mixture ensures absorption and scattering of ionizing radiation as in bone tissue. The ratio of activity concentration in "hot" sources to "warm" background was 10:1. The phantom underwent multiple SPECT/CT examinations for various combinations of high voltage and tube current (from 80 to 120 kV and from 10 to 200 mA, respectively). CT data for each analyzed combination of parameters was used for AC of SPECT data.

The influence of CT image quality on the quality of SPECT image was evaluated based on such parameters as contrast of "hot" sources and coefficient of variance (COV) as a measure of SPECT image uniformity. CT images quality was evaluated for noise in the image, signal to noise ration and CT dose index volume (CTDIvol). Collected data allowed assessment of images quality differences in comparison to the standard image (120 kV and 50 mA – parameters normally used in our nuclear medicine department).

The study presented direction of activities necessary to implement an individualized SPECT/CT diagnostic procedure.

# $^{225}Ac/^{213}Bi$ GENERATOR BASED ON INORGANIC SORBENTS

**Aleksandr Vasiliev[1], Ermolaev Stanislav[1], Elena Lapshina[1], Nicolay Betenekov[2], Evgeniy Denisov[2], Boris Zhuikov[1]**

1 Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia

2 Ural Federal University named after the first President of Russia B. N. Yeltsin, Ekaterinburg, Russia

Among alpha emitters suitable for targeted alpha-therapy, $^{225}Ac$ ($T_{1/2}$ = 9.9 days) and the product of its decay $^{213}Bi$ (46 min.) are the most promising. Clinical trials have been confirmed higher efficacy and less toxicity for patients of radiopharmaceuticals labeled with these radionuclides in comparison with similar beta-emitting ones. A prospective method of producing $^{225}Ac$ (more than 1 Ci for a 10-day run) by irradiation of natural thorium with medium-energy protons (*Radiochim. Acta*, 2012, 100, pp. 1–7) followed by chemical isolation (*Solvent Extraction and Ion Exchange*, 2014, 32, 5, p. 468-477) has been developed at the Institute for Nuclear Research of the Russian Academy of Sciences. A long-lived $^{227}Ac$ (21.7 years) is also formed (~0.1% of $^{225}Ac$ at the end of irradiation), and direct medical application of the product seems questionable. However, $^{225}Ac$ with small impurity of $^{227}Ac$ is appropriate as a mother radionuclide for $^{225}Ac/^{213}Bi$ generator.

$^{225}Ac/^{213}Bi$ generator systems based on ion exchange (AG MP-50, AG 1, BioRad) and extraction chromatography resins (Actinide Resin, UTEVA Resin, Triskem Int.) are well described. The initial activity of generator (not more than 50-100 mCi) is limited not only by $^{225}Ac$ production capabilities but also by the radiation resistance of the sorbents used in the generator. Since the developed method of $^{225}Ac$ production allows increasing the activity of $^{213}Bi$ injected into a patient (at least to 4 GBq (100-150 mCi)), both radiation and radiolytic destruction of the sorbent also grow up. Therefore, in this work we propose the use of more radiation-resistant inorganic sorbents for $^{225}Ac/^{213}Bi$ generator.

The properties of inorganic sorbents made of hydrated titanium, zirconium and yttrium oxides, ferrocyanides and phosphates are considered, and Ac – Bi separation schemes are proposed. The prototype of the inverse generator based on the inorganic sorbent T-39 (zirconium and yttrium oxides annealed at 950 °C) with a grain size of 63-80 μm has been tested. The generator demonstrates high yield of the $^{213}Bi$ product, high degree of purification from the actinium isotopes and the products of $^{227}Ac$ decay and a low radiation impact on the sorbent.

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# ENSURING PROTECTION AND SAFETY IN THE HANDLING OF A DECEASED PERSON THAT IS KNOWN TO CONTAIN AN UNSEALED SOURCE AS A RESULT OF A MEDICAL TREATMENT – HEALTH AUTHORITY CASE STUDY

**Fulger Ciupagea[1], Gabriela Rosca Fartat[1], Marina Anghene[1], Anca Zamfirescu[2], Cristina Petroiu[2], Costin Ghioca[3]**

1 Public Health Directorate-Ionizing Radiation Laboratory, Bucharest, Romania
2 Oncological Institute, Bucharest, Romania
3 AC RAD Medical Consult & Service SRL, Bucharest, Romania

Radioactive sources used for therapy can cause very serious exposures if they are mislaid or misused. The aim of this paper is to present the measures taken in order to ensure the radiation protection in the handling of a deceased person containing I-131.

The prominent pathways of exposure for occupational exposure personnel, medical exposure (family, friends) and public exposure (third person e.q. the mortuary car driver, priest) were assessed.

According to these specific conditions, it was calculated the time after which the body can be taken over by the family and for each category of people were evaluated the doses involved during the handling of the deceased person, the embalming, the transport and the burial ceremony.

Also, the compliance with national legislation and European recommendations is discussed.

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# MEGAVOLTAGE COMPUTED TOMOGRAPHY (MVCT) DOSE ASSESSMENT AT DIFFERENT DEPTHS

**Sibel Karaca, Hamit Başaran**

TC Sağlık Bakanlığı, Erzurum Bölge Eğitim ve Araştırma Hastanesi, Radyoterapi, Erzurum, Turkey

The aim of the study is to evaluate the point doses measured by different parameters at various depths with MVCT in the TomoTherapy Hi- Art (HT) treatment unit. HT is works in two modes: visual modes and therapy modes. The user can choose the scan length and image pitch value. The system has fine, normal and course pitch values. When the same volume is scanned during gentry rotation, the scan times of fine, normal, and course modes are different from each other. Cheese Phantom is used to evaluate the point doses. The measured values ranged from 0.64 to 2.67 cGy with an average dose of 1.40 cGy. The lowest MVCT dose is found when scanned 7 slices with a depth of 20 cm, 51 seconds; the highest MVCT dose is found when scanned 17 slice with a depth of 15 cm, 101 seconds. While when at course mode, high depth and low slices show that the dose values drop. The imaging in the IGRT method can be used before every therapy and can be used more than once if necessary. This is why while conducting the method, it is important that the best mode should be used in order to prevent patients from using unnecessary doses.

# 3D-HDR INTRALUMINAL BRACHYTHERAPY IN OESOPHAGEAL CANCER

**Paweł Cisek[1], Dariusz Kieszko[2], Mateusz Bilski[1], Izabela Kordzińska-Cisek[1], Paulina Kozakiewicz[1], Ludmiła Grzybowska-Szatkowska[1]**

1 Medical University in Lublin, Lublin, Poland
2 Center of Oncology in Lublin, Lublin, Poland

Brachytherapy HDR is a valuable palliative treatment for advanced esophageal cancer. The main indication for this type of therapy is dysphagia, which usually accompanies the advanced stage of the cancer. An important part of the procedure is treatment planning, based on endoscopic studies, X-ray, CT and MRI. Significant progress has been made in treatment planning, and standard planning has been replaced by three-dimensional planning mainly based on computed tomography. Despite the undoubted benefits of 3D planning, this method is not commonly used in esophageal cancer. The reason for this is a considerable lengthening of the planning process. It causes poor tolerance and low comfort of waiting with the applicator established for the treatment plan.

The following paper presents an overview of various techniques for planning treatment in esophageal brachytherapy and describes the three-dimensional planning technique used in the Lublin Center for Oncology in the 2015-2017. This planning was based on computed tomography and the applicator was replaced with a special marker established during gastroscopic examination performed prior to treatment. The position of the marker was adjusted to the position of the applicator. The presence of the marker was well tolerated and the length of the treatment planning did not worse the patient's comfort. Treatment planning in this way allowed to define the length and depth of infiltration based on both gastroscopic examination and computer tomography. It also allowed for estimating doses in such critical organs as lungs or heart.

# 3D RADIATION DOSIMETRY USING A RADIO-FLUOROGENIC (RFG) GEL

**Tiantian Yao, Lee Luthjens, John Warman**

Delft University of Technology, Delft, Netherlands

We have developed an optically-clear radio-fluorogenic (RFG) gel which is non-fluorescent before irradiation but becomes fluorescent in UV light after exposure to high-energy radiation. The main purpose of the RFG gel is to provide a 3D radiation dosimeter as a verification of the treatment plan in radiotherapy quality assurance. The method is based on radiation-induced copolymerization process that the RFG gel consists of two components, i.e. bulk monomer of tertiary-butyl acrylate (TBA) and ca 100 ppm fluorescent dye maleimido-pyrene (MPy). The latter emits fluorescence, and when incorporated into the polymer chain (gel matrix) formed by the bulk monomer upon irradiation and the fluorescence intensity, it was found to be proportional to the absorbed dose. The readout of the gel fluorescence via slit scanning method provides 3D visual images or movies and quantitative dosimetric information of complex radiation fields. The quantitative effect of radiation on monomer to polymer formation was investigated using γ-ray sources (*Rad.Phys.Chem.*, 97 (2014) 147-152). The fluorescence properties of the gel were also investigated with overlapping X-ray beams (*Phys.Med.Biol*, 56 (2011) 1487-1508), 3MV electrons (*Rad.Phys.Chem.*, 84 (2013) 129-135), 80 MeV protons (*Rad.Phys.Chem.*, 85 (2013) 179-181) and an Ir-192 brachytherapy seed (*Advanced Materials*, 23 (2011) 4953-4955). Our goal is to provide 3D dose distribution maps to validate treatment plans using different types of radiation sources.

# POSITIONING AND IMMOBILIZATION AS A BASE OF ACCURATE RADIOTHERAPY

**Jovan Stevanovic, Nikola Gavrilovic**

Institute for Oncology and Radiology of Serbia, Belgrade, Serbia

The ability to position the patient accurately and reproducibly during a course of radiation is fundamental to fractionated radiation therapy. With positioning of patients as key factor in radiotherapy procedures, we achieve the ultimate goal of radiotherapy delivering lethal doses of radiation to predefined target volume – increasing chances of survival, and sparing normal health tissue – reducing side- effects and increasing quality of life. Patient should be lying straight and supine (in most of cases). The sagittal laser should be used to ensure straightness, checking that it bisects the nasal septum, sterna notch, xiphisternum and symphysis pubis as much as is possible. This aids in the minimisation of rotations.

In order to treat the same volume every time it is crucial to reposition the patient exactly for each treatment as at first treatment. In deciding a patient's treatment position, several important issues need to be considered, including comfort, reproducibility and ability to maintain the position for extended period of time. There is no easy way of ensuring this issues and that patient will be positioned identically with their original planning scan. That is the reason why we are using immobilization devices in addition to ensure good reproducibility, high precision and comfort of patient. The purpose of immobilization devices is to ensure that the patient remains in the correct position during treatment and immobilization devices should be easy to use, quick to set up, comfortable for patient and durable enough to withstand to entire course of treatment.

With right immobilization and positioning we maximize daily reproducibility and achieve high precision of radiotherapy treatment.

# A STUDY ON THE OPTIMIZATION STRATEGY OF INTENSITY-MODULATED RADIOTHERAPY FOR PROSTATE CANCER

**Sanghyuk Song[1], Hongshik Chun[2], Tosol Yu[2], Hyeong-min Joo[1], Soo Kon Kim[1], Yong Nam Kim[1]**

1 Kangwon National University Hospital, Chuncheon, South Korea
2 Gangneung Public Health Center, Gangneung, South Korea

**Purpose:** The aim of this study was to make an optimization strategy for IMRT planning for prostate cancer. A novel approach was proposed, which is based on the history of optimization process.

**Methods:** First, we considered a step-by-step approach. In the first step, we have achieved the best target coverage and homogeneity regardless of critical organ damages. The next step is to increase critical organ constraints based on dose volume histogram (DVH) data from the previous step. Considering the trade-off between the target coverage/homogeneity and normal organ damages, we chose the optimal plan for reference. With a novel approach, named “history-based optimization”, we eliminated all fluencies of the reference plan and proceeded with the optimization process using the set of constraints sets in the reference plan from the step-by-step approach. The DVH data and dose distribution of both plans were compared.

**Results:** We compared each DVH data in the IMRT plan for five patients with prostate cancer. Doses received by at least 95% volume of the target volume were higher with history-based optimization ($P=0.030$). Homogeneity index (HI) was lower with history-based optimization ($P=0.034$), indicating a more uniform dose distribution with history-based optimization. The volume of the rectum that received 50, 60, 65, and 70Gy was significantly lower with history-based optimization. The volume of bladder receiving 50 and 60Gy were significantly lower with history-based optimization, but there was no difference in the volume of the bladder receiving 65 and 70Gy.

**Conclusion:** We have improved the quality of the IMRT plan for prostate cancer with a history-based optimization method.

# REDUCTION OF DOSE ESTIMATION ERROR OF AN ARTIFICIAL NEURAL NETWORK ALGORITHM FOR RADIATION TREATMENT

**Yong-Nam Kim, Hyeong-Min Joo**

Kangwon National University Hospital, Kangwon-do, South Korea

Both the accuracy and the speed of dose calculation are crucial a clinical field of radiation treatment. This study intended to apply an artificial neural network (ANN) to develop a real-time computing algorithm for dose calculation for radiation treatment. In order to assess the feasibility of using neural network, a neural network algorithm was constructed and compared with the results obtained with Monte Carlo calculations. First of all, a step known as learning process is necessary. We considered the data set with the pairs of a point-wise dose and its position for training an ANN. The ANN was modeled using the Neural Network tool of MATLAB 7.0 (Mathworks, USA). It was constructed with the three layers including one hidden layer. From the investigation of basic characteristic of learning algorithm of neural network, it is noted that the steep dose gradient in the penumbra region causes the inefficient learning performance and propagate the error in to the whole region of radiation field. A novel method was contrived introducing the intermediate tuning stage in which the weight of hidden layer unit is firstly optimized considering an analytic function with less steep gradient as a dummy target/output and transferred to the original target dose distribution. It provided the successful escapement from the local minima. Except for the penumbra region, the error was less than 5%. By using the dose data measured by 1.5cm interval, the dose distribution was successfully calculated by 0.5cm mesh size. It is indicated that the feasibility of using neural network was verified. It is expected to a neural network could be developed successfully to achieve a real-time calculation of dose distribution in the human body by using the novel method.

# INTENSITY-MODULATED RADIATION THERAPY IN HEAD AND NECK CARCINOMAS

**Lenche Kostadinova**

University Clinic of Radiotherapy and Oncology, Skopje, Macedonia

IMRT (Intensity-modulated radiation therapy) is new modality in radiation therapy based on computer –treatment planning and computer – controlled treatment delivery system. This technology generates dose distributions that sharply confirm to the target, minimizing the delivered dose to the normal tissues.

Carcinomas of head and neck are ideal target for IMRT technology because concave shape of the target volume and close proximity of normal tissues. The head and neck region is an ideal target for this new technology for several reasons. Multiple planning studies and our short experience have clearly demonstrated the ability of IMRT in improving target coverage and dose uniformity for many head and neck sites because of potential for improved tumor control through delivery of high doses to the target volume, sharp dose gradients, and results in the relative sparing of normal structures in the head and neck region, and organ motion is virtually absent in the head and neck region.

Head and neck sites have always been among the most challenging, complex and time consuming to plan. Our experience with head and neck IMRT planning has been that the complete planning process can require 10 to 12 hours of a planner's time, more if image fusion is required. Site-specific class solutions, specifying the clinical criteria for target and normal tissue doses in as much detail as possible, the beam arrangements and constraint templates to use as starting points for planning are mandatory for efficient head and neck IMRT planning.

Early reports of improvement in tumor control and sparing normal tissues with IMRT in head and neck region are promising, but we need to be confirmed long term patients follow-up.

# DOSIMETRIC STUDY ON COMPARISON OF GAMMA INDEX IN PRE-VMAT TREATMENT VERIFICATION PROCEDURE USING DELTA4 AND PORTAL DOSIMETRY

**Dražan Jaroš, Goran Kolarević, Bojan Pavičar**

IMC Banja Luka, Banja Luka, Bosnia and Herzegovina

**Background/Aim:** The aim of this study was to compare Gamma Index (GI) in pre-volumetric modulated arc therapy (VMAT) treatment verification procedure using Delta4 and Portal Dosimetry.

**Methods:** We compared VMAT plans for a total of 40 patients during February, March and April 2014. For each patient two plans were generated, one for Delta4 verification and one for verification with Portal Dosimetry. The plan acceptance criteria were 98% of the PTV to receive at least 95% of prescribed dose and dose to 2% of PTV not to exceed 107% of prescribed dose. Dose for organs at risk were respected as per QUANTEC guidelines. After plan acceptance corresponding pre-treatment verification procedure for VMAT was executed by Delta4 and Portal Dosimetry. The GI results of each patient were recorded. The passing criteria for 3% Dose Difference and 3 mm Distance to Agreement for all cases was more than 95%.

**Results:** Average GI measured with Delta4 was 99.78% and measured with Portal Dosimety was 98.46% with statistical significance $p<0.05$.

**Conclusion:** Gamma criteria of 3% Dose Difference and 3 mm Distance to Agreement favourably exceeds 95% in both verification techniques. Portal Dosimetry is routinely in use because of better spatial resolution and the procedure is less time-consuming.

**Key words:** Delta4, portal dosimetry, gamma index

# TREATMENT PLANNING IN BRACHYTHERAPY HDR BASED ON THREE-DIMENSIONAL IMAGES

**Marcin Sawicki, Jarosław Łyczek, Łukasz Kowalik, Damian Kazalski**

Subcarpathian Cancer Center, Brzozów, Poland

Treatment planning in HDR brachytherapy based on three-dimensional imaging allows for prearranging and realization optimal treatment process. This process consists of procedure planning, the choice of applicators, adjusting the appropriate implantation technique and planning of three-dimensional distribution of dose in computerised treatment planning system. 3D images used in treatment planning in HDR brachytherapy allows for choosing the most appropriate application technique. This in turn allows for the best area coverage by reference dose with simultaneous protection of critical organs. Treatment planning on 3D images assures individual planning of dose dispersion in target area. Several techniques will be presented based on 3D imaging in location such as lung, skin cancer, breast and prostate cancer. For each location, relative cases will be provided where different applicators and techniques were applied. These examples they are going to present images from before and after performed application along with the pictures from computer treatment planning system. In each of described locations, relative advice and rules of conducting accurate application will be provided.

# PRELIMINARY RESULTS: THE EFFECTS OF SOME TRACE ELEMENT CONCENTRATIONS ON RADIATION DOSE IN CANCEROUS TISSUES AT RADIOTHERAPY


**Turan Şahmaran[1], Ayşe Kaşkaş[2]**

1 Ankara Dişkapi Yildirim Beyazit Training and Research Hospital, Ankara, Turkey
2 Ankara University, Faculty of Sciences, Department of Physics, Tandogan, Ankara, Turkey



**Purpose:** In recent years, it has been studied on the importance of the trace elements in carcinogenesis. The trace elements concentrations in healthy and cancerous tissues are compared. In this study, the effects of variation of trace elements concentrations in cancerous tissue on radiotherapy dose distribution were investigated.

**Materials and Methods:** Pure water, which is a tissue equivalent material, was put in a water tank made of acrylic with a size of 30x30x22 $cm^3$. Trace elements concentrations at healthy and cancerous tissues were found experimentally in some literatures. Some water-soluble elements were mixed with pure water at different concentrations to make a form like a tissue equivalent material for healthy and cancerous tissues. Elements such as potassium, calcium and iron which are at different concentrations in healthy and cancerous tissues were taken. Elekta Synergy Linac system was used at 6 MV and 18 MV photon beam energies. IBA CC13 cylindrical ion chamber and electrometer were used for measurements. The ion chamber was placed under the water tank inside a solid water phantom. The distance between the beam source and the surface (SSD) was fixed at 100 cm during the experiments. Experiments were performed at the units for each centimeter from 1 cm to 20 cm at 200 MU. The field size was taken as 5x5, 10x10, 15x15, 20x20 and 30x30 $cm^2$ at 6 MV and 18 MV photon energies. Firstly, the depth-of-dose measurements were performed with pure water. Furthermore, some elements in different concentrations were mixed in pure water. Measurements were taken in different field size and different element concentrations.

**Results and Conclusions:** Fe, Ca and K elements mixing with the pure water in different concentration were used to understand the behavior of depth-dose distribution in tissue equivalent material. Each measurement was repeated three times and the average value was taken. The depth dose distribution was compared with the different field size and photon energies. It can be seen that, the trace element concentrations of healthy and cancerous tissues do not affect the dose distribution at high-energy Linac.

# CONSIDERATION REGARDING THE SECONDARY MIXED RADIATION FIELD AROUND THE MEDICAL LINEAR ACCELERATOR – MEASUREMENTS WITH AND WITHOUT AN ANTHROPOMORPHIC PHANTOM PLACED IN THE RADIATION FIELD

**Piotr Tulik[1], Monika Tulik[2], Maciej Maciak[1], Damian Kabat[2], Jan Lesiak[2]**

1 Institute of Metrology and Biomedical Engineering, Faculty of Mechatronics, Warsaw University of Technology, Warsaw, Poland
2 Maria Sklodowska-Curie Memorial, Cancer Center and Institute of Oncology, Krakow Branch, Kraków, Poland

The aim of the study was to investigate secondary mixed radiation field around the medical linear accelerator (linac), as the part of an overall assessment of out-of-field contribution of neutron dose for new advanced radiation dose delivery techniques (doi.org/10.1093/rpd/ncx199). It seems essential to know how mixed radiation field around linac is precisely formed in static conditions, before measuring neutron dose for dynamic conditions like in advanced techniques. Unwanted radiation outside the treatment field may arise from leakage from linac head, also scatter from collimation devices and components of the therapeutic room. Furthermore, additional secondary radiation originates in the patient's body itself. It could be influenced by beam quality and configuration of linac head (jaws and MLC). Overall contribution of these factors was assessed in the study with the use of recombination chambers and recombination methods.

The measurements around Varian Clinac 2300 C/D (gantry angle 0°, collimator angle 0°) were performed in several positions with active volume of chambers placed at the level of linac's isocenter. Three positions were selected in the axis of the therapeutic cauch (table angle 0°) 100 cm from the radiation axis and 50 cm on both sides of the radiation axis in the direction defined by collimator angle 0°, 50 cm from the radiation axis in the direction defined by collimator angle 180°. Assessment of secondary radiation level was performed for several different configurations of jaws position and MLC sets in each position (jaws completely opened and reference 10 x 10 cm field, with MLC set open or closed). Firstly, no phantom was placed in the beam field (free-in air measurements). Secondly, all measurements were repeated with an anthropomorphic RANDO phantom (pelvic region of the trunk) located so that the accelerator isocentre indicated the prostate area.

Study includes the use of two photon beams: 6 MV and 18 MV at each position and for each configuration. The accelerator was always operated at the dose rate of 300 MU/min for 50 MU.

Recombination chambers REM-2 and GW2 were used for recombination index of quality factor ($Q_4$) determination, measurement of total absorbed dose D*(10) and doses delivered by gamma and neutron components. Estimation of quality factor Q(L) and total absorbed dose allowed the ambient dose equivalent H*(10) calculations.

Spatial distribution of ambient dose equivalent around the linac during the treatment, as well as relative contribution of gamma and neutron secondary radiation inside treatment room, was evaluated.

# PROTON THERAPY: PASSIVE SCATTERING TECHNIQUE IMPROVEMENT

**Ivan Yakovlev, Sergey Akulinichev**

INR RAS, Moscow, Russia

The method of passive scattering in proton beam therapy has some benefits and drawbacks. One of the drawbacks is the formation of hot lesions in the proximal region beyond the borders of the target volume. It leads to the raise of the integral dose of irradiation and lowers the irradiation conformity.

To date, a solution to this problem has been proposed by some other authors in the form of a multi-layer energy filter. Such filter has different amount of material and provides different energy modulation at different impact parameters. Nevertheless, the design of that device leads to an increase in the dose within the planned target volume, which may be critical in some cases. We propose a different design of the depth dose formation device – a composite ridge filter. Our solution allows to change the Bragg peak modulation width by eliminating the selected elements of the energy modulating ridge, while further changing the radiation intensity in the given target region due to the beam absorption. In our previous study, we have performed a Monte-Carlo simulation and obtained a spherical contour of 95% isodoses. Now we have developed a method for more accurate selection of device geometry, thereby reducing the controlled level of isodoses to 90% and lower. We continue our calculations to improve the conformity of irradiation and prepare experimental tests with proton beams of INR linac.

# APPLICATION OF YTTERBIUM SOURCES FOR INTRACAVITARY BRACHYTHERAPY WITH DIRECTED EMISSION

**Sergey Akulinichev, Sergey Chaushansky, Ivan Yakovlev, Vasiliy Derzhiev**

INR RAS, Moscow, Russia

The relatively hard radiation of Ir-192 (and Co-60), used for HDR brachytherapy, requires heavy and expensive afterloaders and complicates the collimation of photon emission. The last fact may lead to posttreatment damages to neighbor healthy organs. These drawbacks of HDR brachytherapy can be resolved by using Yb-169, which has an average photon emission energy of 93 KeV (the half-life is 32 days). Compared to other isotopes for HDR brachytherapy, the radiation of ytterbium-169 is much stronger absorbed in heavy materials, used for shields or collimators. This is particularly important for the intracavitary treatment of all kinds of vaginal tumors because the neighbor critical organs, especially bladder and rectum, are very radiosensitive. We found that a layer of only 1 mm of tungsten makes it possible to sufficiently collimate the ytterbium photon emission, sparing the neighbor critical organs. We have designed a simple and cheap construction of applicators for intracavitary treatment of cancer, allowing to significantly raise the quality of brachytherapy by directing the main photon emission to a tumor.

# THE FOOT EXPERIMENT: FRAGMENTATION MEASUREMENTS IN PARTICLE THERAPY


**Maria Cristina Montesi***
***On Behalf of the FOOT Collaboration**

Univerità di Napoli Federico II and INFN, Napoli, Italy


Charged Particle Therapy (CPT) is a powerful radiotherapy technique for the treatment of deep-seated tumour. The physical dose distribution of charged particles is characterized by a large dose released in the tumour region corresponding to the Bragg peak area and a small dose delivered to the surrounding healthy tissues. Nuclear interactions between charged particle beams and patient tissues produce fragments whose accurate measurements are crucial to improve the clinical treatment plans. In proton treatments, the target fragmentation produces low energy, short range fragments along all the beam range, while in C-12 beam treatments, the projectile fragmentation generates long range fragments releasing dose in healthy tissues surrounding the tumour. The FOOT (FragmentatiOn Of Target) experiment, an international project funded by the Istituto Nazionale di Fisica Nucleare, is designed to study these processes. The target (O-16, C-12) fragmentation induced by 150-250 MeV/n proton beams will be studied via the inverse kinematic approach, where O-16 and C-12 therapeutic beams collide on graphite and hydrocarbons target to provide the cross section on Hydrogen. This configuration allows to explore also the projectile fragmentation of these beams.

A table-top experimental apparatus is being designed and it consists of a start counter providing the trigger and the start of the time-of-flight (TOF) measurement. The direction and position of the impinging particle on the target is registered by silicon strip detectors, while planes of silicon pixel detectors reconstruct the trajectory of fragments downstream of the target, with an angular acceptance of about 20 degrees. This is followed by a magnetic region with planes of silicon detectors to measure the momentum and identify particles in the calorimetric region: a thin plastic scintillator measures the energy loss $\Delta E$ and the stop of TOF and a BGO crystal calorimeter evaluates the kinetic energy of fragments. Moreover, the FOOT apparatus accommodates a dedicated emulsion spectrometer to characterize the production of low Z fragments. The emulsion spectrometer extends the angular acceptance of measured fragments up to about 70 degrees.

The final goal of the FOOT experiment is to measure the differential cross section with 5% uncertainty for ion beams impinging on different targets of carbon and hydrocarbons.

An effort was paid to optimize the design of the FOOT apparatus by means of simulations and tests with particle beams. In this work, the experimental design and the requirements of the FOOT experiment will be discussed and preliminary results on the emulsion spectrometer tests will be presented.

# SMALL FIELD OUTPUT FACTORS AND THEIR IMPACT IN CALCULATION MODEL CONFIGURATION

**Sonja Petkovska[1], Yasin Acarbas[1], Margarita Ginovska[2], Hristina Spasevska[2]**

1 Clinical Center Acibadem Sistina, Skopje, Macedonia
2 Faculty of Electrical Engineering and Information Technologies, Skopje, Macedonia

**Introduction:** Advanced techniques such as IMRT and VMAT become the standard in modern radiotherapy modalities as radiosurgery and stereotactic radiotherapy, the input of small fields is rapidly increasing. Standard dosimetric protocols become too narrow and in order to describe the diversity of small fields and their characteristics, new formalism, dosimetry on small fields is required. The aim of this paper is to analyze the small field output parameters measured by different detectors and their influence in the calculation algorithm.

**Methods:** Measurements are performed for 6MV photon beams produced by Varian linear accelerator. Three different detectors from PTW, Frieburg-Germany are used separately for small field output factor measurements. Measurements are made in water phantom, on two different depth (5 cm and 10 cm) and SPD of 95 cm and 90 cm respectively. These values are used in Treatment Planning System (TPS) determining different calculation models into same base (Analytical Anisotropic Algorithm known as AAA). Different collimator backscatter factors (CBSF) tables are obtained as a consequence of these entered parameters.

**Results:** During beam configuration, depth doses and profiles measurements for field sizes below 2x2 cm2 will be ignored. These measurement are imprecise and do not improve the phase space modeling. In contrast, the output factors have a more visible impact on the configured data. Into new calculation models configured, (compared to the original, 'large field' algorithm configuration), both the output factor table and the collimator backscatter factors contain values down to a 1x1 cm2 field size. They result in the calculation of additional CBSF and directly impact the MU calculation for the small field dimensions.

**Conclusion:** For stereotactic treatment implementation appropriate detector choice is important According to the results analysis, the diode detectors were found suitable for output factor measurements. And, small field output factors are the only data that really need to be added into existing AAA configuration which was already configured down to a 3x3 cm2 field size, to include small field dose calculation.

# MONOCHROMATIC MICROBEAM RADIATION THERAPY (M-MRT) MODALITY – IMPLEMENTATION USING THE SYNCHROTRON LIGHT

**Tomasz W. Wysokinski[1], Elke Brauer-Krisch[2], Mattia Donzelli[2]**

1 Canadian Light Source, Saskatoon, Canada
2 ESRF, Grenoble, France

The classical microbeam radiation therapy (MRT) is based on the spatial fractionation of a high dose-rate (2000 Gy/s), low energy (~100 keV) pink beam X-rays. Monochromatic microbeam radiation therapy (m-MRT) is an extension of the MRT technique and expands this therapy method into a low dose-rate (1-10 Gy/s) regime, where dose rates are comparable to clinical standards. M-MRT technique is using the monochromatic beam with energy that can be optimized for a specific treatment plan. Several possible implementations of the m-MRT technique were proposed, developed and tested. Those included: a step-and-shoot, bi-directional irradiation as well as a spiral m-MRT method. The methods were verified and tested using the synchrotron light and high precision positioning stages at BMIT Facility at the Canadian Light Source.

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# SALVAGE HIGH-DOSE-RATE BRACHYTHERAPY OF LOCAL PROSTATE CANCER RECURRENCE

**Vladimir Solodky, Alex Tsibulskii, Andrey Pavlov, Anton Ivashin, Sergey Garmash**

Russian Research Center of Radiology, Moscow, Russia

**Purpose:** The study objective is a primary analysis of the prostate cancer patients' treatment who underwent the high-dose rate brachytherapy after documented local recurrence following radiotherapy.

**Material and methods:** In 2011-2015, Russian Scientific Center of Roentgenoradiology performed salvage HDR-BT in 10 patients with documented local prostate cancer recurrence. All interventions were performed on Microselectron high-dose rate with transrectal ultrasound probe 4-9 MHz. Brachytherapy was performed in three 9.5Gy fractions with a two week interval between fractions. The total dose was 28.5Gy. The linear-quadratic equivalent dose was 89.6Gy, biologically effective dose was 209Gy (2Gy per fraction, $\alpha/\beta = 1.5$).

**Results:** The tumor biochemical control was in 7 out of 10 patients. 3 patients had PSA increase after the withdrawal of androgen deprivation therapy. Bone scintigraphy, the pelvis MRI with contrast, PET/CT showed local tumor control. However, 2 patients had remote metastases in the bones, and 1 patient had lesions in ileac and paraaortal (juxtaregional) lymph nodes. All 3 patients were offered androgen deprivation therapy. Grade 3 genitourinary toxic reactions were found in 1 patient (10%). No grade 3 gastrointestinal toxic reactions were found.

**Conclusions:** Preliminary results suggest the possibility of efficient HDR-BT treatment of local prostate cancer recurrence with local tumor control and low genitourinary and gastrointestinal toxicity.

# ABSCOPAL EFFECT OF RADIOTHERAPY – THE PURSUIT OF THE UNKNOWN

**Mateusz Bilski[1,2], Paulina Stefaniuk[1], Michał Jędrejek[1], Paweł Cisek[1], Monika Bilska[3], Izabela Cisek[1], Ludmiła Grzybowska-Szatkowska[1]**

1 Medical University of Lublin, Department of Oncology, Lublin, Poland
2 Lublin Oncological Center, Department of Radiation Therapy, Lublin, Poland
3 Department of Ginecological Oncology and Gynecology, Medical University of Lublin, Lublin, Poland

**Introduction:** Approximately 60% of patients with solid tumors are treated with radiotherapy, making it the most common cancer treatment. It is widely used to treat a localized target. Radiation therapy can lead to decrease in tumor size, reduces recurrence and ultimately increases overall survival. In numerous studies, and above all in clinical practice, beneficial local effects of radiotherapy have been proven and as a matter of fact, are not negotiable. Little attention has been devoted to the radiotherapy effect outside the field of primary irritation, called abscopal effect.

**Aim and methods:** The aim of our study was to analyze published data on abscopal effect. We searched Pubmed database, looking for papers published in English, from 2015 to 2017. We also reviewed the bibliography of retrieved articles. The abstracts were evaluated independently by two authors, and in the event of disagreement the third author reviewed the paper.

We make an attempt to summarize the current knowledge about the abscopal effect, with particular attention to issues that may have a direct impact on clinical practice.

**Results:** All authors of the analysed reviewed literature seem to agree that an adequate immunologic response is necessary to achieve abscopal effect. In the study of Chakravarty et al. abscopal effect hasn't been observed in athymic mice, unable to perform proper immunological response. Radiation is capable of causing immunological cell death (ICD), which is characterised by secretion of damage associated molecular patterns (DAMPs), such as HGMB-1 or Calreticuline. DAMPs are able to bind with antigen presenting cells (APCs), which triggers T-lymphocyte mediated response. The strategy to enhance immunostimulatory signals (IL-2, Flt-3-L, TLR) and block inhibitory signals, using checkpoint inhibitors (CTLA-4, PD-L-1), seems to be promising direction in the treatment of solid tumors.

RTH parameters, optimal to achieve abscopal effect, have not been reconciled. It seems that the probability of abscopal effect occurrence enhances with the increase of RT dose and the size of the treatment field.

**Conclusions:** Abscopal effect is a rare event with still not fully explained mechanisms. Previously, it was mainly observed in immunogenic tumors such as renal cell carcinoma, melanoma or hepatocellular carcinoma. However, in combination of radiotherapy and immunotherapy it is possible to be also used in less immunogenic tumors for example: non-small cell lung cancer, breast cancer, thymus cancer, lymphoma and leukaemia. Further clinical studies are necessary to gain wider knowledge of abscopal effect, in order to fully exploit its potential in clinical routine.

# GREAT EFFECT OF RADIATION THERAPY CONNECTED WITH NEOADIUVANT IMMUNOCHEMOTHERAPY IN A PATIENT WITH EXTRAMEDULLARY PLASMACYTOMA OF THE MAXILLARY SINUS – A CASE REPORT

**Mateusz Bilski, Anna Rycyk, Michał Janiszewski, Paulina Kozakiewicz, Anna Brzozowska, Paweł Cisek, Ludmiła Grzybowska-Szatkowska**

Medical University of Lublin, Department of Oncology, Lublin, Poland

**Background.** A plasmacytoma is a solitary mass of neoplastic monoclonal plasma cells arranged in clusters or sheets. It can involve almost any location outside bone marrow. Extramedullary plasmacytoma (EMP) is called a monoclonal proliferation of plasma cells except for the skeletal system where the term SBP (solitary plasmacytoma of bone) is used. Solitary extramedullary plasmacytoma (SEP), located in the soft tissue, can appear in any part of the body especially in the head and neck.

The diagnostic criteria of extramedullary plasmacytoma, published by the International Myeloma Working Group (IMWG), include: extramedullary tumor of clonal plasma cells, no M-protein in serum or urine, normal bone marrow (less than 5% plasma cells), a normal skeletal survey and no related organ involvement or damage.

Very often while observing patients with extramedullary plasmacytoma, there is a possibility of developing multiple myeloma which involves about 17-33%. However, progression of SEP to multiple myeloma stays uncommon. As for plasmacytoma,because of high radiosensitivity, radiotherapy should be a treatment of choice. In tumors larger than 5 cm neoadiuvant systemic treatment can led to shrinkage of tumor mass which enable to achieve lover doses in critical structures while administration of high total doses in target volumes. This type of combination wasn't reported in the literature before.

**Case report.** A case of a 67-year-old man with Epstain-Barr virus-associated extramedullary plasmacytoma presenting as 7x 4x 4.2 cm mass located in the right maxillary sinus, who responded to suggested treatment, is reported. The patient suffered from diplopia, proptosis, pain of the right eyeball and nasal congestion. MRI of head and neck, before starting of treatment, has shown the tumor that must have been verified by histological examination. There was no anemia or hypercalcemia and his renal function was normal so he was qualified to receive needed treatment. After receiving histological examination, the patient was referred to the Department of Radiation Therapy, Lublin Oncological Center. The patient was administered 6 cycles of VCD (Valcade, cyclophophamide, dexomethasone) neoadiuvant immunochemotherapy which led to partial regression. After that patient received radiotherapy based on IMRT technique which led to complete regression in first MRI scan performed 3 months after finishing radiation therapy.

**Conclusion.** For large (> 5 cm) extra medullary plasmocytomas localized in head and neck a neoadiuvant systemic therapy in combination with radiation therapy can led to great results with very low toxicity.

# ASSESSMENT OF CHANGES IN TUMOR VOLUME IN HEAD AND NECK CANCERS IN TERMS OF CRITICAL ORGANS

**Yonca Yahşi Çelen**

Afyon Kocatepe University, Afyon, Turkey

The aim of this study is to document the changes in anatomy and dose distribution observed in patients diagnosed with head and neck cancer who are undergoing radiotherapy or chemoradiotherapy. 25 patients, who had been diagnosed with head and neck cancer, were included in our study. Cone Beam Computer Tomography (CBCT) was taken every other day and fused with images provided by CT. If tumor volume decreased, Magnetic Resonance Image (MRI) images were taken. By integrating MRI and CT images, critical organs and Planning Target Volume (PTV) were recontoured. Using the new contours, new Adaptive Radiotion Therapy (ART) plan were made. The initial treatment plan and the ART plan were then compared using T-Testing and Wilcoxon Testing. If there was a significant difference, patients continued with treatment with the new ART plan. The mean dose for the ipsilateral parotid gland shrank from 3279±608 cGy to 2656±399 cGy (p=0.001) this was a significant decrease. The ipsilateral parotid gland volume size shrank from 15.00±8.57 cc to 10.10±5.85 cc (p=0.046) according to the adaptive CT. At the same time the mean dose for the contralateral parotid gland decreased from 3008.4±377.4 cGy to 2606.2±325.5 cGy (p=0.002) and its volume size shrank to 7.50±3.55 cc from 12.21±7.34 cc (p=0.002) according to the adaptive CT. It was observed that the ipsilateral parotid gland volume was reduced a minimum of 15% and a maximum of 46.3%. It was also observed that contralateral parotid gland volume was reduced a minimum of 16.6% and a maximum of 46.9%. Adaptive radiotherapy is superior to non-adaptive radiotherapy: it can increase the minimum dose in the target volume and reduce the maximum cumulative dose.

# INFLUENCE OF PET-CT ON IRRADIATION VOLUME TARGET DETERMINATION BASED ON PATIENT CASE ANALYSIS WITH LOCALLY ADVANCED ESOPHAGEAL CANCER

**Michał Janiszewski[1], Agnieszka Janiszewska[1], Paulina Kozakiewicz[2], Paweł Cisek[2], Mateusz Bilski[2], Izabela Kordzińska-Cisek[2], Ludmiła Grzybowska-Szatkowska[2], Pawel Korona[2]**

1 Center of Oncology in Lublin, Lublin, Poland
2 Medical University in Lublin, Lublin, Poland

**Purpose:** The aim of the study was to compare volume target, which were distinguished with the use of two available diagnostic techniques, including CT (computed tomography) and 18F-FDG PT-CT (18F-fluorodeoxyglucose positron emission tomography combined with CT). The development of radiotherapy in the treatment of cancer by introducing modern planning techniques such as 3D-CRT (3-Dimensional Conformal Radiation Therapy), VMAT (Volumetric Arc Therapy), Image-guided Radiation Therapy (IGRT) has resulted in significant decrease in the number of side effects as well as has increased the accuracy of the GTV (Gross Tumor Volume), CTV (Clinical Target Volume) and indirectly also the PTV (Planning Target Volume). So the application of modern irradiation techniques without precise description of staging cancer may not allow to achieve expected results. PET-CT imaging is becoming more and more available technique offering sensitivity and specificity that exceed those of standard imaging methods (USG, RTG, CT, MR). Current radiotherapy planning systems enable to fuse images from PET-CT with images from localized tomography.

**Materials and methods:** Two target volume of irradiation established with the use of different diagnostic techniques were compared in the same patient with the diagnosis of esophageal cancer. In both cases, radiotherapy was planned basing on IMRT. The effect of diagnostic method on the size of the primary tumor area and the lymph nodes involved was evaluated. Doses of radiotherapy that were given to the organs at risk (OARs), including heart, lung, liver, spinal cord, were also analysed.

**Results:** The case presented revealed that PET-CT plays an important role in the development of a radiotherapy plan resulting both in a decrease in GTV tumor size and widening of the GTV node area with subsequent change in the dosage in the organs at risk. Patients with esophageal cancer often complain of lack of appetite and pain provoked by eating. Irradiation may temporarily exacerbate these symptoms depending on its intensity. So the smallest area exposed is recommended with preservation of the total planned dose to be given to the areas affected by cancer with a safe margin. In the future, the role of PET-CT or similar studies based on novel marking substances will increase, which can be used not only to distinguish GTV areas, but also to determine what dose should be given to the corresponding part of the tumor depending on the degree of absorption of the so-called "dose painting".

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# DOSE DIFFERENCES BETWEEN TWO-DIMENSIONAL AND THREE-DIMENSIONAL APPROACH TO HIGH DOSE BRACHYTHERAPY DOSE REPORTING OF ORGANS AT RISK IN INOPERABLE CERVICAL CANCER TREATMENT

**Petar Chakalaroski, Violeta Klisarovska, Igor Stojkovski**

University Clinic for Radiotherapy and Oncology – Skopje, Skopje, Macedonia

**Introduction.** Definitive treatment protocols of inoperable cervical cancer utilize radiotherapy in a form of external beam (EBRT) and brachytherapy (BT).

Usually EBRT is applied in a form of concurrent chemo-radiotherapy (CCRT), followed by BT. Radiotherapy goal is to achieve a cumulative dose of 80 to 85 Gy into the target volume while obtaining optimal dose reduction in organs at risk (OAR).

Maximal tolerant doses in OAR volume of 2 ccm are 95(±22) Gy ($\alpha/\beta$=3) for bladder and 65(±12) Gy ($\alpha/\beta$=3) for rectum respectively.

Dose constrains in two-dimensional (2D) dose planning are calculated as a percentage of applied brachytherapy dose to point A, i.e. 80% for bladder and 70% for rectal dose constrain. Cumulative 2D dose constrains for the whole BT treatment (cumulative brachytherapy dose of 21 Gy) are 16.8 Gy for bladder and 14.7 Gy for rectum.

**Materials and methods.** 16 patients were analyzed (total of 48 applications) with diagnosed inoperable cervical cancer.

All patients prior have received CCRT total dose of 50.4 Gy in 28 daily fractions (5 days/week) along with weekly applied Cisplatin (for the duration of 5 weeks).

HDR BT was applied in 3 consecutive weekly applications with target dose of 7 Gy to point A per application (total of 21 Gy for the whole BT treatment).

We used GammaMedPlus™ an Ir-192 apparatus, patients were positioned on C-Arm for 2D and a computer tomography scanner for 3D planning.

Brachytherapy contouring and planning used DICOM and BrachyVision software.

Patients that received higher than dose constrains received corticosteroid and anti-inflammatory drugs.

**Results.** Bladder dose reporting for 2D planning gave an average dose (to bladder point) of 7.79 Gy per application (2.10 – 28.61 Gy) and an average of 23.37 Gy for the whole BT treatment (9.00 Gy – 68.06 Gy). 3D dose was reported in OAR volume of 2 ccm and showed an average of 5.08 Gy per application (1.70 Gy – 13.60 Gy) and 15.25Gy for the whole BT treatment (6.78 – 31.4 Gy).

Rectal dose reporting for 2D planning showed an average dose of 4.48 Gy per application (1.83 – 9.62 Gy) and an average dose of 13.45 Gy (6.33 – 22.49 Gy) for the duration of whole BT treatment. 3D dose was also reported in OAR volume of 2 ccm and the average dose per application was 3.38 Gy (1.50 – 6.53 Gy). For the whole BT treatment cumulative 3D rectal dose was 10.13 Gy in average (5.57 – 15.37 Gy).

All patients that developed mild to average irradiation side-effects such as cystitis and proctitis were successfully treated.

**Conclusion.** 3D dose (in volume) dose reporting offers combined dose/volume display, which gives information about the OAR location and volume where the dose is actually absorbed. Smaller dose-affected OAR volume – should be linked to reduced radiation toxicity.

While short term side-effects may vary, long term side-effects should correlate with lower degree of radiotherapy treatment late toxicity.

# THE EFFECT FROM PACLITAXEL/CARBOPLATIN REGIMEN TO ADVANCED OVARIAN CARCINOMA

**Violeta Klisarovska, Petar Chakalaroski, Igor Stojkovski, Gordana Petkovska**

University Clinic for Radiotherapy and Oncology, Skopje, Macedonia

**Introduction.** Ovarian cancer is the leading cause of death in developed countries and fifth most common cause of mortality in female population. Due to non specific symptoms, compression of bladder and/or rectum it is usually diagnosed in later stages. Approximately 70% are initially diagnosed in stage III with ascites. Treatment outcome is related with the stage. Clinical exam, abdominal ultrasound, CT scans and laboratory (including marker Ca125) are reguired for initial diagnosis. MR may be useful prior operation.

**Methods.** Surgery should be the first treatment option. The aim of surgery is to achieve optimal debulking, at the same time providing tissues for histopathology analysis. Further treatment depends on staging, usually chemotherapy of carboplatin-paclitaxel. The number of cycles administered depends on estimated risk of recurrence.

**Results.** This pattern can be modified to the individual characteristics of certain patients at the presentation. Patient aged 28, referred to University Clinic of Radiotherapy and Oncology in decreased performance status (ECOG1) for chemotherapy treatment with advanced ovarian carcinoma. Explorative laparotomy with multiple biopsies from otherwise, technically inoperable tumor was performed. HP diagnosis revealed ovarian cystadenocarcinoma. Initial high value of Ca125 marker (over 1000 U/ml), with other laboratory findings in referent ranges, allowed the use of chemotherapy with carboplatin-paclitaxel regimen. Pre-treatment CT (Jan 2017) showed bulky abdominal and pelvic tumour mass with enlarged lymph nodes. Her performance status improved shortly after the start of chemotherapy. Ca125 was reassessed after two cycles and its value depleted by half (Ca125=473 U/ml), thus suggesting good response. The level of Ca125 entered normal range values after the fourth cycle of chemotherapy. After the administration of planned six cycles of chemotherapy she was in good performance status, without any symptoms or complains. CT scan from (May 2017) revealed complete response, without radiological disease. Subseguent surgery (Jun 2017) was carried out and she had confirmed complete response according to histopathology analysis. First follow up, three months after the treatment (Sept 2017) consisted of clinical exam, abdominal ultrasound and measurement of Ca125 showed no evidence of disease.

**Conclusion.** This is one more confirmation for the "golden standard" of carboplatin-paclitaxel regimen in treatment of ovarian carcinoma.

# RELATIONSHIP BETWEEN O(6)-METHYLGUANINE-DNA METHYLTRANSFERASE (MGMT) PROMOTER METHYLATION STATUS AND TUMOR SIZE ON PREOPERATIVE CONTRAST ENHANCED MRI IN PATIENTS WITH GLIOBLASTOMA MULTIFORME – SINGLE INSTITUTION EXPERIENCE

**Igor Stojkovski, Gordana Petkovska, Bojana Petreska, Petar Chakalaroski, Valentina Bojovska, Violeta Klisarovska**

University Clinic of Radiotherapy and Oncology, Skopje, Macedonia

**Introduction.** O(6)-methylguanine-DNA methyltransferase (MGMT) promoter methylation status is considered as an important prognostic marker in patients with glioblastoma multiforme. Patients with methylated MGMT promoter are considered that have better prognosis, have longer disease free survival and overall survival.

**Methods.** We performed retrospective analysis of 28 patients with glioblastoma multiforme intended to be treated with radiotherapy and with known MGMT promoter status. Volume of the tumor was measured on initial MR of the brain and it was delineated on transversal MR image DICOM datasets. “Tumor” was defined as contrast enhanced region in T1 weighted image after application of i.v. contrast.

**Results.** From 28 patients, 14 patients were with methylated MGMT promotor (MGMT-M) and 14 with wild type MGMT promotor (MGMT-W). Mean MRI tumor volume in MGMT-M group was 45.41 $cm^3$ (range 4.50 $cm^3$ – 95.26 $cm^3$) and in MGMT-W group 50.46 $cm^3$ (range 3.81 $cm^3$ – 134.79 $cm^3$). Comparison of volumes of 2 groups has shown that there are no significant differences between tumor volumes in the groups p= 0.29864.

**Conclusion.** In our study we can conclude that there is no correlation between MGMT methylation status and initial tumor volume in patients with glioblastoma multiforme.

# DELAYED RADIATION DAMAGE TO LUNGS AND PELVIC ORGANS DEVELOPING IN THE PRESENCE OF T-CELL DEFICIENCY AND HUMORAL IMMUNITY ACTIVATION

**Tatiana Mushkarina, Evgenia Kuzmina, Tatiana Konstantinova, Valentina Kurasova, Nina Sirotkina**

A.Tsyb MRRC- branch of the NMRRC Ministry of Health of the Russian Federation, Obninsk, Russia

**Introduction:** Quality of life of patients after treatment of malignant neoplasms is a problem of great concern due to the possible development of complications including radiation damage. Understanding the origin of dysimmunity at the time of radiation damage forming facilitates search for and justification of using immunocorrecting measures.

**Aim:** to estimate dysimmunity in patients with radiation damage to lungs and pelvic organs.

**Materials and methods:** Immunograms of 65 patients with radiation damage to pelvic organs (proctitis, enterocolitis, cystitis) and 45 patients with radiation damage to lungs (pulmonary fibrosis) were examined by 26 parameters (relative and absolute count of T-, B-, NK-cells, phagocytes, and their functional status). Immune status was estimated before the treatment of radiation damage to pelvic organs at average in 4 years after combined treatment of cervical cancer, and before the treatment of radiation damage to lungs at average in 7 years after combined treatment of lung and breast cancer and Hodgkin's lymphoma. The control group consisted of 100 practically healthy people according to clinical laboratory data.

**Main results:** According to statistical analysis, leukocytosis occurred more often in patients with radiation damage to lung, group mean statistically significant exceeds the reference level of $7.1*10^9$ cells/l. However, in patients with radiation damage to pelvic organs leucopenia occurred more often ($5.3*10^9$ cells/l) against the normal $6.0*10^9$ cells/l. In patients with damage to lungs significant deviations from the norm occurred practically in all chains of immunity. The number of the immunity status deviations in patients with radiation damage to pelvic organs is less (14) than in patients with radiation damage to lungs (23). Lowering the lymphocytes count, suppression of T-cell immunity mainly due to reducing T-helper subpopulation, reducing proliferation of T-lymphocytes induced by mitogen PHA occurred in both groups of patients increase in the number of activated lymphocytes (31/19% vs 13% in control), activated T-lymphocytes (16/9% vs 6% in control) occurs in both groups of patients, possible due to damage to co-stimulating. Activation of T-cells is related to the increased level of spontaneous proliferation of lymphocytes, which was higher in patients with radiation damage to lung.

In both groups response of humoral immunity strengthens due to increasing the percentage of lymphocytes (11.0/9.4% vs 8.0%, norm). In patients with damage to lungs manifestation of acute and chronic B-cells activation is more pronounced (content of immunoglobulins of M and G classes (1.8 g/l vs 1.6 g/l; 15.6 g/l vs 13.4 g/l, norm). In both groups the number of phagocyting cells increased (74/74% vs 70%).

**Conclusion:** Results allows us to conclude that radiation damage develops in the presence of non-specific immunity functional failure (hyperactivation, increased phagocytosis), dysregulation of specific immunity expressed as lowering of cell and humoral antitumor T-cell immunity and rise of humoral reactions, increasing the frequency of autoimmune disorders. It should be stressed that disproportion is more pronounced in patients with radiation damage to lungs. The obtained data show that the use of immunocorrecting therapy is necessary for immunorehabilitation of patients.

# ADJUVANT CHEMOTHERAPY AND RADIOTHERAPY FOR STAGE III ENDOMETRIAL CANCER: IMPACT ON SURVIVAL

**Bojana Petreska, Slavica Veljanoska-Petreska, Igor Stojkovski, Petar Chakalarovski, Violeta Klisarovska, Gordana Petkovska**

University Clinic of Radiotherapy and Oncology, Skopje, Macedonia

**Introduction.** Adjuvant treatment options for advanced-stage endometrial cancer include chemotherapy (CT) and radiation therapy (RT), but the optimal treatment strategy is currently under debate. The aim of this study is to investigate the utilization of adjuvant RT and CT in patients with stage III endometrial cancer and their impact on overall survival (OS) and disease-free survival (DFS).

**Materials and Methods.** A retrospective review was performed of 40 patients with Stage III endometrial cancer who received adjuvant treatment at University Clinic of Radiotherapy and Oncology (UCRO) in Skopje between 2012 and 2015. Postoperative treatment was administered based on performance status and medical comorbidities. Chemotherapy regimens comprised of Carboplatin (AUC 5) and Paclitaxel (175 mg/m2), a 3-week interval for 6 cycles (chemotherapy alone) and 4 cycles (sequential arm). RT was delivered using 3-D CRT with a total dose of 50 Gy in 25 fractions prescribed in PTV for 5 weeks with/without an additional 7 Gy prescribed at a depth of 0.5 cm from the vaginal surface. The primary endpoints were overall survival (OS) and disease-free survival (DFS). Combined radiotherapy and chemotherapy were compared with radiotherapy alone and chemotherapy alone.

**Results.** The distribution of surgical stages is as follows: IIIA accounted for 60% (n=24), stage IIIB accounted for 9.8% (n=4) and stage IIIC accounted for 30% (n=12). The median age was 65 years and median follow-up was 35.5 months. There were 40 patients who received adjuvant treatment, 10% (n=4) received CT alone, 27.5% (n=11) received RT alone, and 62.5% (n=25) received sequential combined CT followed by 3D CRT with/without vaginal vault brachytherapy. Relapse occurred in 55% (n=22) of the patients. High grade and lymphovascular space invasion (LVSI) are risk factors for recurrence and poor prognosis. Overall survival (OS) and Disease-free survival (DFS) at 3 years for patients receiving combined CT and RT, adjuvant RT alone and adjuvant CT alone were 68.8%, 41.26%, and 37.57% for OS and 58.03%, 33.08%, and 24.96% for DFS, respectively. DFS and OS were significantly longer in patients treated with combined RT and CT than in those treated with CT alone (DFS: p= 0.0005; hazard ratio [HR], 5.677; OS: p= 0.0143; HR, 4.289) or RT alone (DFS: p = 0.0137; HR, 2.482; OS: p = 0.0151; HR, 3.036).

**Conclusion.** Combined modality treatment with chemotherapy and radiotherapy can improve both overall and disease-free survival in patients with Stage III endometrial cancer compared with single modality alone.

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# $^{69m}$Zn COMPLEXES WITH THIAZINE AND 2-AMINOPYRIMIDINE DERIVATIVES AS POTENTIAL ANTILEUKEMIC AGENTS

**Marina Orlova[1], Tatiana Trofimova[2], Igor Ivanov[2], Alexey Orlov[3]**

1 Lomonosov Moscow State University, Rogachev Medical Research Centre of Pediatric Hematology, Oncology and Immunology, Moscow, Russia
2 Lomonosov Moscow State University, Moscow, Russia
3 Lomonosov Moscow State University, Scientific Centre for expert valuation of medical products, Moscow, Russia

Modern radiopharmaceuticals (RPHs) can contain two active anticancer components: a suitable radionuclide and a chelator that has not only a vector but also a therapeutic effect. Among the possible chelators should be allocated 2-aminopirimidinovy cycle - one of the most important pharmacophore. Functionalized 2-aminopyrimidines are part of vitamins, coenzymes, as well as new generation drugs, including antileukemic drugs (e.g. Gleevec). Of great interest are thiazine derivatives, being the inhibitors of NO synthases (especially iNOS, overexpressed in various leukemia cells). Salicylates (Sal) and metal ions, among which an important place is occupied by zinc are also demonstrating useful properties.

As a radionuclide, we used $^{69m}$Zn produced from the photonuclear reaction $^{71}$Ga (γ, np) $^{69m}$Zn on a split microtron with the bremsstrahlung photon beam obtained the retardation of electrons with an energy of 55 MeV. $^{69m}$Zn was isolated by extraction and ion exchange chromatography (yield ~ 60%, radiochemical purity is not less than 99%). The chelators were 2-aminopyrimidine (L1), 2-aminopyrimidine salicylate (L2), N(5,6-dihydro-4H-1,3-thiazin-2-yl)benzamide (L3), and $[L1]_2ZnCl_2$ (I), and the first time obtained and characterized $[L1]_2ZnSal_2$ (II), $L3ZnCl_2$ (III). The studies were carried out using spectrophotometry, confocal microscopy, TLC, ARG, as well as MTT tests and flow cytometry on leukemia cell lines K-562, HL-60, MOLT-4, MOLT-4(res.) compared of mononuclear cells of healthy donors ((res.) is means that cells are resistant to asparaginase).

It has been shown that the compounds containing ions of zinc, salicylate and aminopyrimidine (or its derivatives) in various combinations may increase the specificity towards different types of leukemia, including MOLT-4 (res.). Introduction of aryl and acyl substituents can enhance the magnitude of the therapeutic window. The chelating of $^{69m}$Zn by ligands L1 and L2 led to the formation of radiolytic stable complexes (log $K_{binding} > 10$ for both complexes), characterized by TLC and ARG methods.

Microscopy showed all the signs of apoptosis for all compounds; however, for I, II and III complexes containing zinc, cell aggregation and the appearance of necrotic phenomena were observed. Complex III, which has a number of advantages, proved to be stable in alcohol, but unstable in aqueous and physiological solutions, which requires its packaging into polymeric carriers or hydroxyapatite (HAP). Since it has been shown that sorption does not occur upon contact of L3 with nanoparticles of GAP, this gives additional degrees of freedom of interaction for the ligand when GAP is used as a carrier for $L3ZnCl_2$.

It is important that zinc in the complex, even at low concentrations, is able to overcome the cell membrane.

# PHYTOPREPARATIONS IN THE CORRECTION OF RADIATION EFFECTS

**Olha Storchylo**

Odessa National Medical University, Odessa, Ukraine

Frequent testing of nuclear weapons, accidents at nuclear power stations have led to increased attention to the problem of correcting the effects of irradiation of living organisms. Gamma irradiation, like X-ray irradiation, belongs to the category of penetrating and, accordingly, the most dangerous types of radiation. High doses of radiation cause radiation sickness, accompanied by headache, diarrhea, nausea, vomiting, dehydration and finally death. Irradiation in small doses depletes the adrenal system and causes damage to the genome, thus the effects of irradiation are manifested in several generations of posterity of the affected organism in the form of delayed growth and development, impaired functions of the genitourinary system, heart disease, memory impairment and associative thinking, increased fatigue, and other.

Therefore, the search for the socially adapted methods for correcting the effects of irradiation of living organisms does not lose relevance. Among them, special attention is paid to phytopreparations, which in comparison with the patented preparations have low toxicity, wide spectrum of activity and soft prolonged effect. A number of phytopreparations used to correct the effects of irradiation are discussed, and a comparative evaluation of their advantages and limitations is carried out. Recommendations for the use of the most effective phytopreparations in the correction of results of low dosage irradiation are grounded.

Cancer Research

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# PHOTOCHEMISTRY OF Pt(IV) COMPLEXES PROSPECTIVE IN PHOTODYNAMIC THERAPY OF TUMORS

**Evgeni Glebov[1], Anton Shushakov[2], Ivan Pozdnyakov[1], Danila Vasilchenko[3], Alexey Melnikov[4]**

1 Voevodsky Institute of Chemical Kinetics and Combustion, Novosibirsk, Russia
2 Novosibirsk State University, Novosibirsk, Russia
3 Nikolaev Institute of Inorganic Chemistry, Novosibirsk, Russia
4 Institute of Spectroscopy of the Russian Academy of Sciences, Troitsk, Moscow, Russia

Photodynamic therapy (PDT) involves the selective damage of target tissue by using a photosensitizing drug and light. The scheme of PDT used in clinical practice is based on the formation of singlet oxygen resulted by quenching of triplet states of sensitizers (typically porphyrins) by dissolved oxygen. The requirement for oxygen is a major drawback as many malignant and most aggressive cancer cells are hypoxic. Photoactivated platinum compounds are free of this drawback. Mixed-ligand Pt(IV) complexes are considered to be prodrugs providing cytotoxic Pt(II) species. Their action is similar to that of well-known anti-cancer drug cisplatin. Similar properties are also known for several mixed-ligand Ru(II) complexes. The information on the mechanisms of photochemical processes for mixed-ligand complexes of platinum metals in the literature is scarce.

The first generation of light-induced prodrugs for oxygen-free PDT were diazide diamino complexes of Pt(IV). They are stable in cell media in dark and demonstrate light-induced cytotoxicity compared with that if cisplatin. In this work, primary photophysical and photochemical processes for *cis,trans,cis*-$[Pt(N_3)_2(OH)_2(NH_3)_2]$ and *trans,trans,trans*-$[Pt(N_3)_2(OH)_2(NH_3)_2]$ complexes were studied by means of stationary photolysis, nanosecond laser flash photolysis and ultrafast pump-probe spectroscopy.

The process of photolysis is multistage. The first stage is the photosubstitution of an azide ligand to a water molecule. This process was shown to be a chain reaction involving redox processes. The primary photochemical process is the inner-sphere electron transfer from an azide ligand to the central cation followed by the release of an azide radical to the solution bulk. Pt(IV) and Pt(III) intermediates responsible for the chain propagation were recorded using ultrafast pump-probe spectroscopy and nanosecond laser flash photolysis. The mechanism of photosubstitution is proposed.

Prolonged photolysis results in photoreduction of Pt(IV) to Pt(II). The light-induced cytotoxicity of the complexes is probably the combination of two factors, namely (i) a cisplatine-like effect of Pt(II) products (DNA platination preventing replication and transcription) and (ii) an azide radical reactivity.

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# NOVEL 1,3,4-THIADIAZOLE-CHALCONE HYBRIDS CONTAINING ANTIOXIDANT PHENOLIC MOIETY: SYNTHESIS AND BIOLOGICAL EVALUATION

**Violeta Markovic[1], Katarina Jakovljevic[1], Ivana Matic[2], Tatjana Stanojkovic[2], Milan Joksovic[1]**

1 Faculty of Science, University of Kragujevac, Kragujevac, Serbia
2 Institute of Oncology and Radiology of Serbia, Belgrade, Serbia

Anticancer hybrid molecules incorporate two or more different, covalently linked pharmacophores with ability to modulate multiple biological targets and improve therapeutic potential of the designed compounds in comparison to single bioactive precursors. Using molecular hybridization techniques it is possible to synthesize numerous hybrids based on known anticancer scaffolds leading to a more favorable pharmacological profile than the sum of each individual compounds (*RSC Adv.* 7 (2017) 28313–28349). The reported anticancer activities of 1,3,4-thiadiazoles (*Chem. Rev.* 114 (2014) 5572–5610) and chalcone analogues (*Eur. J. Med. Chem.* 98 (2015) 69–114), as well as antioxidant properties of phenolic compounds (*Cancer* 75 (1995) 1433–1439), led us to rational design and synthesis of thirteen novel molecular hybrids in moderate to good yields (53-87%). In order to examine their biological potential, antioxidative activity of the synthesized compounds was determined using DPPH assay. All synthesized hybrid molecules exhibited better radical scavenging activity compared to the referent ascorbic acid. Further, their possible effects on ROS generation in MRC-5 cells were also examined. The antiproliferative activity of the prepared compounds was determined against HeLa, HL-60 and A549 human malignant cell lines and normal MRC-5 cells. The most prominent derivatives were selected for further examination of mechanisms of the antiproliferative activity which involved cell cycle analysis, identification of target caspases involved in the apoptotic signaling pathways, *in vitro* angiogenesis assay and examination of the effects of tested compounds on gene expression levels of MMP2, MMP9, TIMP3 and VEGFA.

# LOW COUNT OF LYMPHOCYTES AND CD4 CELLS IN PATIENTS WITH PREVIOUSLY UNTREATED HODGKIN'S LYMPHOMA CORRELATES WITH UNFAVORABLE DISEASE PROGNOSIS

**Evgenia Kuzmina, Alena Terekhova, Tatiana Bogatyreva, Tatiana Mushkarina, Tatiana Konstantinova, Natalia Riabikina, Irina Zamulaeva, Svetlana Smirnova, Nina Orlova, Viacheslav Pavlov**

A. Tsyb MRRC, branch of NMRRC, Ministry of Health of the Russian Federation, Obninsk, Russia

**Introduction.** Existence of lymphocytes depletion before the treatment worsens prognosis of malignant diseases including lymphomas. Lymphocytes score is one of the negative risk predictors in the International Prognostic Score (IPS) for Hodgkin lymphoma. Recently it was found that deficiency of CD4-cells is a negative factor for Hodgkin lymphoma and other malignant neoplasms.

**The aim** is to study prognostic significance of lymphocytes depletion existing before the treatment and reduce count of CD4-lymphocytes in patients with Hodgkin lymphoma of all stages.

**Materials and methods.** Retrospective analysis of 162 case histories included information of lymphocytes and CD4 cells counts determined by flow cytometry was carried out in order to clarify relationship between the cells counts and efficiency of the first line therapy for Hodgkin lymphoma.

**Results and discussion.** Absolute lymphocytes count is reduced (≤1000/μl) in 53 (33%) of 162 patients, more of them are females (p=0.029) with unfavorable morphology (p=0.014); incidence of lymphopenia increased with increasing the stage of the disease (p=0.007) and IPS (p<0.0001). Moderate deficiency of CD4 (400-210/ μl) was found in 36 (22%) of 162 cases; in 10 (62%) of 16 males and in 2 (10%) of 20 females the lymphocytes count was within the norm. Generalized CD4-lymphopenia (≤200/ μl) was found in 24 (15%) of 162 patients; it associates with the age ≥45 (p=0.031), advanced stage of the disease (p=0.03) and IPS score ≥4 (p<0.001). At the median follow-up of 60 months progression free survival of all patients with CD4 ≤400/μl was lower, the overall survival (OS) of these patients was lower than survival of patients free of CD4-lymphopenia. Among cases with Hodgkin lymphoma, stage I-II and favorable prognosis (n=13), progression was found in patients with low CD4 count, overall survival was 100%. Among cases with Hodgkin lymphoma, stage I-II and unfavorable prognosis (n=29), in 6 patients with CD4 deficiency PFS was 50% against 95%, p=0.007; OS – 30% against 100%, p=0.001. Among patients with the disease of stages III and IV (n=120) in patients with low CD4 count (n=53) 5-year PFS was 64% against 87%, p=0.006; OS – 70% against 95%, p=0.004. Results of analysis of data of 94 cases with stages III and IV and IPS 0-3 confirmed negative effect CD4-lymphopenia (PFS 69% against 88%, p=0.054; OS – 76% against 97%, p=0.058). The study showed that CD4-lymphopenia developed before the treatment of Hodgkin lymphoma was independent prognostic factor of stages I and II of the disease, and stages III and IV with relatively favorable prognosis and IPS 0-3.

**Conclusion.** We think that easily determined indicator CD4 score is a promising test for estimating prognosis for Hodgkin lymphoma. Low CD-cells count existing before the treatment should be taken into account at planning therapy for Hodgkin lymphoma as additional indicator of unfavorable prognosis along with IPS factors. It can be used for prognosis at early stages of the disease. Existence of lymphopenia and CD4 lymphopenia requires novel therapeutic approaches, which will improve treatment outcome.

# IMMUNOREGULATORY T-CELLS IN THE ONSET OF LYMPHOPROLIFERATIVE DISORDERS AND THEIR RESPONSE TO CHEMORADIATION THERAPY

**Tatiana Mushkarina, Evgenia Kuzmina, Tatiana Konstantinova, Galina Neprina**

A. Tsyb MRRC- branch of the NMRRC Ministry of Health of the Russian Federation, Obninsk, Russia

**Purpose and objectives** of the research is to determine the count of regulatory T-lymphocytes (Treg) in patients with *de novo* Hodgkin lymphoma; *de novo* B-cell chronic lymphocytic leukemia; in the onset, recurrence period, local tumor extension and release of aberrant cells into the blood flow in patients with non-Hodgkin's lymphomas; evaluation of Treg-cells response to chemoradiation therapy.

**Materials and methods** 134 tests of peripheral blood of patients with Hodgkin lymphoma (before treatment – 19, after treatment – 10), non-Hodgkin lymphoma (local forms – 28, release into the blood flow – 6, after treatment – 12, recurrence – 13), B-chronic lymphocytic leukemia (before treatment – 40, after treatment – 6). Control group consisted of 40 practically healthy people. Treg-cells were identified by phenotype CD45+CD4+CD25+CD127-.

**Results.** At the onset of Hodgkin lymphoma, non-Hodgkin lymphoma and B-CLL Treg-cells counts were 4.94%/0.032*$10^9$ cells/l; 7.09%/0.051*$10^9$ cells/l; 7.75%/0.208*$10^9$ cells/l respectively, the norm count was (3.69%/0.031*$10^9$cells/l). In local and leukemic non-Hodgkin lymphoma the percentage and the count of Treg-cells exceeds the norm by 1.5-2 times on the average. In recurrent non-Hodgkin lymphoma relative and absolute count of T-regulators was comparable with the level before the treatment (7.83%/0.069*$10^9$cells/l, $p>0.05$). After the treatment the percentage of regulatory T-cells increased at 10.9% ($p<0.05$), the cells count decreased twofold (to 0.026*$10^9$ cells/l), in all patients emission was observed. After the treatment of B-CLL the percentage of regulator T-cells did not change, it was 8.0%, at the same time, the cells count reduced by ten times (0.018*$10^9$cells/l), most of the patients experienced remission. After the treatment of Hodgkin lymphoma the percentage of Treg-cells increased twofold 9.1%, absolute count of the cells decreased twofold (0.019*$10^9$ cells/l), no difference between relative and absolute levels in patients depending on the completeness of the response was not observed. The lower loss of Treg-cells as compared with other types of T-lymphocytes and B-cells, after treatment of Hodgkin and non-Hodgkin lymphomas and B-CLL was found in previous research. This evidences relative resistance of cells to the used methods of chemo- and radiation therapies.

**Conclusion.** Obtained results justify the need to develop the strategy of targeted elimination of Treg-cells or modulation of their suppressing function in Hodgkin and non-Hodgkin lymphomas and B-CLL, and to use the strategy in clinical practice.

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# Environmental Chemistry

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# A STUDY ON THE CATION EXCHANGE FIBERS PREPARED BY THE RADIATION-INDUCED GRAFTING

**Joon-Pyo Jeun, Yeong-Ju Lee, Phil-Hyun Kang**

Korea Atomic Energy Research Institute, Jeongeup-si, Jeollabuk-do, South Korea

Water pollution caused by industrial water and domestic wastewater can cause serious problems that destroy ecosystems and adversely affect human health. In order to solve these problems, various studies have been carried out by various methods such as purification, adsorption, ion exchange, membrane separation, oxidation and reduction. In particular, ion exchange materials are one of the most promising fields because they are renewable and environmentally friendly and economical.

In this study, ion exchange materials were developed using environmentally friendly cellulose. Cellulose has a molecular structure of linear chain with many hydroxyl groups, and the hydroxyl group has possible uses for various applications after surface modification.

The graft copolymerizaton using a radiation is an effective method for surface modification of the chemical and physical properties of cellulose. Graft copolymerization makes it possible to form a functional material by attaching a functional polymer chain to the surface of the base polymer. Graft copolymerization of glycidyl methacrylate (GMA) onto cellulose is advantageous because of the epoxy group.

During GMA grafting copolymerization onto cellulose, the epoxy ring is initiated through irradiation. Ring opening of the epoxy group of GMA generates new functional groups. The ring-opened epoxy groups were converted to a sulfonic acid group as a cation-exchange group to adsorb pollutants. The sulfonic acid groups have been known as one of the most efficient functional for removal toxic material ions of water.

To prepare ion exchange fibers, GMA was grafted onto cotton cellulose by electron beam irradiation. The energy of electrons generated an absorbed dose of 100 kGy with a 5 MeV acceleration voltage, and the current 17.7 mA. And then, treatment with sulfonic acid was performed to react with the cation pollutants. The grafting reaction was carried out by the pre-irradiation method and the degree of grafting was determined as a function of reaction time. The degree of grafting increased up to about 800% with the increase of reaction time. The prepared samples were characterized by SEM, elemental analysis, FT-IR spectroscopy, TGA and DSC. And then, the ion exchange capacity of the sulfonic acid groups introduced onto the GMA-grafted cellulose was evaluated.

# CHEMICALLY DEPOSITED ELECTROCHROMIC FILMS AND SOLAR LIGHT MODULATION

**Isak Aliji[1], Julijana Velevska[2], Metodija Najdoski[3], Atanas Tanuševski[2]**

1 Faculty of Natural Sciences and Mathematics, Tetovo State University; Institute of Physics, Faculty of Natural Sciences and Mathematics, Sts Cyril and Methodius University, Tetovo; Skopje, Macedonia
2 Institute of Physics, Faculty of Natural Sciences and Mathematics, Sts Cyril and Methodius University, Skopje, Macedonia
3 Institute of Chemistry, Faculty of Natural Sciences and Mathematics, Sts Cyril and Methodius University, Skopje, Macedonia

Chemical bath deposition method was employed for preparation of iron hexacyanoferrate (FeHCF), cobalt hexacyanoferrate (CoHCF), and tungsten oxide (WO) films. The films were deposited onto fluorine doped tin oxide (FTO) coated glass substrates. For practical electrochromic investigations, an electrochromic test device (ECTD) was constructed consisted of FeHCF (or CoHCF) film as working electrode, together with WO film as counter electrode, in 1 M KCl aqueous solution as an electrolyte. Visible transmittance spectra were recorded in-situ. The output integral of the spectral intensity and the integral of the spectral modulation, as well as the saved energy, were calculated by taking the solar irradiance spectrum AM 1.5 for a normal illumination on the ECTD and the transmittance data of the bleached and the colored states.

# INCOMPATIBLE ELEMENTS IN BOTTOM SEDIMENTS FROM ACARAY DAM RESERVOIR – EASTERN PARAGUAY

**Juan F. Facetti-Masulli[1], Peter Kump[2], Virginia Romero de González[3]**

1 Universidad Nacional de Asunción, Asunción, Paraguay
2 Jožef Stefan Institute, Ljubljana, Slovenia
3 Comisión de Energía Atómica, Asunción, Paraguay

Incompatible elements (IE) from the bottom sediments of the Acaray reservoir in the Alto Paraná region of Eastern Paraguay were investigated by EDXRF technique; most of them are refractory, that is, they maintain their primary relationships and are transferred almost directly into sediments and thus, they are considered as geoindicators. In this regard, IE are of utmost interest in sediments studies. The refractory trace elements analyzed were Y-Rb-Sr-Zr-Nb-Ba-La-Ce-Nd, using an Am source and the minor elements Ti-Mn-Fe, with an X-ray tube. Samples were taken from six different stations. Interesting correlations were found with sediments from the Itaipu Dam segmented body and at some sampling sites slight positive anomaly of Ce was found. The sediments also present the signatures of the sandstones from Misiones Formation, as per their spidergrams. The Acaray Power Plant Dam, was the first built in the country (1967); its reservoir covers an area of 20 $Km^2$ and has a volume of $10^8 m^3$.

# MECHANISMS OF MICROPOLLUTANTS PHOTOOXIDATION BY NATURAL PHOTOSENSITIZERS

**Ivan Pozdnyakov[1], Peter Sherin[2], Tamara Romanova[3], Feng Wu[4], Olga Shuvaeva[3], Victor Plyusnin[1]**

1 Voevodsky Institute of Chemical Kinetics and Combustion, Novosibirsk State University, Novosibirsk, Russia

2 International Tomography Center, Novosibirsk State University, Novosibirsk, Russia

3 Nikolaev Institute of Inorganic Chemistry, Novosibirsk State University, Novosibirsk, Russia

4 Wuhan University, Wuhan, China

Photochemical processes playing important role in global cycles of organic nutrients in environment. For example, photosynthesis is on of the most known and important photochemical events which support existence of life on the Earth. Less known but no less important process is photodegradation which in opposite to photosynthesis leads to transformation of organic carbon to inorganic one. Humic substances (HS, including humic and fulvic acids) and Fe(III) complexes are naturally photoactive components, which widely present in surface waters. Both classes are able to generate reactive oxygen species (ROS) under solar irradiation, which can react with dissolved organic pollutants initiating their degradation. That is why much attention is paid nowadays to investigation of HS and Fe(III) complexes photochemistry and to development of approaches to water treatment based on generation of ROS.

The talk exhibits several examples of mechanistic study of emerging micropollutants UV photooxidation by Fe(III) species and humic substances (*Chemosphere* 146 (2016) 280-288; *Photochem. Photobiol. Sci.*, 2016, 15, 431-439; DOI 10.1007/s11356-017-8580-x; *Chemosphere*, 181 (2017) 337-342). Main information was obtained by combination of steady-state and flash photolysis methods with ICP-AES, ICP-AES-HG, LC and LC/MS techniques. Main attention was paid to:

(i) identification of active short-lived transient species (including ROS, triplet states and organic radicals)

(ii) nature of final photoproducts

(iii) quantum yields of photoreactions

(iv) construction of whole mechanism of photodegradation of target compounds

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# TRACE AND MINOR ELEMENTS IN SUSPENDED SEDIMENTS OF SELECTED RIVER AND BROOKS FROM EASTERN PARAGUAY BY X-RAY FLUORESCENCE

**Juan F. Facetti Masulli[1,3], Peter Kump[2], Mirna Delgado[3]**

1 Universidad Nacional de Asunción, Asuncion, Paraguay
2 Jožef Stefan Institute, Ljubljana, Slovenia
3 Hydroconsult SRL, Asuncion, Paraguay

Selected minor and trace elements in suspended sediments from the Tebicuary River, a tributary of the Paraguay River, as well as from Tapiracuai, Yhu and Kuarepotí Brooks on the left side of the later river basin have been investigated by X-Ray Fluorescence (XRF) techniques to determine their correlation as well as provenance. The analysis of complex spectra was performed by the AXIL software and the quantitative analysis by the QAES software. Analyzed trace and minor elements were the refractory Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Nd as well Ti, Cr, V, Mn, Fe, Cu and Zn from the 3d series. The spidergrams of refractory elements normalized to Primordial Mantle (PM) and Upper Crust (UC) values suggest the recycling of materials of the sediments ie, they have been subjected to weathering cycles. Spidergrams of the 3d elements normalized to PM present the typical W distribution.

# APPLICATION OF NOVEL ANALYTICAL METHODS FOR PESTICIDE DICAMBA DETERMINATION IN BABY FOOD

**Ana Miletic, Emilija Pecev Marinkovic, Aleksandra Pavlovic, Snezana Tosic, Ivana Rasic Misic**

Faculty of Sciences and Mathematics, University of Nis, Nis, Serbia

**Introduction.** Dicamba is a selective systemic herbicide, belongs to the group of Phenoxy acid herbicides (PAs). It is used in agriculture against annual and perennial broad-leaved weeds and brush species. Due to they strong polarity PAs can easily dissolve and diffuse in waters. By moving in agricultural ecosystems, they can lead to the contamination of the environmental surface and waters. They can cause soft tissue carcinoma in humans and embryotoxicity in animals.

Many analytical techniques like HPLC, UHPLC, LC-MS/MS, has been used for determination of pesticide dicamba.

**Materials and methods.** The purpose of this paper was the application of a new kinetic-spectrophotometric method and HPLC method for the determination of residues pesticide dicamba in baby food based on cereals. The method is based on the inhibited effect of dicamba on the oxidation of sulfanile acid (SA) by hydrogen peroxide in universal buffer in presence Co(II) ion. The reaction was monitored spectrophotometrically by measuring the increase in absorbance of the reaction product at 368 nm. Calibration curves were constructed in the interval of 0.31 to 3.10 μg $mL^{-1}$ and from 3.10 to 31.0 μg $mL^{-1}$ dicamba concentration. Twenty five commercially available baby foods were used for the optimization and validation of the analytical method. For the real sample analysis, baby food of different brands produced by different companies was purchased in 2015 in local supermarkets. After appropriate preparation of food samples kinetic method and HPLC method were successfully applied for determination of dicamba in baby food with recovery of 91.25-105.85%, and of 92.50-107.11%, respectively. Statistical comparison of the results with parallel HPLC method showed good agreement and indicates no significant difference in accuracy and precision.

**Conclusion.** The proposed kinetic method was applied to the determination of dicamba in baby food samples using the direct calibration curve. It can bee concluded that the results obtained for the kinetic method are in accordance with the HPLC method, and F and t values at 95% confidence level are less than the theoretical ones, confirming no significant differences between the performance of the kinetic and HPLC method. Both recovery percentages and relative standard deviations (RSD) were satisfactory and indicated good performance of the proposed method for the analysis of dicamba in baby food. The proposed method is highly sensitive and simple, rapid, inexpensive and the precision is very acceptable for the determination of low ranges of dicamba in the real samples.

# THE USE OF THE NEUTRON ACTIVATION ANALYSIS TECHNIQUE TO DETERMINE HEAVY METALS IN *NICOTIANA TABACUM SOLANACEAE*

**Tufic Madi Filho[1], Elson Barros Ferreira[2], Maria da Conceição Costa Pereira[1], José Roberto Berretta[1]**

1 Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP, São Paulo, Brazil
2 Secretaria da Educação do Estado de São Paulo, São Paulo, Brazil

Tobacco addiction has been mentioned as a leading cause of preventable illnesses and premature disability and tobacco smoking is the main cause of lung cancer and one of the factors that most contribute to the occurrence of heart diseases, among others. The herbaceous species *Nicotiana tabacum* is a plant of the *solanaceae* family used for tobacco production.

Some authors have researched about heavy metals and the toxicity of tobacco. Heavy metals are frequently found in low concentrations in ground, superficial and underground waters, even though it does not have environmental anthropogenic contributions. However, with the increase of the industrial activities and mining and the agrochemical use of contaminated organic and inorganic fertilizers, an alteration of the geochemical cycle occurs. As a consequence, the natural flow of heavy metals increases the release of these elements into the biosphere, where they are frequently accumulated in the superior layer of the ground, accessible to the roots of the plants.

Traces of available heavy metals may be found in surface and subsurface aquatic systems and soils, even when there is no anthropogenic influence on the environment, and they frequently accumulate in the upper layer of the soil, where they are accessible to the roots of the plants. Except for the exclusion species, most plant species that grow on soil contaminated by heavy metals cannot avoid the absorption of these elements, but only limit their translocation.

During planting and plant development, fertilizers and insecticides, including organochlorines and organophosphates, are used and the smoke from cigarette smoking presents various toxic substances, including heavy metals such as Chromium (Cr) and Manganese (Mn).

The samples preparation procedures were carried out in our laboratories and submitted to the irradiation with thermal neutrons in the IPEN/CNEN-SP, in the IEA-R1 research reactor. The irradiated material was analyzed by gamma spectrometry using a high purity germanium detector (HPGe).

# QUANTIFICATION OF HEAVY METALS AND TRACE ELEMENTS IN SOILS AROUND METALLURGICAL INDUSTRY BY COMBINED ATOMIC AND NUCLEAR TECHNIQUES

**Antoaneta Ene[1], Florin Sloata[1], Marina V. Frontasyeva[2], Dana Iulia Moraru[1], Sergey S. Pavlov[2]**

1 Dunarea de Jos University of Galati, Galati, Romania
2 Joint Institute of Nuclear Research, Dubna, Russia

Soil around industrial enterprises is subjected to contamination with heavy metals and other toxic elements and its quality must be protected from inorganic pollutants. In this paper, determination of concentrations of selected chemical elements in soil samples collected in the vicinity of an iron and steel enterprise in Romania was conducted in order to assess the anthropogenic impact of metallurgical industrial activity on the study area.

The soil samples were collected at sites located in the industrial area of the iron and steel plant, in the western part of Galati town, SE Romania. Soil samples were randomly taken, during several campaigns, from three depths (0, 5 and 30 cm), close to the coking plant, sinter plant, steel plants, blast furnaces, zinc plating section, mills, lime factory, slag dump and decantation pond.

The samples were analyzed by combined atomic and nuclear methods, such as X-ray fluorescence (XRF), atomic absorption spectrometry (AAS) and epithermal neutron activation analysis (ENAA), employed in collaborating research laboratories of Dunarea de Jos University of Galati, Romania, INPOLDE international network and the IBR-2 nuclear reactor of the Frank Laboratory of Neutron Physics, Joint Institute of Nuclear Research in Dubna, Russia. A total of 45 chemical elements were quantified, included heavy metals, trace and radioactive elements: Al, Ti, V, Cr, Mn, Fe, Ni, Co, Zn, As, Mo, Cu, Sb, Sn, Cd, Pb, Nb, Br, Rb, Sr, Y, Hg, Zr, Na, Mg, K, Ca, Cs, Ba, I, La, Ce, Nd, Sm, Eu, Tb, Dy, Tm, Yb, Hf, Ta, W, Au, Th, and U. The results obtained are discussed in relation with Romanian norms regarding the levels of heavy metals and toxic elements in soils with various usages.

# HEAVY METALS IN *PRIMULA VERIS L., PRIMULACEAE* - THEIR SPREAD IN KOSOVO

**Arjana Ylli, Laura Binxhija (Qeska)**

Biotechnology Department, Faculty of Natural Sciences, University of Tirana, Tirana, Albania

*Primula veris L.,Primulaceae*, is found in various regions of Kosovo and it is widespread throughout Central Europe and East Asia. *Primula veris* is extensive in Kosovo mountains and hills as well as in sub alpine areas. It is mainly grown in slightly destroyed forests and in open forests. During this work we intended to study the presence of heavy metals in this plant. We collected samples of *Primula veris L.,Primulaceae,* in an area such is Novo Brdo location, as an clean environment, with no pollution impacts. Also samples of Primula veris L*., Primulaceae* have been taken in Badovc near Pristina, known as environmentally clean zone. Materials such as soil, flower, stem, root have been collected in all area indicated below. This large collection of biological material has been carry out, not only to analyze the distribution of heavy elements, like Cd, Cu, Fe, Ni, Pb, Zn, but also to evaluate correlation between them and to study a number of other indicators. During the analysis of *Primula veris L, Primulaceae* materials such as soil, flower, stem, root have been obtained by selected areas in Badovc and Novo Brdo. Analysis of samples and evaluation of heavy elements has been conducted using an Inductively Coupled Plasma atomic emission spectroscopy (ICP-AES), to determine concentrations of trace to major elements, according to EPA method. 6010C: 2007. In both study areas, Cd has not been met in analyzed soil and plants in any indication. In the area of Novoberdo, Fe and Pb are at high levels, but these are not reflected in as high as in selected parts of plants, flower, stem and root of *Primula veris L,.*

**Key words:** *Primula veris,* macro elements, heavy elements, medical plants

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# Environmental Physics

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# STUDY OF THE BANK-FILTERED ZAGREB AQUIFER SYSTEM USING ISOTOPE ANALYSES NEAR WELL FIELD KOSNICA

**Jadranka Barešić[1], Zoran Kovač[2], Jelena Parlov[2], Ivona Mijatović[2], Andreja Sironić[1], Damir Borković[1], Ines Krajcar Bronić[1]**

1 Ruđer Bošković Institute, Zagreb, Croatia
2 Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia

The Sava River is the longest river in Croatia and the main source of water for the Zagreb aquifer system. The fluctuations of the Sava River water levels cause fluctuations in the groundwater levels of the Zagreb aquifer, especially in the vicinity of the Sava River. Due to constant decrease of groundwater levels and possible groundwater quantity issues, especially in dry periods, construction of a new regional well field Kosnica is in progress. Kosnica well field is considered as a main well field supplier for Zagreb and determination of recharge areas is of prime concern, as such areas have to be protected in order to preserve good groundwater quality and quantity. Groundwater often consists of a mixture of recharge from surface water (lakes or rivers) and local precipitation. It is important to know the proportions of the recharge components in order to increase the sustainable supply of drinking water through bank infiltration, and to prevent drinking water pollution by infiltration of water from a contaminated surface water source.

Different recharge components can be identified through the stable isotope composition of groundwater (d$^2$H and d$^{18}$O) because of different isotope composition of end components and evaporation in surface water bodies. Tritium has also been used as a good tracer. In the case of the Sava River there is additional source of anthropogenic tritium from Krško Nuclear Power Plant (30 km upstream from Zagreb) which can be used as a tracer.

Samples for determination of isotopic composition, $^3$H activity and d$^2$H and d$^{18}$O, were collected during 2016 in the Sava River, precipitation (monthly samples from Zagreb–Grič, meteorological station included in GNIP–Global Network of Isotopes in Precipitation) and groundwater at 10 monitoring wells close to the Sava River. $^3$H activity was measured by liquid scintillation counter (Quantulus 1220) and samples were electrolytically enriched before measurement. d$^2$H and d$^{18}$O were determined by Liquid water isotope analyser, Los Gatos. Significant increase of $^3$H activity in the Sava River was observed in October 2016, (178 ± 21) TU, and in groundwater of the observation well nearest to Sava River with damped response (maximum 35 TU) and with delay of 2.5 months related to the Sava River. This increase was explained by release of tritiated water from the Krško Nuclear Power Plant. Stable isotope analyses showed similar range of $\delta^2$H and $\delta^{18}$O values for the Sava River and groundwater samples with higher variations in surface water. Differences in monthly variations of $\delta^{18}$O values between particular monitoring wells, together with $^3$H values, indicated different infiltration times of surface water of the Sava River to different observation wells in the vicinity of Kosnica well field.

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# ENVIRONMENTAL ISOTOPE RESEARCH FOR A MORE EFFICIENT PROTECTION OF THE FUTURE KOSNICA WELL FIELD (ZAGREB, CROATIA)

**Zoran Kovač[1], Jelena Parlov[1], Jadranka Barešić[2]**

1 Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia
2 Ruđer Bošković Institute, Zagreb, Croatia

The Zagreb aquifer presents the main source of potable water for the City of Zagreb and part of Zagreb County, and is protected by Croatian state government. In the last decades issues regarding groundwater quantity and quality have been observed. Groundwater levels are declining in average 1-2 m per decade, generally due to lowering of the Sava River bed and excessive pumping. Currently, groundwater for water supply is pumped from six different well fields. There is new regional well field Kosnica on-going project, with aim to avoid groundwater quantity issues in future, especially in dry periods. Isotopic research at Kosnica site has been performed in 2016. Samples from the Sava River, Zagreb precipitation and groundwater from 10 observation wells were taken on monthly basis. The Sava River has been identified as a main boundary condition of the Zagreb aquifer. The influence of this boundary, on groundwater levels in the Kosnica area, has been investigated. Kosnica well field is located approximately 800 m from the Sava River what suggested, as well as all the results of previous research, that the Sava River will be the main source of recharge for the new well field. Previous researches recognised three main zones of identical groundwater table changes in time. Recession curve models also revealed areas near the river with higher impact of the Sava River on groundwater levels. Water stable isotopes ($^{2}H$ and $^{18}O$) were determined by liquid water isotope analyser, Los Gatos Research. Data was prepared, processed and interpreted in LIMS (laboratory information management system). $^{3}H$ activity was measured by liquid scintillation counter (Quantulus 1220) and samples were electrolytically enriched before measurement. The results of environmental isotopes measurements in groundwater near Kosnica well field in the Zagreb area indicate strong connection between the Sava River and nearby observation wells. Accordingly, mixing of water from the Sava River and groundwater is occurring in the near vicinity of the Sava River and it weakens further away. Furthermore, local precipitation has a small contribution to groundwater recharge and attention needs to be directed to the Sava River. Determined groundwater velocity in combination with existing Croatian legislation point to the distinction of two different protection zones between the Sava River and the Kosnica well field. The results of this study allow better understanding of the relationship between surface water and groundwater and consequently more precise definition of the sanitary protection zones of the Kosnica well field.

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# GEOEFFECTIVE IMPACTS OF SOLAR AND GEOMAGNETIC DISTURBANCES

**Milena Cukavac[1], Elra Hasanagic[1], Spomenko Mihajlovic[1], Lazo Pekevski[2], Jovica Jankovic[1], Miodrag Rasic[1]**

1 Republic Geodetic Authority, Belgrade, Serbia
2 University “Sts. Cyril and Methodius”, Seismological Observatory, Skopje, Macedonia

When we discuss space conditions or the space weather, then we notice the parameters of speed and strength of the solar wind, observe the activity of sunspot groups, during the one or more solar cycles. Conditions in space or solar weather often can be determined by activity of CMEs emission (Coronal Mass Ejections), or by eruptions of coronal plasma and energy. *Solar Weather* is changed as is changed number of registered solar storms, number and speed of magnetic clouds and if they were observed by weakening or intensive magnetic storms. At a distance of one or two astronomic units (AU), as the solar wind became stronger and accelerated, the conditions in the geomagnetic activity were changed. Hourly, daily, monthly and yearly values of index of the solar and geomagnetic activity, appearance of the magnetospheric, ionospheric and geomagnetic disturbances and geomagnetic storms constitutes *Magnetic Weather*. All the changes in the magnetic weather can influence processes and dynamic in Earth’s atmosphere, climate and directly and indirectly influence living organisms.

Solar-geophysical processes which determine changes in the index of solar-geomagnetic activity will be analyzed in this study. These are changes in the speed and power of the Solar wind, the appearance of intense solar flares, which are associated with the emission of Coronal Mass Ejections (CMEs) and the radiation of coronal holes (CH). The geoeffective impact of solar-geomagnetic disturbances will be analyzed on the case of three solar and geomagnetic storms (March 2013, March 2015 and September 2017).

**Key words:** Solar and magnetic weather, solar, magnetic storms, solar fler, CME’s, CH, magnetic clouds

# SPACE WEATHER EFFECTS ON IONOSPHERE CONTAMINATION BY HEAVY IONS ORIGINATED FROM SPACE DEBRIS

**Nadezda Yagova, Evgeny Fedorov**

The Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences (IPE RAS), Moscow, Russia

The total mass of space debris in the outer magnetosphere (about and above the geostationary orbit) is comparable with the total mass of the natural magnetospheric particles in this region of space. Degradation of macroscopic fragments is caused by space radiation and it can lead to growth of heavy ion concentration in the outer magnetosphere. These ions are influenced by the same processes plasma processes as the background population of magnetospheric ions and they can be lost in the ionospheres during magnetic storm intervals. Physical mechanisms for space weather sources of contamination of the ionosphere by heavy ions (probably, with a fraction of active isotopes) from high apogee space debris and possible levels under various space weather parameters are discussed.

# ANALYSIS OF AEROSOLS IN AIR AFTER FIREWORKS IN THE CITY OF RIJEKA BY X-RAY FLUORESCENCE TECHNIQUE (XRF)

**Gordana Žauhar[1], Marija Čargonja[2], Darko Mekterović[2]**

1 Medical Faculty and Department of Physics University of Rijeka, Rijeka, Croatia
2 Department of Physics University of Rijeka, Rijeka, Croatia

Influence of fireworks on air pollution in the city of Rijeka was measured by X-ray fluorescence technique (XRF). Fireworks are great fun but unfortunately firework smoke is rich in tiny metal particles. Because of that fireworks can pollute the air with toxic heavy metals such as copper, strontium, lithium, lead, mercury, aluminium, cadmium, barium, etc.

Concentrations of fine particulate matter ($PM_{2.5}$) were monitored in the city of Rijeka, Croatia from 2014 until 2018. In this period, large concentrations of toxic heavy metals have been recorded after big fireworks especially in the period around the New Year and after football matches. The fine aerosol sampling on thin Teflon filters and subsequent XRF elemental analysis were performed.

During the four years of monitoring of fine particulate matter in the city of Rijeka we have measured particularly high concentrations of strontium in air after fireworks. The pollution levels were up to 65 times the usual level of strontium in the air.

Neutron
and
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# ON THE GROUND-STATE NUCLEAR PROPERTIES OF SUPERHEAVY Hs, Ds AND Cn NUCLEI

**Şevki Şentürk, Tuncay Bayram**

Department of Physics, Karadeniz Technical University, Trabzon, Turkey

One of the important topics in nuclear physics research is superheavy nuclei. Still synthesizing of superheavy nuclei researches are continued in lab. These efforts also trigger theoretical studies on nuclear structure properties of superheavy nuclei. In the present study, we have investigated nuclear ground-state properties of isotopic chains of Hs (Z=108), Ds (Z=110) and Cn (Z=112) superheavy nuclei by using Relativistic Mean Field (RMF) approach which is well know as successful model for description of finite nuclei. The binding energies, two-neutron separation energies, alpha decay energies, charge radii and quadruple moment deformation parameters of considered isotopic chains have been calculated by using non-linear version of RMF model with NL-SH and NL3* parameter sets. The results have been found as in agreement with the limited number of experimental data. Also, alpha decay half-life of the considered nuclei has been predicted by using a semi-empirical formula based on our calculated results. Furthermore, the nuclear ground-state properties of Hs, Ds and Cn isotopic chains have been carried out by using RMF model.

# CHARACTERIZATION MEASUREMENTS OF E_LiBANS THERMAL NEUTRON SOURCE

**Valeria Monti[1], Marco Costa[1], Elisabetta Durisi[1], Lorenzo Visca[1], Marco Ferrero[1], Roberto Bedogni[2], Matteo Treccani[2], Oriol Sans-Planell[2], Silvia Anglesio[3], Katia Alikaniotis[4], Gianrossano Giannini[4], Andrea Pola[5], Davide Bortot[5], Jose Maria Gomez-Ros[6], Luca Menzio[1], Ettore Mafucci[1], Nicola Amapane[1]**

1 Università di Torino, Torino, Italy
2 INFN Frascati, Frascati, Roma, Italy
3 Azienda Ospedaliera San Luigi Gonzaga, Orbassano, Torino, Italy
4 Università di Trieste, Trieste, Italy
5 Politecnico di Milano, Milano, Italy
6 CIEMAT, Madrid, Spain

In the framework of the E_LiBANS project (INFN, CSN 5) an intense thermal neutron source has been designed and characterized at the Physics Department in Turin, using novel diagnostics developed inside the project.

This contribution is focused both on the analysis of the experimental data and the comparison with the MCNP6 simulation predictions.

An extensive simulation study has been carried out to find the optimal configuration of the source beam shaping assembly. Suitable materials and geometries have been chosen to slow down neutrons to thermal energy and to reduce gamma contamination and the fast-neutrons component in an easily accessible irradiation cavity where samples can be exposed to the neutron field. In the final source configuration the dimension of the cavity can vary up to a maximum cross section of 30 cm by 30 cm and with an expandable depth from 5 cm to 40 cm with the possibility to work in open or closed modality.

To qualify the thermal neutron field measurements have been carried out with different techniques. Active detectors, based on silicon diodes, developed inside the project, have been employed to determine the neutron fluence rate together with gold activation foils. The spatial homogeneity of the neutron field has been checked with a matrix of novel active devices based on silicon carbide detectors. The neutrons energy spectrum has been measured with a Bonner Spheres System coupled with the novel thermal neutron rate detector. The gamma contamination of the thermal neutrons field has been determined inside the irradiation cavity using Geiger counter and film badge dosimeters. Furthermore gamma and neutron ambient dose equivalents around the source have been measured for radiation protection assessments.

The results of the characterization measurements together with a description of instruments and methods are the content of this communication.

# THE E_LIBANS PROJECT: INTENSE THERMAL AND EPITHERMAL NEUTRON FIELDS BASED ON A MEDICAL LINAC

**Marco Costa[1], Nicola Amapane[1], Elisabetta Durisi[1], Valeria Monti[1], Lorenzo Visca[1], Roberto Bedogni[1], Oriol Sans Planell[1], Andrea Pola[3], Davide Bortot[3], Gianrossano Giannini[4], Katia Alikaniotis[4], Ugo Nastasi[5], Silvia Anglesio[6], Marta Ruspa[1], Luca Menzio[1], Ettore Marcello Mafucci[1]**

1 University & INFN Torino, Torino, Italy
2 INFN Frascati, Frascati, Italy
3 Politecnico & INFN Milano, Milano, Italy
4 University & INFN Trieste, Trieste, Italy
5 Azienda Ospedaliera San Giovannni Antica Sede, Torino, Italy
6 Azienda Ospedaliera San Luigi Orbassano, Orbassano, Italy

The E_LIBANS project (INFN, CSN 5) aims, in its first stage, at producing intense thermal neutron fields for diverse interdisciplinary irradiation purposes. The primary source will be a reconditioned medical LINAC Elekta SL18, recently commissioned in a dedicated bunker at Physics Department and INFN in Torino.

The LINAC has been configured to deliver gamma or electron beams with or without flattening filters. Different primary electron beam energies can be chosen up to 18 MeV. The Linac head was coupled with a photoconverter-moderator apparatus, developed within the e_LiBANS collaboration, equipped with a 30x30xL $cm^3$ irradiation cavity. The depth L can be modulated between 10 cm and 40 cm. Taking advantage of extensive Monte Carlo simulations, the photoconverter and moderator designs were optimized to achieve a pure thermal spectrum, very few gammas and nearly constant homogeneity profile in the irradiation cavity.

To measure and to characterize in real time the intense field inside the cavity new thermal neutron detectors based on silicon and silicon-carbide devices were designed with high radiation resistance, low noise and very high neutron-to-photon discrimination capability. All devices have been calibrated to a metrological reference.

This communication gives an overview of the E_LIBANS project, describes the results of the benchmark experiments and gives the possible applications of this novel facility.

# APPLICATION OF TAGGED NEUTRON TECHNOLOGY FOR MEASURING RESPONSE OF GAMMA-DETECTORS TO 14 MeV NEUTRONS

**Maxim Karetnikov**

All-Russia Research Institute of Automatics, Moscow, Russia

A measurement of gamma-spectrum at the 14 MeV neutron background is urgent for some problems of applied nuclear physics such as diagnostics of thermonuclear plasma and neutron activation analysis. A response of scintillation gamma-detectors to 14 MeV neutrons can be determined by experimental or numerical simulations. A certain difficulty at the numerical simulation is caused by assessment of a scintillator light output from secondary charged particles. For its correct calculation one should predict an energy dependence of light output for protons, deuteron and alpha-particles generated in (n,p), (n,d) and (n,α) reactions at the neutron interaction with the scintillator. In experiments it is preferable to use monoenergetic 14 MeV neutrons without gamma-background or slowed-down neutrons. It is not an easy mission as far as the generation of 14 MeV neutrons is accompanied by emission of gamma-rays and moderated neutrons due to 14 MeV neutron interactions with the body of the neutron generator. This problem can be overcome by time-of-flight methods when the 14 MeV neutrons are separated by time from the gamma-rays and moderated neutrons. The report considers an application of a tagged neutron technology for calibration of gamma-detectors by 14 MeV neutrons. It is based on the following. At the T(d,n)He4 reaction each 14 MeV neutron is accompanied (tagged) by 3.5 MeV alpha-particle emitted in the opposite direction. A position- and time-sensitive alpha-detector provides time and coordinates of the associated alpha-particle providing the time and direction of neutron escape. Measuring the time between the recording of signals at the gamma- and alpha-detectors, it is possible to separate gamma-signals caused by 14 MeV neutrons, gamma-rays and slowed-down neutrons. The response of inorganic (LaBr3, BGO, LYSO, NaI) scintillators to 14 MeV neutrons was measured. The data are in a good agreement with the results of numerical simulations and experiments of other teams.

# BEAM INSTRUMENTATION OF FLNR JINR ACCELERATOR COMPLEX FOR APPLIED PHYSICS RESEARCHES

**Semen Mitrofanov**

JINR FLNR, Dubna, Russia

FLNR's unique particle accelerators provide excellent possibilities for a wide range of both applied physics and fundamental researches in the range of high energy (1-63 MeV/nucleon) heavy ion beams. The talk will present the FLNR activities in the field of the interactions between heavy ions and matter: radiation hardness tests of space and avionic microelectronics and radiobiological effects.

Onboard equipment of spacecraft is exposed to ionizing radiation from the Earth's natural radiation field, as well as galactic and solar cosmic rays during its operation. There are two types of effects in microelectronic circuits caused by radiation: 1—those related to accumulated dose; and 2—those caused by a singular hit of a swift heavy ion (single event effect, SEE). Despite its relatively minor contribution (~1%) of the total amount of charged particles, it is heavy ions that cause the most damage to microelectronics hard ware components due to the high level of specific ionization loss. Hence, to reproduce the effects of the heavy ion component of cosmic radiation for the prediction of electronic device radiation hardness usage of low intensity (up 106 ions cm−2 s−1) heavy ion beams with linear energy transfer (LET—the measure of energy losses per path length in the material) levels in silicon, specific for the ion energy range of 50–200MeV/nucleon, is supposed. Considering that actual integrated circuits in metal and plastic packages, as well as ready to use electronic boards need to be tested, ion beams with energies in the range of 3–50 MeV/nucleon are used in model experiments. The SEE testing facility was established at the accelerator complex of the Flerov Laboratory of Nuclear Reactions (FLNR) of the Joint Institute for Nuclear Research (JINR). The full value facility, consisted of three different beamlines, was successfully commissioned and routinely used.

Historically, radiobiological studies at JINR have been mainly aimed at studying the regularities of the biological effect of accelerated heavy ions. At the JINR FLNR, 25 years ago, a "Genome" setup was created, on which irradiation with beams of heavy ions accelerated by U400M FLNR cyclotron was carried out. Recently, the facility has been seriously upgraded regarding a new beam control system and control of the biological samples irradiation process. The "Genome-M" setup, located on the MC-400 cyclotron, was designed for sequential controlled irradiation of live biological samples with nuclear beams released into the atmosphere.

Since then, plenty of efforts were spent for evaluation and modernization both and beamlines and methodic of heavy ion beam monitoring. The status of these activities, the last news of the ion beam control at different level of LTE and the 7-year roadmap will be presented.

# APPLICATION OF NEUTRON RADIOGRAPHY FOR DETECTION OF HYDROGEN DISTRIBUTION IN NUCLEAR FUEL CLADDINGS IN LVR15 RESEARCH REACTOR

**Hygreeva Kiran Namburi[1], Jaroslav Soltes[1], Jakub Krejci[2]**

1 Research Centre Rez, Husinec Rez, Czech Republic
2 UJP PRAHA a.s., Praha – Zbraslav, Czech Republic

Zirconium based nuclear fuel claddings act as barrier against loss of fuel particles into the coolant water during plant operation, handling and dry storage of the spent fuel rods. Claddings absorb hydrogen produced during reactor operation due to aggressive corrosion. Increase in the hydrogen concentration limit can lead to hydride precipitation, resulting in the reduction of cladding strength and/or mechanical failure by a process called Delayed Hydride Cracking (DHC). Damage mechanism is related and dependent on the hydrogen concentration limits in the cladding. Therefore distribution and quantification of hydrogen in zirconium based fuel claddings is an object of intensive research. The high sensitivity of neutrons for hydrogen and as a non-destructive method makes neutron radiography a useful technique for detection metal hydrides and their distribution/location in cladding.

Un-irradiated Zirconium based fuel clads (Zr-1%Nb) have been investigated at neutron radiography facility of LVR-15 research reactor in Rez, Czech Republic. The samples were investigated in horizontal channel that offers an intense thermal neutron beam with a diameter of 10 cm. The facility is equipped with newest Timepix based detectors, with thin 6LiF converters for neutron detection capable of delivering high resolution. 2D radiography results have been obtained from 3 fuel cladding sections that differ in their hydrogen content. Qualitative information on hydrogen concentration locations in fuel cladding was identified. The H-distribution was revealed by image processing based on intensity histograms. Based on the neutron radiography results, quantitative evaluation of hydrides distribution was performed by classical metallographic procedure and electron microscopy. Qualitative and quantitative inspection of hydrogen distribution in fuel claddings is reported in this paper.

# A NEW CONCEPT OF THERMAL NEUTRON IRRADIATOR

**Roberto Bedogni[1], Antonino Pietropaolo[2], Jose-Maria Gomez-Ros[3]**

1 INFN-LNF, Frascati, Italy
2 ENEA, Frascati, Italy
3 CIEMAT, Madrid, Spain

A new type of thermal neutron irradiator, characterized by extended and very uniform field, was developed by the INFN-ENEA Frascati collaboration. Its name is HOTNES (HOmogeneous Thermal NEutron Source) and consists in a radionulcide neutron source located on bottom of a large cylindrical cavity (30 cm diameter, 70 cm in height) in a polyethylene block. The irradiation volume is separated from the source by a shadow-bar, preventing fast neutrons to directly reach the irradiation volume. Neutrons can only reach the irradiation volume after being theramlized through multiple scattering with the cavity walls. The field across iso-fluence planes is very uniform (1-2%). Compared with tradional thermal piles, exploiting the leakage field from cubic-meter sized moderating blocks, HOTNES offers much higher thermal neutron yield (per source fast neutron) together with low parasitic fast neutron and photon fields. This communication will describe HOTNES's design and experimental characterization. In addition, the main outcomes of the first HOTNES users program (2016-2017) will be shown.

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# VARIATIONS IN ATR FTIR SPECTRA OF SEVERAL LIQUIDS

**Irina Shpachenko, Nikolay Brandt, Andrey Chikishev**

Lomonosov Moscow State University, Moscow, Russia

Attenuated total reflection (ATR) is often employed in the measurements of FTIR spectra. Such a configuration is convenient in experiments with liquid samples, especially aqueous solutions, since pressing to the surface of the ATR crystal is not needed and water absorption is smaller than in transmission geometry.

Spectral changes that occur in the course of measurements with liquids are studied. Pure substances and homogeneous solutions of 2,4-dinitrophenyl acetate in acetonitrile and ethyl benzoate in ethanol are investigated. It is shown that significant variations in the concentrations of components may occur in the ATR FTIR measurements of solutions. Redistribution of solution components in the vicinity of ATR crystal may lead to inhomogeneity of the sample under study.

**Key words:** ATR FTIR spectroscopy, ATR element, diamond, liquid, mixture

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# UV INDEX FORECAST IN VOJVODINA REGION

**Zorica Podrascanin[1], Milica Atlagic[1], Zoran Mijatovic[1], Ana Firanj Sremac[2]**

1 Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia
2 Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia

The UV index (UVI) values were calculated by an empirical model over Novi Sad (19.8 E, 45.3 N, 84 m), Vojvodina region, Serbia, on clear sky days divided in seasons. The ground-based ozone measurements for this location, solar zenith angle and the distance from the Sun were used as input data for the model. At the same site, the UVI values were measured by a Yankee Environmental Systems (YES) UVB-1 pyranometer. The measured values were compared to the calculated values. This comparison was performed to improve a possibility of this model for UVI forecast in the Vojvodina region. The differences between the modeled and measured data are small enough that this model could be used for UVI forecast in this region.

# ESTIMATION OF GLOBAL SOLAR RADIATION FROM SUNSHINE DURATION FOR MOSTAR AND SPLIT AREA

**Slavica Brkić, Blanka Tuka**

Faculty of Science and Education, University of Mostar, Mostar, Bosnia and Herzegovina

As it is well known, the most important parameter for estimating global solar radiation is sunshine duration combined with knowledge of local atmospheric conditions. Knowing the monthly mean daily sunshine duration it is possible to obtain the hourly global solar radiation incident on a horizontal surface. There are a number of available models to apply for studies on solar radiation, such as linear Angstrom-Prescott model and non-linear polynominal relations correlating sunshine hours and sun radiation, but for particular geographical location is of vital importance to find out and apply an adequate model for the development of solar energy devices and for estimates of their performances. In this paper are given the results of testing the applicability of several models according to the data obtained from two different meteorological stations: one located in Mostar and the other in Split (approximately one hundred kilometers afar).

Estimated values of global solar radiation were compared with the measured values in terms of the coefficient of determination, coefficient of regression, mean percentage error and root mean square error, and the most applicable model for those two locations is determined on the base of agreement between the measured and estimated data.

# UV-STABILITY STUDIES OF SULFANILAMIDE IN LIPOSOME VESICLES

**Ana Tačić[1], Sanja Petrović[1], Saša Savić[1], Sanela Savić[2], Vesna Nikolić[1], Ljubiša Nikolić[1]**

1 University of Niš, Faculty of Technology, Leskovac, Serbia
2 DCP Hemigal, Leskovac, Serbia

The main goal of this study was to investigate the stability of sulfanilamide, synthetic antibacterial drug, towards UV-A, UV-B and UV-C irradiation, after incorporation in liposomes. Liposome dispersions with incorporated sulfanilamide were prepared by thin-film hydration method using 1,2-diacyl-*sn*-glycero-3-phosphocholine as a lipid component. Liposomes role in the sulfanilamide stability was investigated by using absorption spectroscopy method. In order to investigate the influence of liposome size on incorporated sulfanilamide stability, three types of liposomes, small unilamellar vesicles (SUV), large unilamellar vesicles (LUV) and multilamellar vesicles (MLV), were prepared. Comparatively, sulfanilamide in phosphate buffer solution was exposed to the UV-irradiation, which provides the possibility for kinetic analysis. The sulfanilamide samples in buffer solution and in liposomes were prepared and exposed to the UV-A, UV-B and UV-C irradiation and the total measured energy flux (hitting the samples) was about 12.86 $W/m^2$, 15 $W/m^2$ and 14.29 $W/m^2$, respectively. UV irradiation resulted in sulfanilamide instability and irreversible degradation in all examined samples, where sulfanilamide instability increased with the increase of the energy input strength (UV-A < UV-B < UV-C).

**Acknowledgments:** This work was supported under Projects of the Ministry of Education, Science and Technological development of the Republic of Serbia, Projects No. TR-34012.

# IDENTIFICATION OF SULFANILAMIDE DEGRADATION PRODUCTS AFTER UV IRRADIATION

**Ana Tačić, Sanja Petrović, Vesna Nikolić, Saša Savić, Ljubiša Nikolić, Ivana Nikolić**

University of Niš, Faculty of Technology, Leskovac, Serbia

Sulfonamides, synthetic antimicrobial drugs, are considered unstable due to presence of heteroatoms, aromatic ring and other functional chromophores sensitive to solar radiation, in their structure. There is a great need to determinate the sulfonamide stability and potential degradation products in pharmaceutical formulations, because of the wide use of these active compounds. Sulfanilamide, 4-aminobenzenesulfonamide, is the basic representative of sulfonamide antimicrobial drugs, hence, it is used as the model-drug. UHPLC technique in combination with absorption spectrophotometry was employed to analyze the formation of sulfanilamide degradation products induced by continuous UV-A, UV-B and UV-C irradiation. The phosphate buffer solutions of sulfanilamide were treated by UV-A irradiation during the period of 0–9000 s, by UV-B irradiation during the period of 0–180 s and by UV-C irradiation during the period of 0–30 s, in the cylindrical photochemical reactor "Rayonnet" with 10 symmetrically placed UV-A and UV-B and 8 UV-C lamps having an emission maximum at 350 nm, 300 nm and 254 nm, respectively. The total measured energy flux was about 12.86 W/m$^2$ for UV-A, 15 W/m$^2$ for UV-B and 14.29 W/m$^2$ for UV-C irradiation, at the distance of 10 cm from the lamps. The samples were filtered through the cellulose membrane and analyzed by the UV–Vis method as well as UHPLC-MS/MS analysis to detected sulfanilamide degradation products. The sulfanilamide instability to UV irradiation resulted in formation of degradation products that are identified as: sulfanilic acid, aniline and benzidine. Since the same degradation products are identified after the influence of all three UV irradiation types, obtained results pointed to the same degradation mechanism.

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# ELECTROMAGNETIC FIELD EXPOSURE FROM TELECOMMUNICATION SOURCES IN AREAS WITH "SENSITIVE" BUILDINGS AND PLACES

**Ivanka Topalova[1], Tsvetelina Shalamanova[1], Victoria Zaryabova[1], Michel Israel[2]**

1 National Centre of Public Health and Analyses, Sofia, Bulgaria
2 National Centre of Public Health and Analyses, Medical University-Pleven, Sofia, Bulgaria

There is a significant increase in the use of mobile communications services and it is expected that this growth will continue with the introduction of new generations of technology standards such as LTE (Long Term Evolution), for example. The exposure from environmental sources in urban areas is formed mainly by broadcasting antennas, and base stations for mobile communications. The large number of telecommunication sources placed in the urban areas provoked serious concerns on possible health effects, considering the exposure to EMF. Particular attention has been paid to the so- called "critical" or "sensitive" areas around hospitals, schools, kindergartens, etc. Hence, there is a need of adequate exposure assessment of the electromagnetic field levels in some selected high populated urban areas especially around hospitals, schools, kindergartens to ensure that the power density levels are well below the prescribed threshold limits.

The report presents an exposure assessment of electromagnetic field emitted by telecommunication sources which has been performed at selected "sensitive" areas around hospitals, schools, kindergartens, located throughout the Sofia city.

The study is conducted under the BG07 Program: Public Health Initiatives with the financial support of the Norwegian Financial Mechanism 2009-2014 and the European Economic Area Mechanism, 2009-2014, entitled "Improving control and information systems in risk prevention and healthcare".

Different methods of exposure assessments have been used: in-situ measurements (outdoor spot measurements of electromagnetic field values) using a non-selective and selective measurement methods, also a broadband EMF monitoring for continuously measuring the total EMF from all surrounding telecommunication sources were provided.

The analyses of the measurement results suggest that the exposure levels to RF-EMFs are generally well below the reference levels defined by the national and European legislations. The electromagnetic field levels at the most studded locations are lower (up to 50%) than the limit values according to the Bulgarian legislation and less than 1% of the limit values according to the European legislation for the frequency band about 900 MHz.

# OCCUPATIONAL EXPOSURE TO ELECTROMAGNETIC FIELD – TRANSPOSITION OF THE EUROPEAN POLICY

**Michel Israel[1], Mihaela Ivanova[2], Victoria Zaryabova[2], Tsvetelina Shalamanova[2], Petya Ivanova[2]**

1 National Centre of Public Health and Analyses, Medical University-Pleven, Sofia, Bulgaria
2 National Centre of Public Health and Analyses, Sofia, Bulgaria

The health policy connected with electromagnetic fields' exposure to workers in Europe was developed on the basis of the ICNIRP Guidelines through the implementation of the Directive 2013/35/EC. The transposition of the EU Directive into the national legislation is a large process including the implementation of an ordinance, training of employers and workers, occupational health services, specialists performing measurements. An additional activity is the development of standard methods for risk assessment at for practical implementation in concrete occupations and working places. Special attention should be paid to the workplaces with magnetic resonance imaging.

# EVALUATION OF THE ELECTROMAGNETIC FIELD EXPOSURE OF THE GENERAL PUBLIC AROUND TELECOMMUNICATION SOURCES

**Mihaela Ivanova[1], Tsvetelina Shalamanova[1], Ivanka Topalova[1], Michel Israel[2]**

1 National Centre of Public Health and Analyses, Sofia, Bulgaria
2 National Centre of Public Health and Analyses, Medical University-Pleven, Sofia, Bulgaria

The exposure to electromagnetic fields (EMF) in the living environment is due to variety of sources, predominantly for telecommunications – radio and TV stations and base stations for mobile communication emitting in the frequency range from 100 kHz to several GHz. The research in recent years has shown that such systems have significantly increased EMF levels in urban areas compared to those measured in the 1980s, when the major sources in the environment are analogue radio and TV stations.

The aim of the report is to present the assessment of electromagnetic field exposure to the general public from telecommunication sources on the territory of the country. Separately data from measurement and exposure assessment of EMF levels around base stations for mobile communication and Radio and TV stations are considered.

The data contain results of spot measurements of EMF levels emitted by separate base stations for mobile communication and radio and TV stations and measurements in areas with high density of EMF sources – 105 regions in the country. It covers 1376 base stations and 280 radio and TV stations.

The received results show that EMF levels are below the permissible levels according to the national legislation. Higher values, within the exposure limits, are found in areas with large number of sources or when the emitters are mounted on small height, but in such cases the values are less than 30% of those in national legislation. Compared to the European legislation the registered EMF levels are below 1 % of exposure limits.

The measured values of the electric field strengths and power densities around the radio and television stations are within the exposure limits according to the national legislation. Values above exposure limits have been found in 1-2% of cases, but they were measured outside the urban areas where only incidental stay of the general public is possible.

In comparison to the European legislation (Council Recommendation 1999/519/EC), the measured values of the electric field strength and power density around radio and TV stations are well below the limit values.

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# THE EFFECTS OF MICROWAVE HEATING ON THE KINETICS OF CLRP FOR POLY(ACRYLIC CO-METHACRYLIC ACID) AND POLY(ACRYLIC -CO-MALEIC) HYDROGELS

**Jelena Jovanovic, Borivoj Adnadjevic**

Faculty of Physical Chemistry, University of Belgrade, Belgrade, Serbia

Microwave heating (MWH) significantly accelerates the rate of chemical reactions, gives higher yields of the products and leads to favoured selectivity of the products, which is the reason why microwave synthesis represents a major breakthrough in synthetic chemistry methodology, an important change in the way chemical synthesis is performed and in the way it is perceived in the scientific community. The use of microwaves attracts more and more attention and accordingly microwave heating grows into broadly accepted non-conventional energy source for organic and polymer synthesis as well as different physicochemical processes. The use of microwave heating as a heating source for polymerizations reactions is rapidly growing branch in polymer science. In spite of this, the use of microwave heating for hydrogel synthesis is one of the least applied. Here, the two types of hydrogels based polyacrylic acid, i.e. poly(acrylic acid-co-methacrylic acid) (PAM) and poly(acrylic acid-co-maleic) hydrogel (PAMA) were synthesized in a procedure based on free-radical crosslinking copolymerization the (CLRP) of acrylic acid with methacrylic acid and maleic acid in our laboratory both under the microwave heating conditions (MWH) and in conventionally heated (CH) conditions. The kinetics curves of the overall free-radical crosslinking copolymerization, i.e. hydrogel formation, at temperature range from 303 K to 323 K were recorded. The reaction rates under MWH are 5-7 times higher in comparison to the CH conditions for each copolymer system. The kinetics model of PAA and PAMA hydrogel formation under MWH conditions was established by applying the model-fitting method.

The kinetic parameters (the activation energy (Ea) and the pre-exponential factor (lnA)) were determined for both MWH and CH conditions based on the reaction rate constant change with temperature. The values of the kinetics parameters, the Ea and the lnA of the CLRP process under microwave heating are lower than the values for conventional heating (CH) for both types of copolymer hydrogels. There is mutual relationship between the calculated values of the kinetic parameters for MWH and CH conditions for both process of hydrogel synthesis, known as compensation effect. The decrease in both activation energy and preexponential values of the investigated hydrogel formation under MWH is caused with increased energy of the reactive species when compared with their energy in thermal activation. Increased energy of the reactive species is a consequence of rapid transfer and absorption of the energy of microwave field to the existing reactive species. The increase in the reaction rate and the change of the kinetic parameters for MWH conditions in comparison to the CH conditions is not a consequence of the existence of hot-spots in the reaction system.

# KINETIC STUDY OF WATER EVAPORATION AND PMA HYDROGEL DEHYDRATION UNDER THE MICROWAVE FIELD

**Borivoj Adnadjevic, Jelena Jovanovic**

Faculty of Physical Chemistry, University of Belgrade, Belgrade, Serbia

Hydrogels are three-dimensional cross-linked polymeric structures that have the capability to swell in aqueous environments. Hydrogels are considered of great significance in various fields like medicine, pharmacy, hygienic devices, agrochemistry, and ecology. Microwave heating (MWH) significantly accelerates the rate of chemical reactions, gives higher yields of the products and improves the properties of the products, which is the reason why the use of microwaves has started attracting more and more attention. The poly(methacrylic acid) hydrogel (PMA) was synthesized in our laboratory by a procedure based on free-radical crosslinking polymerization of methacrylic acid and its primary structural properties were determined. The isothermal kinetic of water evaporation and PMA hydrogel dehydration in temperature was investigated under microwave heating conditions (MWH). The isothermal kinetics curves of the PMA hydrogel dehydration at temperature range from 293 K to 333 K were recorded. The degree of complexity of water evaporation and hydrogel dehydration were confirmed by applying the differential isoconversion method. The kinetics model of water evaporation and hydrogel dehydration under MWH conditions was established by applying the model-fitting method. Based on the obtained results it was found the following.

The rate of isothermal dehydration of the PMA hydrogel under MWH was 5 times higher than the same process under conventional heating (CH). The microwave heating does not influence the change the kinetic complexity nor the kinetic model of isothermal dehydration of the PMA hydrogel in comparison to the CH process. The values of Arrhenius kinetic parameters under the MWH are lower than the comparative values under conventional heating. The values of Arrhenius kinetics parameters obtained from dehydration under the MWH and CH are in mutual relationship with the compensation equation. The activation f the absorbed water molecules for dehydration is achieved by a resonant selective transfer of energy from the reaction environment to the absorbed molecule of water, both for CH and MWH.

The selective transfer of energy occurs at resonant frequency with the wave number, n=837 $cm^{-1}$, which corresponds to the intermolecular vibration of the absorbed water. The activation energy of the dehydration process is a quantized value and it is predetermined by a number of the resonant quanta which are selectively transferred from the reaction environment to the resonant oscillator. The increase in the isothermal rate of dehydration under the MWH in comparison to the CH is a consequence of the increased value of energy of the ground state of the resonant oscillator, under the conditions of MWH, when compared to CH. The suggested mechanism of microwave action is possible to be applied to wider range of chemical reaction and physicochemical process.

# QUANTIFICATION OF OPERATOR PROXIMITY EFFECT ON MEASURING RESULTS OF ELECTRIC FIELD STRENGTH IN THE VICINITY OF OVERHEAD POWER LINES

**Maja Grbić, Aleksandar Pavlović**

Nikola Tesla Electrical Engineering Institute, Belgrade, Serbia

In this paper, the operator proximity effect on measuring results of the electric field strength in the vicinity of the overhead power lines is analyzed. The operator proximity effect depends on the distance between the operator and the probe for measuring the electric field strength and the height on which the probe is placed. The paper presents the results of the electric field strength measurements in the vicinity of the 220 kV overhead power line which were performed in order to quantify the influence of the proximity of the operator. The measurements were done by using 3-axis cube shaped isotropic probe. During the measurements, the probe was placed on a wooden tripod and connected to the electromagnetic field analyzer by optical cable. The measurements were performed at the heights of 1 m, 1.5 m and 1.7 m during which the distance between the operator and the measuring probe was changed from 1 to 10 m, with the 1 m pace. The obtained results are analyzed in detail in this paper. These results can be used for estimating the electric field strength measurement uncertainty. The significance of these results is also in demonstrating the way how the influence of the operator on the measured field can be reduced to an acceptable level.

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# Medical Imaging

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# EFFECT OF GRID PARAMETERS ON eDQE AND CORRELATION OF OBJECTIVE AND SUBJECTIVE ASSESSMENTS IN DIGITAL RADIOGRAPHY

**Asena Yalçın[1], Turan Olğar[2]**

1 Institute of Nuclear Sciences, Ankara, Turkey
2 Ankara University of Physical Engineering, Ankara, Turkey

To quantify the imaging properties of a detector, DQE was defined as a gold parameter which was standardised by IEC. It is an objective and quantitative metric which describes how effectively a detector converts incident x-ray photons into a useful signal. DQE reflects performance of a detector but it does not take into consideration the clinical conditions such as focal spot blurring, scatter radiation from the patient and magnification. To alter this problem, a new metric, effective Detective Quantum Efficiency (eDQE), has been developed and reported in the literature. In this study we investigated the effect of grid parameters on eDQE. We calculated the eDQE of our indirect digital radiography (DR) system with different types of antiscatter grids. In order to mimic different size of patients, four different thicknesses of PMMA blocks (10, 15, 20 and 25cm) were used. Two group of grids with different grid ratios (10:1 and 12:1) and grid frequencies (40 and 60 lines/cm) and three different tube voltages (70, 90 and 120kVp) were used in the study. We showed that, eDQE was decreased with grid ratio. We also evaluated the image performance of system by using CDRAD measurement at the same conditions and test the correlation of CDRAD results with eDQE. We used integrated eDQE (IeDQE) over the frequency range to test the correlation with the inverse image quality figure ($IQF_{inv}$) obtained from CDRAD measurement. Correlation between IeDQE and $IQF_{inv}$ showed good agreement. Experimental setup and grids were simulated using MCNP5 Monte Carlo code and transmission fractions of PMMAs and scatter fractions for each grid were determined both with MCNP5 and experimentally. The results showed good agreement.

# 3D RECONSTRUCTION OF INNER STRUCTURE OF RADIOACTIVE SAMPLE UTILIZING GAMMA TOMOGRAPHY

**David Zoul[1], Pavel Zháňal[2]**

1 Research Centre Rez, Ltd., Husinec, Řež, Czech Republic
2 Research Centre Rez, Ltd., Department of Physics of Materials, Charles University, Husinec, Řež, Czech Republic

Unique 3D tomography apparatus was built and successfully tested in Research Centre Rez.

The apparatus allows three-dimensional view into the interior of low-dimension radioactive samples with a diameter up to several tens of millimeters with a resolution in order of cubic millimeters and is designed to detect domains with different levels of radioactivity.

Structural inhomogeneities such as cavities, cracks or regions with different chemical composition can be detected using this equipment.

The advantage of computed tomography is the possibility of 3D imaging. The source of radiation is the scanned sample itself in the case of SPECT. After passing through the sample, the radiation is detected by a suitable detector.

# A TISSUE-SPECIFIC METHOD FOR CT SLICE DOSE ESTIMATION

**Spasoje Vučković, Katarina Paunović, Miloš Vujisić**

University of Belgrade, School of Electrical Engineering, Belgrade, Serbia

Personalized optimization of medical CT scans has become the focus of much investigation. Precise knowledge of the dose that a patient receives from such a scan is an important part of this task. A method is proposed herein for estimating absorbed dose from a CT scan. Dose to an axial CT slice is computed from both the projections acquired at the detector and the Hounsfield units in the reconstructed image. The method is tested on several computational phantoms. For the purpose of investigation, data for each projection are obtained from a simulation of X-ray transport through the phantom. Starting from an analytically generated X-ray energy spectrum, exponential attenuation of the photon energy fluence is used for obtaining the total energy deposited within the observed slice at each projection angle. If implemented on a scanner, with full access to raw detector data, the deposited energy would be obtained directly from an energy-integrated detector signal. Reconstructed image of the slice is used next, for calculating its total mass. Assuming a certain pixel size and slice thickness, mass of each voxel in the slice is found from CT numbers (i.e. Hounsfield units) assigned to the pixels of the reconstructed image. This is accomplished by the two-tissue piecewise-linear conversion model. Absorbed dose is finally calculated as the ratio of the total energy deposited within the slice to the slice mass. The dose thus calculated is an overestimation of the real dose in the slice, since all photons scattered within the slice are assumed to contribute to it. The overshoot in estimated dose is assessed through comparison of the values provided by the proposed method to doses calculated by Monte Carlo simulations of the same scanning scenarios. Results of these comparisons are presented in the paper for various phantoms and scanning conditions. The calculated dose is tissue-specific in that it is calculated for the total slice mass found from the reconstructed CT image of that same slice, in which various tissues are distinguished by their composition and size.

# ESTIMATION OF CT PATIENT-DOSE SAVINGS FROM THE UTILIZATION OF DIFFERENT IMAGE RECONSTRUCTION ALGORITHMS

**Katarina Paunović, Spasoje Vučković, Miloš Vujisić**

University of Belgrade, School of Electrical Engineering, Belgrade, Serbia

Optimization of medical CT scans can be accomplished through utilization of alternative and novel image reconstruction techniques. Dose savings associated with these reconstruction algorithms come from the lower number of projections and lower X-ray fluence per projection needed for attaining a desired image quality. In the present paper, a recently developed method for tissue-specific CT slice dose estimation is used for comparing absorbed doses associated with CT scans relying on different iterative reconstructions. Several phantom images are used for the comparison. Quality of images is established based on quantitative metrics. First, the number of projections, and hence the dose, is varied, while the quality of images reconstructed by different algorithms is kept constant and equal between the various images. Then, the dose is set at a fixed low value, and images obtained through different reconstruction algorithms are set against each other based on the quality indices. Results of the investigation point to specific iterative algorithms that can provide high-quality CT images at lower doses than delivered in current medical scans. Based on the differences between the imaging phantoms used, the calculated dose savings also suggest which of the tested reconstruction algorithms are suitable for medical applications, in which slice images are more geometrically intricate.

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# Medical Devices

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# INCREASE OF DIAGNOSTIC ROENTGENOLOGY EFFICIENCY BY ADDING DYNAMIC DIGITAL RECEIVERS TO THE OPERATED CONVENTIONAL X-RAY EQUIPMENT

**Yuriy Kovalenko[1], Sergei Miroshnichenko[2], Andrei Nevgasymyy[3]**

1 P.L. Shupyk National Medical Academy of Postgraduate Education, Kyiv, Ukraine
2 National Aviation University, Kyiv, Ukraine
3 Teleoptic PRC Ltd, Kyiv, Ukraine

**Purpose of the work.** Over 1.5 thousand digital and film fluorographs and over 7 thousand roentgen diagnostic complexes are now used in Ukraine for radiographic examinations.

The purpose of the work was implementation of tomosynthesis on standard roentgen diagnostic equipment available in health care entities.

**Materials and methods.** Fluorograph with protective cabin, roentgen diagnostic complexes for two working places with linear tomographic console and x-ray remote control table with tomography regimen were used in the work. In the fluorograph instead of X-ray tube and power unit a roentgen monoblock with 5 kW output power was installed on a mobile platform. During exposure (4-6 s) X-ray unit rotates 40 degrees using this platform. Instead of fluorocamera dynamic digital receiver with working area 43 x 60 cm was installed on the protective cabin of the fluorograph. Both roentgen diagnostic complexes have been equipped with high-frequency x-ray generator with a 'pulse-fluoro' mode and dynamic digital receiver with working area 36x43 cm, positioned in place of a bucky. Longitudinal tomography mode with tomographic angle ±20 ° and anode voltages of 90-120kV were used in the examinations. Chest test phantom with x-ray target and the examiners themselves were objects of examination in the work.

**Results.** Tomography mode has been implemented on all three units of x-ray diagnostic equipment. About 200 slices of examined objects have been received. Image plane resolution was 2.1x1.6 line pairs per millimeter (lp/mm) that is better, than that of computer tomography, Point Spread Function – PSD0.5 value – 0.2-0.5 lp/mm. Total exposure of tomosynthesis did not exceed 20.0 mAs that is only 3-6 times higher vs. the standard chest radiography. According to the experts, on the obtained phantom and chest slice details were observed which are not visible on the radiographic images. The mode of tomosynthesis allowed more precisely measuring the geometrical dimensions of the detected items, and also to estimate relative density of tissues in each of slices. Also, the analysis of chest condition thanks to absence of superposition effect became easier. The possibility of slice after slice analysis of the object of examination minimizes the need for more views to be performed and increases probability of correct diagnosis without referring the patient to CT and MRI studies.

**Conclusion.** The implementation of digital tomosynthesis on standard roentgen diagnostic equipment allows accelerating introduction of this method of x-ray visualization into clinical practice and raising the efficiency of diagnostic roentgenology, first of all, in primary health care settings.

# NOVEL GENERATORS FOR NUCLEAR MEDICINE: TECHNICAL AND ANTITUMOR CHARACTERISTICS

**Dmitry Yurkov[1], Sergei Syromukov[1], Vladimir Sysoev[1], Ruslan Dobrov[1], Victor Tatarsky[2], Ekaterina Ivanova[2], Vladimir Zverev[1], Alexander Shtil[2]**

1 Dukhov Research Institute of Automatics, Moscow, Russia
2 Blokhin National Medical Center of Oncology, Moscow, Russia

The antitumor radiotherapy involves a variety of modern modalities. Among these gamma-irradiation of tumors remains the most important. Nevertheless, this treatment may induce tumor cell resistance; furthermore, escalation of the site dose can be problematic due to damage of normal tissues. The hadron particle therapy that includes protons, carbon atoms and neutrons emerged as a promising strategy. The advantages of this treatment are a high linear energy transfer in the tumor, a bigger value of biological efficacy and a low oxygen enhancement ratio. The neutron therapy gained momentum in treatment of radioresistant and/or deeply located tumors. However, the use of this modality presumes powerful sources that are environmentally safe, compact and affordable. A unique portable generator of fast neutrons NG-24 has been engineered at Dukhov Research Institute of Automatics. In this device a compact ion accelerator is placed inside a hermetically sealed case. Unlike vacuum accelerators, in NG-24 the atmospheric pollution by the exhausted tritium is completely prevented; this important invention seriously improves safety for patients and personnel. The device 40×110 cm in size can generate up to $10^{11}$neutrons/sec, the intensity acceptable for radiotherapy. The NG-24 generator currently undergoes testing with a perspective to become a widely applicable medical device for neutron therapy. The biological characterization of the neutron beam generated by NG-24 was performed on a panel of human tumor cell lines such as MCF7 breast carcinoma and HCT116 colon cancer as well as HCT116p53KO subline with non-functional p53. We determined a range of single irradiation doses that cause a sublethal or lethal effect as determined by colony formation assays. The density of cell monolayer is a critical parameter to be considered in the design of radiosensitizing agents, in particular those that disrupt cell-cell cooperation. Irradiation of cells with the neutron beam (up to 6 Gy single dose) led to activation of signaling events both dependent and independent of p53. Apoptosis was not a major mode of cell death; alterations of cell cycle distribution were associated with p21 activation and emergence of a senescence phenotype by irradiated cells. This phenomenon can be regarded as an opportunity for the cell to escape death, at least temporarily. Thus, we designed and engineered a prototypic device for generating therapeutically relevant flow of fast neutrons. Our further strategy is aimed at the production and marketing of clinical instruments with a reliable safety and efficacy. These instruments will also be used for basic studies in cancer radiobiology.

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# Pharmaceutical Sciences

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# THE USE OF OVER-THE-COUNTER DIETARY SUPPLEMENTS, THEIR SAFETY AND INTERACTIONS WITH CHRONIC THERAPY

**Maja Cvetkovic[1,2], Dusan Ilic[1,2], Dusica Stojanovic[1]**

1 Faculty of Medicine, Nis, Serbia
2 Dona Farm Pharmacy, Nis, Serbia

**Introduction:** The use of herbal supplements and medicines is increasing rapidly as most people consider them to be of natural origin and therefore safe. Many herbal medications are used to treat diseases but while they are often efficacious, their safety has not sufficiently considered by physicians or users. One particular safety concern is the risk of interactions with drugs, which often lead to toxicity or loss of therapeutic efficacy. A significant number of patients combine herbal remedies with prescription medications and there is growing evidence for interactions of drugs with herbal remedies or single compound originating from plants. The aim of this paper is to evaluate the possible interactions between chronic patient therapy and herbal substances.

**Materials and methods:** The research is presented as a descriptive study which included patients 30 to 80 years of age, who were randomly selected in Niš from September to December 2017 and who agreed to be interviewed, and who completed questionnaires.

**Results**: We surveyed 157 patients, 115 respondents (73.24%) reported use of dietary supplements. In total, 105 (66.87%) interactions with potential clinical significance were identified. The 5 most common natural products with a potential for interaction (garlic, valerian, ginkgo, and St John's wort) accounted for 68% of the potential clinically significant interactions. The 4 most common classes of prescription medications with a potential for interaction (antithrombotic medications, sedatives, antidepressant agents, and antidiabetic agents) accounted for 94% of the potential clinically significant interactions. No patient was harmed seriously from any interaction.

**Conclusion:** It is imperative that pharmacists and doctors ask patients what they are using within their chronic illness treatment and estimate the possible use of a dietary supplement based on the data obtained.

# FT-IR INVESTIGATION OF ORGANICALLY MODIFIED SILICA NANOPARTICLES – CARRIERS FOR ANTICANCER DRUG

**Beti Djurdjic[1], Bojan Markovic[2], Zdenka Zoricic Mitrovic[3], Vineta Vuksanovic[3], Boban Mugosa[3]**

1 Department of Pharmacy, Faculty of Medicine, University of Montenegro, Podgorica, Montenegro
2 Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Belgrade, Belgrade, Serbia
3 Institute of Public Health, Podgorica, Montenegro

**Objective:** The aim of the present study was to prepare and investigate structural characteristics of organomodified silica nanoparticles.

**Methodology:** Silica nanoparticles were prepared by hydrolysis and polycondensation of tetraethyl orthosilicate (TEOS) co-hydrolized with 1mol% 3-Aminopropyltriethoxysilane (APTES), water, ethanol and acetic acid as catalyst, under continuous stirring at elevated temperature (45°C). Oxaliplatin (OXP) is chosen as a model anticancer drug. Prepared nanoparticles (NPs) collected by centrifugal ultrafiltration (Vivaspin 20, 1000 kDa) followed by freeze-drying. In order to study the interactions in the system, Attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectra were obtained with FT-IR spectrophotometer (Nicolet iS10, Thermo Scientific, USA) in the 4000-525 $cm^{-1}$ region (16 scans per spectrum, 4 $cm^{-1}$ resolution). Samples of pure OXP, lyophilized empty (NP1) and OXP loaded nanoparticles (NP2) formulation were analyzed.

**Results:** Prepared NPs were with unimodal size distribution and average particle sizes 140 and 154 nm for NP1 and NP2, respectively. The encapsulation efficiency of OXP was 31%. In the FTIR spectra of obtained NPs there are bands that represent the $SiO_2$ structure: the band arising from the symmetric Si-O-Si stretching vibration is positioned at 795 and 799 $cm^{-1}$, while the antisymmetric Si-O-Si stretching mode can be found in the spectrum at 1050 and 1066 $cm^{-1}$ for the NP1 and NP2, respectively. The band that appears at 942 (NP1) and 950 $cm^{-1}$ (NP2) is combination of stretching modes of Si-OH and Si-O-$CH_2CH_2CH_2NH_2$. The wide asymmetric band that appears in the high frequencies region (3258 $cm^{-1}$ for NP1 and 3274 $cm^{-1}$ for NP2) is originating from the combination of the O-H stretching (water) and N-H stretching vibration (APTES). Perceived bands in the region 1550-1400 $cm^{-1}$ (deformation vibrations of $CH_2$ and $NH_2$ groups) are due to the incorporation of APTES in the silica matrix. The characteristic bands that appeared in the FTIR spectra of empty and loaded NPs are strong indication for the development of a complex inorganic-organic hybrid network during the hydrolysis and condensation of TEOS and APTES. Observed characteristic band shifting in the spectra of loaded NPs by comparison with empty NPs, as well as observable bands shifting for OXP in respect to the same bands in the spectra of pure compound (579 and 2453 $cm^{-1}$), implies that the active ingredient is incorporated in polymer matrix during the nanoparticle formation.

**Conclusion:** FTIR results confirmed the successful synthesis of amino-modified silica nanoparticles and the entrapment of the active substance into the nanoparticles.

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Biomedicine

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# SOME DATA ON SURGICAL TREATMENT OF GASTROESOPHAGEAL REFLUX

**Saimir Heta[1], Ilma Robo[2], Hysen Heta[3]**

1 University Hospital Center, Pediatric Surgery, Pediatrician Surgeon, Tirana, Albania
2 Head of the Department of Periodontology, Albanian University, Tirana, Albania
3 Pediatric Surgery, QSUT, Tirana, Albania

**Introduction:** Clinical presentation of gastrointestinal reflux, such as terminal illness that solution is surgical intervention has been a challenge for its therapeutic treatment. This type of treatment has started properly positioning the child was breastfed, to the use of drugs, such as omeprazole.

**Materials and methods:** Purpose of the study: determining the efficiency of surgical techniques for gastroesophageal reflux, comparison of two methods: open and laparoscopic, determination of the advantages and disadvantages of techniques operators. The study was conducted over a 4 year period, from 2011-2015. The study involved 59 children operated for gastroesophageal reflux with laparoscopic method and for the same period 14 children operated by the open method.

**Results:** The duration of the operation is greater in the group treated with laparoscopy compared with open method. In the open method we have been 2 cases of wound redness operators. In both groups, a significant statistical difference is seen at the use of antibiotics. The duration of stay in laparoscopic method, is significantly lower.

**Conclusions:** In conclusion, it is seen that sparing incision infant morbidity fundoplikacion by Nissen, performed with laparoscopy has the same success as he conducted the open method. Regime and placement of food is in both cases is the same efficiency in both operated groups.

# FIBRINOGEN AS AN INFLAMMATORY MARKER OF THE CONNECTION OF PERIODONTITIS WITH ARTERIOSCLEROSIS

**Saimir Heta[1], Ilma Robo[2], Ermelinda Gina[3], Nevila Heta[4]**

1 University Hospital Hospital, Pediatric Surgery, Pediatric Surgeon, Tirana, Albania
2 Head of the Department of Periodontology, Albanian University, Tirana, Albania
3 Department of Pedodonty, Albanian University, Tirana, Albania
4 Biochemical Laboratory, QSUT, Tirana, Albania

**Purpose:** Risk factors for periodontitis, combined with genetic and etiologic factors, affecting the oral and systemic clinical view of the patient, assisting in promoting of atherosclerosis. Plasma levels of markers of inflammation are expressive, in interconnection of existing periodontitis, with advancing arteriosclerosis.
This study aims to assess the effect of non-surgical periodontal treatment, expressed in levels of periodontal indices, correlated with the quantitative and qualitative level, of the plasma markers of inflammation.

**Materials and methods:** The first phase of the study is the application of the designed protocol at experimental sample of 10 patients. The second phase, current, is the reflection of correlations expressed before, in the biggest sample of patients, about 54 patients. Patients were evaluated for percentage of bleeding surfaces and probing depth to Ramfjord teeth. Blood analysis and evaluation of periodontal status of patients was performed before treatment and 1 week post-treatment or after the terminal stage of treatment. P value ≤ 0.0002 indicates statistically significant relationship.

**Results:** The data showed that the average of clinical bleeding areas and probing depth are reduced by 62% and 2.5mm, respectively. Non-surgical periodontal treatment significantly reduces the level of fibrinogen in the blood, in the range 10-20 mg/dL.

**Conclusion:** Microoral flora is a potential source of temporary periodontal bacteremia, with the potential of promoting atherosclerosis, through increased interaction with blood cells. Non-surgical periodontal treatment significantly reduces the level of fibrinogen, known as risk factor for the development of arterial arteriosclerosis.

**Keywords:** Fibrinogen, probing depth, bleeding gingival surfaces

# REDUCTION OF EARLY SUPPRESSIVE IMMUNE RESPONSE AND SYSTEMIC INFLAMMATION DUE TO APPLICATION OF THE ENHANCED RECOVERY AFTER PATIENTS' SURGERY OF COLORECTAL CANCER

**Evgenia Kuzmina, Daria Zemskova, Aleksandr Potapov, Oleg Vatin, Tatiana Mushkarina**

A.Tsyb MRRC, branch of NMRRC Ministry of Health of the Russian Federation, Obninsk, Russia

**Introduction.** Such components of surgical intervention as narcosis and operational trauma, cause stress response in an organism. The use of the "Fast track surgery" program is supposed to facilitate stress reduction. Objectification early rehabilitation of patients should include consideration of its anti-inflammatory and anti-stress mechanisms.

**Aim.** Estimating immunity response at the early period after laparoscopic surgery for colorectal cancer with spinal anesthesia included in the "Fast track surgery" program.

**Materials and methods.** 45 patients were examined after surgery of colorectal cancer. For care management of Group 1 patients (n=22) the "Fast track surgery" program, which included laparoscopic access, general anesthesia together with spinal anesthesia (10-12.5 mg of **Bupivacaine** + 0.2 mg of morphine), early activation, oral fluid and food intake on the first postoperative day was used. For care management of Group 2 Patients (n=23) the conventional treatment, which included open access, general anesthesia, systemic opioid analgesia, activation, oral fluid and food intake on the second or the third postoperative day was used. The patients were examined before the surgery, 2 hours, 2 days and 3-5 days after the operation. The count of blood leucocytes, absolute count of lymphocytes in the blood and the level of pro- and anti-inflammatory cytokins IL-6, IL-10 in the blood serum induced by the treatment were estimated. Pain intensity was estimated with the visual analog scale and the number of used narcotic analgesics on the first day after the surgery.

**Results.** Inflammatory and suppressive components, such as increased level of leucocytes and cytokins, IL-6, IL-10, were found before the surgery in several patients in both groups. In the Group 1 inflammatory response and suppression of immunity were very high (leucocytosis, increase in the level of IL-6 and IL-10 by10 and 7 times as compared with pre-operative period) in 2 hours after the surgery, however, these parameters significantly decreased on the 2$^{nd}$ postoperative day: leucocytes count was within limits of norm, amount of IL-10 decreased to the initial level, amount of IL-6 exceeds the initial level by 4 times. In patients of the Group 2 high postoperative response reduced more slowly, the leucocytes count and cytokins in the group 2 came close to the level in the Group 1 on the later postoperative days. Postoperative pain intensity in the Group 1 was significantly lower. This was the reason for reducing intake of narcotic analgesics by 60-80%, in some cases the analgesics were withheld.

**Conclusion.** Due to use of the accelerated recovery program "Fast track surgery" and spinal anesthesia after patients' surgery of colorectal cancer the duration of immune suppressive and systemic inflammatory response in early postoperative period and the stay at the hospital significantly decreased. The earlier the reduction of inflammatory reactions in comparison with the traditional treatment can be a consequence of reducing operating injury and improve the quality of perioperative analgesia and decrease in volume applied of narcotic analgesics.

# ANATOMICAL STUDY OF NUTRIENT FORAMINA ON THE DIAPHYSIS OF THE HUMAN FIBULA

**Lejla Dervisevic, Zurifa Ajanovic, Amela Dervisevic, Eldan Kapur, Ilvana Hasanbegovic**

Medical Faculty, Sarajevo, Bosnia and Herzegovina

**Objectives:** The main objective of the study is to give a detailed overview of the nutrient foramina and nutrient channels by macroscopic examination of fibula diaphisis and to determine its utmost important variations for clinical practice.

**Methods and Materials:** This was a cross-sectional-descriptive study in which we observed 50 fibula. We considered only nutritional foramina located at diaphysis of the bone. During the research we determined the following parameters: total number of nutrient foramina on diaphisis of each bone, value of Foramina Index (FI), the length of the bones, the position of the nutritional foramina regarding to values of FI, and position of nutritionl foramina on the sides of the diaphysis of bone and the obliquity of nutrient canal. The obtained data were statistically analysed using SPSS version 17.0.

**Results:** Nutritional foramina were recorded at 84.0% fibula. In 57.1% fibula nutritional foramina were placed on the facies posterior, in 40.5% on the facies medialis and on 2.4% bones nutritional foramina were on the facies lateralis. All fibula had nutritional foramina located on the middle third of the diaphysis of bone. Distally directed nutritional canals were observed on 90.5% fibula and proximally directed nutritional canalas were observed on 9.5% fibula. There was a negative correlation between the length of the fibula of the right and left limb and the number of nutritional foramina.

**Conclusion:** Knowledge of the topography of nutritional foramina helps preserve bone vascularization during surgery.

**Keywords:** Nutritional artery, nutritional canals, fibula, topography

# LEGS/TRUNK AND ARMS AND LEGS SUM TO TRUNK FAT MASS INDEXES DETERMINED WITH DUAL-ENERGY X-RAY ABSORPTIOMETRY IN CUSHING'S AND NON-CUSHING'S OBESE WOMEN

**Slavica Shubeska Stratrova, Sasha Mishevska Jovanovska, Goran Petrovski, Marija Zivkovic**

Clinic of Endocrinology, Diabetes and Metabolic Disorders, Skopje, Macedonia

The aim of this study was to evaluate the central obesity, which is a main characteristic of Cushing's syndrome (CS), with dual-energy x-ray absorptiometry (DXA) and to determine DXA indexes that precisely differentiate CS from non CS obese women. In 12 CS women and 12 control obese (CO) with appropriate BMI which was not significantly different from CS, and 12 healthy control women (C) with normal BMI, following DXA parameters were evaluated: regional (trunk, arms and legs) fat mass (FM), legs/trunk FM ratio, (arms+legs)/trunk FM ratio, and also the sensitivity, specificity and diagnostic accuracy (DG) for their ratio index cut-off points (CP).

Results: Arms FM (3.37±0.7 kg) in CS was not significantly higher compared to CO (3.02±0.85 kg), but it was significantly higher in CS and CO compared to C (1.55±0.39 kg) ($p<0.001$). Legs FM (9.82±3.77 kg) in CS was not significantly lower compared to CO (11.83±2.54 kg), and not significantly higher compared to C (8.5±1.73 kg). Legs FM value in CO was significantly higher compared to C ($p=0.007$). Trunk FM in CS (19.76±4.96 kg) was higher than in CO (16.39±3.6 kg), for very low significance of the difference ($p=0.037$), but it was significantly higher in CS and CO compared to C (9.48±2.33 kg) ($p<0.001$).

Legs/Trunk FM ratio value 0.49±0.14 in CS was significantly lower compared to CO (0.73±0.13) and C (0.92±0.18) ($p<0.001$), and the difference between CO and C was highly significant ($p<0.005$). Value of (arms+legs)/trunk FM ratio in CS (0.67±0.13) was significantly lower in CS compared to CO (0.92±0.15) and C (1.09±0.19) ($p<0.001$), but there was very low significance of the difference between CO and C ($p=0.017$).

CS patients were characterized with legs/trunk FM values lower than 0.65, and (arms+legs)/trunk FM values lower than 0.80. The best differentiation of CS from C obtained CP of 0.69 for legs/trunk FM ratio with DG of 91.67%, as well as sensitivity and specificity of 91.67%, while CP for (arms+legs)/trunk FM ratio (0.85) had DG of 87.5 %. Legs/trunk FM ratio (CP 0.65) and (arms+legs)/trunk FM ratio (CP 0.80) differentiated CS from CO with DG of 87.5%.

Conclusion: DXA indexes legs/trunk FM and (arms+legs)/trunk FM discovered extreme central body fat distribution in CS, differentiated them significantly from C and CO, and could be used as DXA indexes of extreme central, abdominal obesity in CS and non CS obese women. Legs/trunk FM index had higher DG and predictive value of extreme visceral obesity in CS, compared to (arms+legs)/trunk index.

**Key words:** Cushing's syndrome, central obesity, DXA indexes, cut-off points, diagnostic accuracy

# AMBIVALENT EFFECT OF CHRONIC L-NAME TREATMENT IN PERIPHERAL TISSUE AND BRAIN

**Olga Pechanova, Stanislava Vrankova, Martina Cebova**

Institute of Normal and Pathological Physiology Slovak Academy of Sciences, Bratislava, Slovakia

The goal of our study was to analyze the time course of $N^G$-nitro-L-arginine methyl ester (L-NAME) effect on nitric oxide synthase (NOS) particular isoforms and NF-κB protein expression, total NOS activity measured by conversion of 3[H]Arginine to 3[H] Citrulline, and blood pressure (BP) in rats. Adult 12-week-old Wistar rats were subjected to treatment with L-NAME (40 mg/kg/day) for four and seven weeks. Both 4- and 7- week – L-NAME treatments increased BP in comparison with age-matched controls. NOS activity was decreased after 4 weeks of L-NAME treatment in all tissues examined. However, prolongation of the treatment to 7 weeks increased NOS activity in the aorta, heart and kidney, while NOS activity in the brainstem, cerebellum and brain cortex was decreased highly significantly. After 4 weeks of L-NAME treatment, eNOS expression in the aorta, heart and kidney increased significantly and this increase was amplified after 7 weeks of the treatment. On the other hand, after 4 – week – L-NAME treatment, eNOS expression in the brain regions remained unchanged and prolonged treatment led to significant decrease of eNOS expression in these tissues. NF-κB protein expression increased in both peripheral and brain tissues after 4 weeks of the treatment and prolongation decreased it in the aorta, heart and kidney. Increased expression of eNOS may be responsible for increased NOS activity in the peripheral tissues after 7 – week – L-NAME treatment. Decreased expression of eNOS led, however, to a highly significant decrease of NOS activity in the brain regions. Since BP increase persisted after 7 weeks of L-NAME treatment, we hypothesize that central regulation of BP is predominant in L-NAME-induced hypertension.

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# PROTECTIVE EFFECT OF NANOPARTICLE-LOADED ALISKIREN ON CARDIOVASCULAR SYSTEM IN SPONTANEOUSLY HYPERTENSIVE RATS

**Olga Pechanova, Martina Cebova, Andrej Barta**

Institute of Normal and Pathological Physiology Slovak Academy of Sciences, Bratislava, Slovakia

Aliskiren is the most recent antihypertensive agent that acts by inhibition of renin, the first step in renin–angiotensin–aldosterone-system. Aliskiren has been shown to exert renoprotective, cardioprotective, and anti-atherosclerotic effects independent of its blood pressure (BP) lowering activity. Clinical use of aliskiren is limited, however, by short lifetime of this drug. Therefore, the aim of our study was to determine the effect of nanoparticle-loaded aliskiren, with gradually realized drug, on BP, nitric oxide generation and structural alterations of the heart and aorta developed due to hypertension. 12-week-old male SHRs were divided to the untreated group, group treated with powdered aliskiren (25mg/kg per day), group treated with nanoparticle-loaded aliskiren (25mg/kg per day), and group treated with nanoparticles only for 3 weeks by gavage. BP was measured by tail-cuff plethysmography. Nitric oxide synthase (NOS) activity was determined by conversion of $^{3}$[H]Arginine to $^{3}$[H] Citrulline and NOS isoforms were analyzed by Western blot. Collagen and elastin contents were measured by picro-sirius red staining in both heart and aorta. Wall thickness (WT), inner diameter (ID) and cross sectional area (CSA) were determined in the aorta. At the end of experiment, BP was lower in both powdered aliskiren and nanoparticle-loaded aliskiren groups with more pronounced effect in the second one. Both aliskiren groups reduced myocardial hypertrophy in comparison to untreated SHR. Only nanoparticle-loaded aliskiren increased the expression of nNOS along with increased NOS activity in the heart. Moreover, nanoparticle-loaded aliskiren was able to decrease collagen content (by 11%) and CSA (by 25%) in comparison to the powdered aliskiren group, while it had no significant effect on the similar parameters in the heart. There were no significant changes in elastin content, WT and ID among aliskiren groups and control group. Polymeric nanoparticles, however, increased collagen and elastin contents and WT of the aorta. In conclusion, nanoparticle-loaded aliskiren seems to be promising drug for cardiovascular system, more suitable polymeric nanoparticles, however, are needed for better tissue protection.

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# SOME BASIC ELEMENTS OF THE DIFFERENTIAL DIAGNOSIS BETWEEN HEPATITIS AND SICKLE CELL ANAEMIA IN PREGNANT WOMEN (CASE STUDY)

**Shpresa Thomaj**

American Hospital, Tirana, Albania

The purpose of this study is to emphasise the basic elements of the differential diagnosis between the sickle cell anaemia and viral hepatitis and to define the most adequate way of treating these patients, especially in the third trimester of the pregnancy. Hemoglobinopathies, which include sickle cell anaemia as well, are blood inherited diseases of the autosomal recessive disorder which is not connected to sex.

Sickle cell anaemia belongs to the qualitative hemoglobinopathies group which are the result of a wrong placement of an amino acid in the polypeptidic chain ß of the hemoglobin. In this case it is in the position 6 of the polipeptidic chain ß, instead of the glutamic acid there is valina. The clinical signs of sickle cell disease are various and for this reason it is called “the great imitator”. The iron metabolism suffers big changes. An overload of iron ions in the organism is a condition of the anomalies in other organs. Iron ions overload in the liver causes changes regarding its measures and functions. Liver’s function is irregular from secondary hemocromatosis. As a result, the liver’s ability to synthesise proteins becomes lower (albumin, transferin, hemosiderin). Because of the necrosis in the hepatic cells, transaminases SGOT, SGPT and bilirubin increase. It is because of their increase and similar clinical signs that this disease is confused with viral hepatitis. To do the differential diagnosis it is necessary to do hemoglobin electrophoresis and viral load for hepatitis A,B,C. This is very important to define properly the patient’s treatment.

**Case:** The patient referred to was a-37-week pregnant woman hospitalised in the infection hospital. She showed clinical signs of hepatitis, but laboratory tests for hepatitis A,B,C, resulted negative. After the electrophoresis check was done, it was defined the diagnosis of sickle cell disease. Based on this fact, the patient was transferred in the maternity home.

**Conclusions:** The pregnant patients suffering from sickle cell disease need to undergo a multidisciplinary treatment and in their third trimester it is necessary to be hospitalised in maternity home because of their complications.

**Key words:** Pregnancy, sickle cell disease, hepatitis

# CORRELATION BETWEEN THE APPLICATION OF ANTIHYPERTENSION DRUGS AND THE INCIDENCE OF PROSTATE CANCER

**Edina Bilić-Komarica**

UKCS, Sarajevo, Bosnia and Herzegovina

**Problem.** Prostate cancer is a disease most often associated with old age (second most frequent cancer in men over 50 years of age). Most of these patients also suffer from hypertension and receive hypertension therapy. It is believed that an increase in sympathetic activity, whether directly or indirectly through androgen, can affect stromal prostate cells and in turn its epithelial cells. Several antihypertensive drugs are associated with hormonal reactions. Inhibition ACE reportedly exhausts the level of testosterone. The application of several beta-blockers (Nadol and Anaprilin) is related with an increase in prolactin and estradiol on the one hand, and a lower concentration of testicle hormone. These changes may lead to androgen-stimulated prostate cancer. Four long-term studies show that in the 1970s a positive correlation had been established between hypertension and prostate cancer, although there some that did not.

**Hypothesis.** Application of various antihypertensive drugs in patients with hypertension is one of the reasons for increased incidence of prostate cancer.

**Purpose**. Establishing whether treatment of hypertension leads to a higher incidence of prostate cancer through evaluation of antihypertensive drugs used by the screened patients.

**Sample.** Thirty patients (fifteen in the primary group (P1) and thirty in the control group (P2)) were treated at the Sarajevo University Clinical Centre. The P1 were patients with prostate cancer (PC) identified through PH and treated for arterial hypertension. The P2 should have a minimum of 10 patients with the same characteristics. Both groups will be included in the study according to the inclusion and exclusion criteria.

**Methodology.** This study is being conducted partly as a retrospective and partly as a prospective study until the planned number of patients is reached. The patients are all treated hypertension patients with prostate symptomatology. Besides standardised clinical reviews where anamnesis is taken and blood pressure taken, other relevant data are being gathered through laboratory tests (cholesterol and triglyceride concentration, hormones and biochemical parameters – PSA and TER) as per the questionnaire as a tool for this research.

**Expected results.** The results of this study may contribute to a better assessment and understanding of the relationship of prostate cancer and hypertension and its treatment with antihypertensive drugs (type of drugs and treatment period) and therefore help to select and screen suspected prostate cancer patients. Should this relationship be proved, the treatment of hypertension could be modified to either prevent prostate cancer incidence or help these patients survive the disease. Many studies were similar and most of them confirmed a certain type of antihypertensive drug to the onset of prostate cancer.

**Key words**: Hypertension, antihypertensive drugs, prostate cancer

# PREOPERATIVE RISK FACTORS AND CORRECTIVE MEDICATION FOR THE SUCCESS OF OPERATIONS AND THE REDUCTION OF POSTOPERATIVE COMPLICATIONS IN MIDDLE-AGED AND SENIOR PATIENTS

**Edina Bilić-Komarica, Selma Gicić, Zenaida Dedović**

UKCS, Sarajevo, Bosnia and Herzegovina

**Problem.** Since the Sarajevo University Clinical Centre admits patients from the whole of Bosnia and Herzegovina, it can be said that in the country, just as is the case globally, there is an upward trend in the number of patients subjected to surgical operations of various kinds. This research encompasses patients from 50 to 85 years of age. While old age poses less operation-related risk, the problem lies in risk factors that rise with age, such as stress, smoking, genetic predisposition and unhealthy lifestyle that lead to certain diseases and conditions such as hypertension, diabetes and heart rhythm disorders. In general, cardiovascular diseases were the most common cause of postoperative complications and even mortality in old age, however, this boundary seems to have has moved closer to middle age. The evaluation of senior patients with cardiovascular diseases is hampered by cardiac changes associated with aging, and types of risk factors and atypical appearance of the disease. Premedication is an integral part of the patient's preparation for the surgical procedure. It involves administration of the drug at least 2 hours before the application of anaesthesia. The aim of pharmacological premedication is primarily to reduce the risk by correcting all the parameters to the acceptable physiological boundaries, such as blood pressure, HP; minerals, respiratory parameters, and possibly rhythm and heart rate, followed by. Premedication should not deteriorate the patient's current condition, and the choice of the drug, dose, time, and frequency must be tailored for each particular patient.

**Purpose.** The purpose is to determine the effects of good internist preoperative preparation by identifying possible risk factors and applying medications in such a way as to reduce postoperative complications to the lowest level possible.

**Methodology.** In a retrospective study, 51 patients aged 50-85 were tested by random sampling for acute surgical interventions in urology, thoracic, abdominal and glandular surgery in the course of 2017.

**Results.** The average age of patients was 65.5 years, men being in majority. 24 (64.7%) patients were operated for cancer (47%) and 27 (52%) for benign tumours. A majority of patients had two or more risk factors identified (hypertension 60%, cardiovascular 35.2%, 25.4% frequency freezing, 25.4%). 46 (90%) patients required correction of the internist therapy applied hitherto or the introduction of new drugs. Postoperative complications during hospitalization occurred in 3 patients, namely, lung embolism and deteriorated hypertension. No fatalities occurred in the examined group during hospitalization.

**Conclusion.** Appropriate preoperative internist preparation of both middle-aged and senior patients reduces the incidence of postoperative complications.

**Key words**: Middle-aged and senior patients, risk factors, internist preoperative preparation

# ASSESSMENT OF ANTI-INFLAMMATORY EFFECT OF ALPHA-TOCOPHEROL ON INDUCED RHEUMATOID ARTHRITIS IN RATS

**Amela Dervišević[1], Almira Hadžović-Đuvo[1], Nermina Babić[1], Nesina Avdagić[1], Almir Fajkić[2], Anela Šubo[3], Lejla Dervišević[4], Asija Začiragić[1]**

1 Department of Human Physiology, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
2 Department of Pathophysiology, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
3 Department of Internal Medicine, General Hospital Prim. dr. Abdulah Nakaš, Sarajevo, Bosnia and Herzegovina
4 Department of Anatomy, Faculty of Medicine, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

**Introduction:** It has been shown that Adjuvant-induced arthritis (AiRA) in rats, in many respects, shares a significant amount of similarities with RA in humans and it is widely used as a model for detection and evaluation of compounds with anti-inflammatory or anti-rheumatic activity.

The aim of the study was to assess the anti-inflammatory properties of α-tocopherol (α-T) in the treatment of RA using AiRA animal model.

**Materials and methods:** Study was designed as a prospective, experimental study in which we used twenty-four adult male Wistar albino rats, reared in standard laboratory conditions. Experimental animals were divided randomly into three groups (6 rats in each group): control group (CG), rheumatoid arthritis group (iRA group) and arthritis treated with the α-T group (α-T group).

RA was induced by a single intradermal (i.d.) injection into the base of the tail with 0.1 mL Complete Freund's adjuvant (CFA). Alpha-T was administrated for 30 days, on a daily basis, by oral gavage. The blood samples from all groups were collected on the 1st, 17th and 30th day of the experiment from the tail vein for the purpose of determining the level of IL-17. Disease progression was monitored by measuring arthritis score (AS), mobility score (MS), paw thickness (Pt), local hyperthermia (Lh) and body mass (Bm). Animals were sacrificed by the ether vapors. Obtained data were statistically analyzed using SPSS version 13.0 (SPSS Inc., Chicago, IL, USA).

**Results:** In iRA group we observed statistically significant decreases in the value of Bm ($p=0.017$) and MS ($p=0.003$) on the 30th experimental day compared to the 1st experimental day. There was no statistically significant difference in serum values of IL-17 between individual measurements during experimental period in iRA group of animals. In the α-T group, we noted a linearly decreases of serum IL-17 levels during the experimental period, but differences between individual measurements were not statistically significant. Alpha-tocopherol treated rats expressed statistically significant decrease ($p=0.035$) in AS on the 30th day of the experiment in comparison with the 1st day of the experiment.

**Conclusion:** Taken together, our results indicate that α-tocopherol may act as an anti-inflammatory treatment agent, targeting several different points of the inflammatory process in RA.

**Keywords:** Rheumatoid arthritis; animal model; alpha tocopherol; interleukin-17

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# INDIRECT PROOF OF BILIRUBIN TYPE II PHOTOSENSITIZING PROPERTIES UNDER CONTINUOUS UV IRRADIATION REGIME

**Jelena Stanojević, Dragan Cvetković, Jelena Zvezdanović, Ljiljana Stanojević, Sanja Petrović, Dejan Marković†**

Faculty of Technology, University of Niš, Leskovac, Serbia

Photosensitized oxidations take place via two competitive mechanisms designated as Type I and Type II. According to Foote's definition Type I mechanism refers to the direct reaction between the excited triplet sensitizer ($^3$Sens) and the substrate (fatty acids, phenolics *etc.*) producing free radicals via hydrogen abstraction or electron transfer. Type II mechanism implies energy transfer from $^3$Sens to molecular oxygen ($^3O_2$) *i.e.* triplet-triplet annihilation, giving rise to extremely electrophilic singlet oxygen ($^1O_2$), which easily oxidizes surrounding biomolecules.

Bilirubin (BRB) is water insoluble yellowish-orange pigment permanently created in the health adults as a final product of heme catabolism. It sensitizes $^1O_2$ creation, being simultaneously suitable substrate for its attack. Therefore, it is often stated that BRB sensitizes its own degradation. Riboflavin (vitamin $B_2$, RFL) has a central role as a redox coenzyme in energy-yielding metabolism and it is well known for its photosensitizing properties acting as both Type I and Type II sensitizer.

The aim of the present study was to consider BRB and RFL mutual interaction in methanol solution under continuous UV-A and UV-B irradiation regime. Continuous irradiations of samples were performed in a cylindrical photochemical reactor "Rayonet", with 10 symmetrically placed lamps having the emission maximum at 300 nm (UV-B) and 350 nm (UV-A). The rate of BRB and RFL photodegradation along with simultaneous products formation, as a function of UV exposure time, was followed by combining UV-VIS absorption measurements with RP-HPLC analysis. The compounds were separated by gradient elution with mobile phase A (formic acid, 0.1% water solution) and B (formic acid, 0.1% methanol solution).

According to the results obtained in this study, BRB degradation in the absence of RFL was almost 22 times *i.e.* 9 times slower in comparison to its degradation observed in BRB-RFL mixture under continuous UV-A *i.e.* UV-B irradiation, respectively. Moreover, BRB degradation in BRB-RFL mixture under anaerobic conditions was almost 24 times *i.e.* 16 times slower in comparison to the degradation in aerobic conditions under UV-A *i.e.* UV-B light, respectively. The latter observation suggests that presence of ROS species bear responsibility for BRB degradation. These experiments provide the indirect proof of BRB acting as Type II sensitizer because of the fact that $^1O_2$ produced by RFL mediates BRB irreversible degradation giving rise to dipyrrole methanol adducts as typical products obtained via Type II mechanism.

**Acknowledgements:** This work is part of the research project "Plant and synthetic bioactive products of new generation" no. TR 34012 financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

# ANALYSIS OF THE PLASMA FREE FATTY ACID PROFILE AND COMPOSITION IN PREDIABETIC SUBJECTS

**Šaćira Mandal[1], Adlija Čaušević[1], Sabina Semiz[2]**

1 Faculty of Pharmacy, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
2 Faculty of Engineering and Natural Sciences, International University of Sarajevo, Sarajevo, Bosnia and Herzegovina

Prediabetes represents a condition of impaired fasting glucose or impaired glucose tolerance, both being risk factors for type 2 diabetes (T2D). Impaired glycemia in prediabetes is associated with insulin resistance (IR), accompanied with altered fatty acid metabolism and inflammation. Elevated free fatty acids (FFAs) disturb the normal glucose homeostasis, decrease insulin release and reduce the efficiency of glucose uptake in insulin-sensitive tissues. Studies related to FFAs composition in prediabetic individuals are lacking and therefore in this study we analysed both their plasma concentration and specific composition.

Total of 85 subjects (45 prediabetics and 40 patients classified as controls on the basis of glucose tolerance test), with no evidence of hepatitis B or C viral infection or active liver and kidney damage were recruited in this study. Classification of patients was made according to criteria used by WHO and European Association for the Study of Diabetes. Standard IFCC protocols were used for analysing glycated hemoglobin, glucose and other biochemical parameters, while FFA profile, composition and concentrations were determined by gas chromatography with mass spectrometry detection.

The FFA profile and compositions of the controls and prediabetic subjects were different for 5 of 14 fatty acids with 14 to 22 carbons. The most common fatty acids in both groups of patients were C16:0, C18:1 and C18:2. Compared to controls, total FFA (saturated and monounsaturated fatty acid) concentrations was higher in prediabetic patients. Interestingly in prediabetic population, C22 polyunsaturated fatty acids were not detected. Also, there were no significant differences in concentration between male and female patients. In addition, our data also showed a significant difference in C16:0 levels in prediabetics with poorly and well-controlled disease.

These observations indicate that changes in composition and concentrations of FFA are associated with the development and progression of the disease.

# UV-INDUCED CHANGES OF BILIRUBIN-BENZOPHENONE-RIBOFLAVIN-QUERCETIN-PHOSPHOLIPIDS MIXTURE IN METHANOLIC SOLUTION

**Jelena Stanojević, Dragan Cvetković, Jelena Zvezdanović, Ljiljana Stanojević, Dejan Marković†**

Faculty of Technology, University of Niš, Leskovac, Serbia

The aim of the present study was to consider mutual interaction of bilirubin (BRB), benzophenone (BZP), riboflavin (RFL), quercetin (QC) and phospholipids (Phospholipon 90® -PL90) in methanol solution under continuous UV-A and UV-B irradiation regime. Their interaction was studied dynamically speaking, through the trail of events: initiation (by photosensitizers – BRB, BZP, RFL) → control (by antioxidant – QC) → protection (of the chosen biological target – PL90).

Continuous irradiations of samples were performed in a cylindrical photochemical reactor "Rayonet", with 10 symmetrically placed lamps having the emission maximum at 300 nm (UV-B) and 350 nm (UV-A) under aerobic and anaerobic conditions. The rate of BRB, BZP, RFL, QC and PL90 photodegradation along with simultaneous products formation, as a function of UV exposure time, was followed by combining UV-VIS absorption measurements with RP-HPLC analysis. The compounds were separated by gradient elution using mobile phase A (formic acid, 0.1% water solution) and B (formic acid, 0.1% methanol solution). Formation of LP products (conjugated dienes) was followed by isocratic elution of the mixture using 100% B as mobile phase. By comparing UV-VIS spectra of the observed degradation products of BRB, RFL and QC with those available in the literature, the appropriate structures were proposed.

According to the results obtained, the rate of BRB, RFL and QC degradation (following 1$^{st}$ order kinetics) was slower under anaerobic in comparison to aerobic conditions. Bilirubin degradation was 49 times *i.e.* 10 times slower; RFL 2 times *i.e.* 4 times slower and QC 101 times *i.e.* 56 times slower during UV-A *i.e.* UV-B irradiation, respectively. Slower degradation observed under anaerobic conditions could be ascribed to the absence of ROS species (first of all $^1O_2$, $O_2^{\cdot-}$, $L^{\cdot}$, $LOO^{\cdot}$). Structures proposed for the degradation products of BRB, RFL and QC were those of biliverdin, lumichrome and 2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-2,3-dimetoxy-2,3-dihydro-4H-chromen-4-one, respectively. The observed conjugated dienes formation, despite the presence of well-known antioxidant QC, suggests its inability to inhibit studied photosensitized LP. Enormous degradation of QC, as the cause of decreased antioxidant activity in the observed mixture, could be roughly ascribed to its preventive activity (absorption of UV irradiation), chain-breaking ability (scavenging of free radicals) as well as quenching of photosensitizers' excited states.

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# BIOCHEMICAL AND PATHOPHYSIOLOGICAL CHANGES IN PANCREATIC TISSUE CAUSED BY LIPID PEROXIDATION

**Jasmina Jovanović Mirković[1], Gordana Kocić[2], Ružica Nikolić[3], Danijela Dejković[1]**

1 College of Nursing, Ćuprija, Serbia
2 Faculty of Medicine, University of Niš, Niš, Serbia
3 Department of Chemistry, Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia

**Introduction:** Lead as a pollutant can be detected at all stages of the living and working environment, as well as in biological systems. The average lead concentrations in the soil are between 15 and 25 mg / kg. Lead contamination sources are products of combustion in metallurgy and chemical industry, traffic, industrial wastewater and landfills. Due to its presence in the environment, lead poisoning remains a significant health problem in the world.

**Aim of the study**: The aim of this study is to study lipid peroxidation in the pancreatic tissue under conditions of chronic lead intoxication by measuring the value of malondialdehyde (the secondary product of lipid peroxidation) and the consideration of the protective role of glutathione in conditions with and without intoxication with this toxic metal.

**Material and methods:** Experimental animals white (albino) Wistar rats of female sex, 2 months old, were divided into 4 groups. Group I was a control group, the II group of animals was inoxed with lead (II) acetate. Group III received addition of glutathione supplementation with lead (II) -acetate. Animal Group IV received supplemental glutathione with normal nutrition. From the 10% homogenate of pancreatic tissue stored in the appropriate medium, the following study was performed: analysis of the determination of malondialdehyde concentrations (MDA) in the homogenate of the pancreatic tissue.

**Results and discussion:** Lipid peroxidation is an oxidative damage that affects cell membranes, lipoproteins and other lipid-containing molecules under conditions of oxidative stress. From these results it can be seen that under conditions of chronic lead intoxication, the MDA level increases with respect to the control group of animals in the pancreas (from $0.75 \pm 0.18$ to $2.34 \pm 0.32$). In the group of experimental animals, in which glutathione was supplemented with lead, the concentration of MDA (from $2.34 \pm 0.32$ to $0.96 \pm 0.20$ in the pancreas) was significantly reduced compared to the lead-prone group.

**Conclusion:** Reducing the toxic effect of lead in the presence of glutathione is the result of the interaction of Pb2 + ions with S-donor GSH atoms and points to the possibility that the GSH and the intentions contained therein can be a good supplement in order to reduce the toxic effects of heavy metals, especially lead.

**Key words:** Lead, lipid peroxidation, MDA, glutathione, pancreas

# OXIDATIVE STRESS DEVELOPED BY TOXIC LEAD IN THE PANCREATIC TISSUE OF WISTAR RATS

**Jasmina Jovanović Mirković[1], Gordana Kocić[2], Ružica Nikolić[3], Danijela Dejković[1]**

1 College of Nursing, Ćuprija, Serbia
2 Faculty of Medicine, University of Niš, Niš, Serbia
3 Department of Chemistry, Faculty of Sciences and Mathematics, University of Niš, Niš, Serbia

**Introduction:** Since ancient times, the toxic effect of lead in the living and working environment has been known. Every year, the industry produces about 2.5 million tons of lead worldwide. Apart from food and drinking water, lead can also be introduced through air polluted by fossil fuel combustion products. Lead circulates, in large part, to erythrocytes, then to plasma albumin, and far less in relation to low molecular weight proteins and in ionic form.

**Aim of the study:** The aim of this study is to investigate the effect of lead as well as the protective role of supplements, glutathione on the activity of DNase in homogenate of pancreatic tissue in albino rats, Wistar strains chronically inoculated with sublethal dose of lead.

**Material and methods:** The activity of the alkaline and acid DNase (U / g proteins) was monitored through the formed acid-solubilizing nucleotides spectrophotometrically by the method of Bartholeyns et al., 1975, in 10% homogenate of pancreatic tissue.

**Results and discussion:** In this study it was shown that the activity of alkaline and acid DNase in the homogenate of the pancreatic tissue increases, after treatment with lead. Lead can directly impair the biological function of the antioxidant system as it leads to the increased formation of reactive oxygen species accumulating in the homogenate of the pancreatic tissue. In this study, glutathione (GSH), which has an antidote function, has been shown as an antioxidant effect because it exhibits antioxidant effects during lead oxidative toxicity. Lead poisoning therapy is based on the giving of a chelating agent that "blocks" ions of metal, thus achieving a slight improvement.

**Conclusion:** Lead has a pronounced affinity for thiol groups with which it builds stable mercaptids and inactivates systems in natural conditions, and the added GSH supplement reduces its negative effects with the same mechanism.

**Key words:** Lead, oxidative stress, DNase, glutathione, pancreas

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# PHYSIOLOGICAL STATE OF HORSE BLOOD CELLS IN CONTINUOUS AND PULSED ULTRASONIC FIELD

**Anna A. Oleshkevich**

Moscow State Academy of Veterinary Medicine and Biotechnology, Moscow, Russia

The work included *in vitro* studies on the blood cells of a group of ungulates. Morphological, biochemical and biophysical studies on blood cells of different horses were conducted. The movable liquid tissue (i. m., blood) samples were exposed to a running continuous or pulsed ultrasound (US). The unused blood had been left over from the planned clinical and hematological studies in animal clinics and branches of the Academy was irradiated. The sample volume was from 5 to 10 ml. The US carrier frequency was 0.88 MHz or 2.64 MHz, the therapeutic intensity from 0.05 to 1.0 W/cm$^2$, with exposure on animal blood samples of 15 sec— 1 min, the 10 msec–impulse. Destructive, cytolytic, nucleolytic, and some other effects were discovered. The optimal conditions of US influence on tissue, resulting in a blood physiology, change in the cell cytomorphology up to the completely destruction of blood cells and cell structures in horses' tissues were found.

The following cytomorphological US effects in the red and white blood cells were detected: change of shape and of cell area, change in the volume of the cytoplasm, vacuolization of nuclei and cytosol, the formation of symmetric groups around the cell and red blood cell chains without cytolysis, the appearance of shadows cells, karyorexis, karyopicnosis, chromatinysis, karyokinesis, karyo-fragmentation. White blood cells changed before erythrocytes, after 12–20 sec sonication. The effect on granulocytes, led to the damage of cytoplasmic membrane and then the whole cell, began earlier than the same effect in agranulocytes. In small lymphocytes, degenerative and destructive changes recorded later, after 50–90 seconds. We recorded changes in platelet permeability, shape, deformation, rupture of the cytoplasmic membranes and trespassing. Effects named of continuous and pulse-modulated ultrasound generally correlated with the size of tissue cells of animal species. The results obtained will allow to develop a comprehensive strategy for the development of new methods and devices for physiotherapy of domestic animals. Identified effects should be considered in individually selected safe methods and modes of action of acoustic vibrations on animals of a certain type.

# RADIATION HORMESIS IN THE LIGHT OF LAWS OF QUANTUM THERMODYNAMICS

**Yu. P. Chukova**

The Moscow Society of Researchers of Nature, Krasnopresnenskiy Ecological Fund, Moscow, Russia

Radioactivity is the most terrible danger in understanding of the peace population. Radioactivity has been studied in such aspect all time. Therefore, occurrence of messages about useful effects of weak influence of a radioactivity has caused counteraction and has generated the debate lasting till this moment.

Thermodynamics is capable to bring clearness into this problem. Else, in the 19 century thermodynamics has discovered two types of interaction of system with environment. In one case, a volume and entropy are constant in a system, and in the second one, a volume and temperature remains constant. The process in the second case is called an isothermal one and in the first case – a thermal one. The quantum thermodynamics was developed in second half of the 20 century for electromagnetic radiation. It has shown that an isothermal processes have place at weak influence on system, and thermal ones – at strong influences

Let us pay attention that the logarithmic scale for the absorbed energy is used for isothermal processes, and linear scale is used for thermal processes. The logarithmic scale allows to open what is hidden in the zero point of the thermal processes.

In the previous reports of the author at conferences RAD 2012, 2014, 2017 it was shown that quantum thermodynamics is valid for all three parts of radiation (a, b, g-radiation) and not only for g-radiation. Application of thermodynamic theory to hormesis effects allows to provide fresh insight in essence of proceeding processes. For the experimenters who recorded an U- curve of a dose-effect dependence, it is useful to understand and remember, that they study the identical answer of an organism which is a result of two fundamentally different processes: the left branch shows the end of processes of weak influence on an organism, and the right branch is the beginning of effect of strong influences. Strong influences give linear (or close to it) dependence a dose – effect. They are studied comprehensively and for a long time and they are object of hygienic standardization. Among the investigators studying strong influences, there is a divergence of sights at a threshold of dangerous action: some consider any – even small – doses dangerous, whereas others reject any effects of doses below the threshold. Maybe they are excused by their ignorance of thermodynamics, especially if we consider that in thermodynamics there is no concept of harm. However, if experimenters wish to understand deeply an essence of processes studied by them, they should get acquainted with general laws of quantum thermodynamics. Then it becomes clear to them, why hormesis was found out not only in radiobiology, but also in many other sciences. Hormesis is fixed by any experimenter working in a certain range of influences where the system changes the type of answer to environmental influence (boundary of isothermal and thermal processes).

# RAMAN SPECTROSCOPY IN THE STUDY OF ENZYME KINETICS

**Irina Shpachenko, Nikolay Brandt, Andrey Chikishev**

Lomonosov Moscow State University, Moscow, Russia

The rate of chemical reaction is the most important characteristic of a chemical process. Today several highly sensitive and specific methods can be used to study enzyme kinetics. Some of these methods are indispensable. Each method is efficient in the measurements of concentration of a certain reaction component, but no universal method is known at the moment. In physics, one of the most informative method of studying the structure of molecules (enzymes) is Raman spectroscopy. In this work, we apply the method of Raman spectroscopy to the study of enzyme kinetics.

It is shown that Raman spectroscopy data can be used in calculation of chemical reaction rates in the presence and in absence of enzyme.

Chemical reaction of hydrolysis of 2,4-dinitrophenyl acetate catalyzed by α-chymotrypsin is studied. Reaction kinetics is interpreted as time dependence of the intensity (area) of a single Raman band. To determine rate characteristics, we fit experimental kinetics with analytical solution of the corresponding system of Michaelis-Menten equations. Michaelis ($K_M$) and catalytic ($k_{cat}$) rate constants are calculated. The results are consistent with available literature data. The method is promising for the measurements of enzymatic activity and can be used to estimate the functional activity level.

**Keywords:** Raman spectroscopy, reaction rate, enzyme kinetics, enzymes, functional activity

# DETERMINATION OF THE FEATURES OF THE COAT BY BIOPHYSICAL METHODS

**Svetlana A. Komarova, Anna A. Oleshkevich**

Moscow Academy of Veterinary Medicine and Biotechnology, Moscow, Russia

Hair is extremely plastic in terms of adaptation to living conditions. The structure of mammal's hair is diverse. Some features could be diagnostic indicators. Because of the keratinization of the scaly and cortical cells, the main substance of the hair is keratin. The main properties of wool fibers are extensibility and elasticity which is based on the cross-linking of spirals with disulfide bridges. One of the most important characteristics of hair is a high content of sulfur. Hair pigments belong to the melanin group. Melanins are polymers of quinoid compounds. This is a long chain polymer. All the features and characteristics listed above make it possible to determine whether the studied sample belongs to a certain species by biophysical and biochemical methods. The difference in the structure of the hair in related closely related species can widely vary, as well as in one individual on various stages of development. However, the traditional methods of light microscopy can not always determine these features.

In our study, absorption bands of hair hydrolyzates of various mammalian species were determined for several sex and age groups: a sheep domestic; Noble deer; reindeer; dappled deer; black crested baboon; goat; fox silver-black. In this article, we compared the similarities and differences in absorption bands of wool hydrolysates of domestic sheep and reindeer. Hair samples from 10 adult animals of each species were examined.

You can see from the graphs both general trends and specific differences in the absorption spectra of wool hydrolyzates of sheep and reindeer. The absorption spectrum of wool hydrolyzate does not have pronounced minima or absorption maxima, it is closer to the exponential. The absorption spectrum of the sheep wool hydrolyzate determined absorption maxima at wavelengths of 230–250 nm, 250–260 nm, and 270–290 nm. The absorption spectrum of the hydrolyzate of reindeer fur is different by absorption maxima at 270–280 nm.

Based on the analysis of absorption bands and the features of the exponential attenuation of light absorption by solutions of the corresponding samples, we can speak of the possibility of determining reference series for the wool of animals of various kinds.

# REMOTE SENSING-BASED EMPIRICAL APPROACHES FOR ESTIMATION OF BIOPHYSICAL VARIABLES OF PLANTS UNDER STRESS

**Dora Krezhova[1], Kalinka Velichkova[2], Nikolay Petrov[3]**

1 Space Research and Technology Institute, Sofia, Bulgaria
2 University of Mining and Geology, Sofia, Bulgaria
3 New Bulgarian University, Sofia, Bulgaria

Remotely sensed data have been used for a variety of applications, such as yield prediction and vegetation stress detection. Information on the physiological stage and biophysical variables of crops is essential for growth diagnostics and yield prediction. The chlorophyll content, photosynthetic pigments, soil and leaf water content, and leaf area index are the most important biophysical parameters for determining vegetation health, biomass, photosynthesis, and evapotranspiration. Remote sensing has great potential for these applications because it enables wide-area, non-destructive, and real-time acquisition of information about plant physiological conditions. With recent advances in sensor technology a variety of reflectance signatures can be acquired using ground-based, airborne, and satellite platforms. The hyperspectral data are driving the development of new methods for data analyses at leaf and canopy scales. In this study some empirical approaches based on relationships between leaf reflectance in the red, red edge, and near infrared ranges of the electromagnetic spectrum are developed for estimation of the changes in chlorophyll/pigment content of crops under stress. Red edge position (REP, the rise of reflectance at the boundary between the chlorophyll absorption feature at red range wavelengths and leaf scattering in near-infrared wavelengths) is analysed since it is affected by changes in the biochemical and biophysical parameters and it has been used as a means to estimate foliar chlorophyll content.

In present study, young pepper and potato plants grown in greenhouse were infected with two viruses – Cucumber Mosaic Virus (CMV) and Potato Virus Y (PVY). Spectral measurements were performed on two groups of plants for each crop – healthy (control) and infected with a virus. Hyperspectral leaf reflectance data were collected by means of a portable multichannel spectrometer in the visible and near infrared spectral ranges (450-1100 nm) with a spectral resolution of 1.5 nm. To assess the REP three approaches were applied: first derivative analysis, linear four-point interpolation procedure and polynomial fitting technique. The statistical analyses (Student's t-test, F-test, cluster analysis) were carried out to assess the best empirical models, spectral ratios, and optimal spectral narrow bands for monitoring of the plant health. The study demonstrates that hyperspectral reflectance data in red and red edge spectral ranges can be used to quantify plant stress due to viral infection and related changes in biophysical parameters.

**Key words:** Hyperspectral remote sensing, biophysical variables, empirical models, plant stress, viral infection

# COUPLING FUNCTIONS: UNIVERSAL INSIGHTS INTO DYNAMICAL INTERACTIONS

**Tomislav Stankovski[1,2]**

1 Faculty of Medicine, University 'Ss. Cyril and Methodius', Skopje, Macedonia

2 Department of Physics, Lancaster University, Lancaster, United Kingdom

Interacting dynamical systems abound in nature and science attempts to understand them as much as possible. Often, the interest is not only to understand the structure of systems, but also the functions and mechanisms that define and connect them. This is facilitated by *coupling functions* which contain detailed information about the functional mechanisms underlying the interactions and prescribe the physical rule specifying how an interaction occurs.

We developed a *method* for time-evolving dynamical Bayesian inference of coupled systems in the presence of noise. By decomposing the dynamics into base functions, the method is able to infer and reconstruct the coupling functions from data.

We applied it to better *understand* the biomedical oscillatory interactions under time-varying conditions. The reconstructed cardio-respiratory coupling functions showed in detail how the heart oscillations accelerate or decelerate due to the coupling influence from the lungs. Furthermore, we studied how the cardio-respiratory coupling functions are affected by ageing. It was found that such coupling functions reduce and become more varying and unstable with age. Similarly, recently we inferred the cross-frequency coupling functions of multivariate neuronal oscillations. The strength and the form of neuronal coupling functions were also quantified for spatially distributed brain electrodes. Moreover, we found that the forms of biological i.e. cardio-respiratory coupling functions are time-varying processes for themselves.

Then we used this knowledge of time-varying coupling functions and *applied* it to build a new improved secure encryption protocol. We encode the information signals as modulating scales of plurality of coupling functions between two dynamical systems at the transmitter. Knowing the exact form of coupling functions in use (eventually forming the encryption key) we were able to decrypt the information signals by use of the time-evolving dynamical Bayesian inference. In this way, we showed that the coupling function protocol has unbounded encryption possibilities, allows multiplexing inherently and is extremely noise resistant.

Being a theoretical construct, the coupling function describes the interaction between dynamical systems in general, no matter whether if they are chemical, biological, mechanical or communication systems. Because of this property of *universality* we were able to connect two seemingly very different areas – biology and communications. Needless to say, the methodology and the theoretical concepts have wide implications for interacting dynamical systems in general.

# COMPARATIVE ANALYSIS OF HYPERSPECTRAL VEGETATION INDICES FOR STRESS DETECTION AND ESTIMATION OF BIOPHYSICAL VARIABLES IN CROPS

**Kalinka Velichkova[1], Dora Krezhova[2]**

1 University of Mining and Geology, Sofia, Bulgaria
2 Space Research and Technology Institute, Sofia, Bulgaria

Hyperspectral remote sensing, based on leaf reflectance measurements, is a rapid and reliable method for estimating vegetation's conditions from individual plant to canopy. The advances in remote sensing technologies (optical sensors with high spectral and spatial resolutions) allow receiving accurate information for most important biophysical variables. Algorithms based on Hyperspectral Vegetation Indices (VIs) obtained from reflectance data are comparatively simple and effective means for quantitative and qualitative evaluations of vegetation cover, above-ground biomass and growth conditions, among other applications. These indices have been widely implemented within remote sensing applications using different airborne and satellite platforms as well as contemporary unmanned aerial vehicles. Due to the complexity of different platforms, instrumentation, resolutions, and light spectra combinations customized algorithms have been developed and tested against a variety of applications according to specific mathematical expressions that combine visible (mainly green and red) and near infrared regions of electromagnetic spectrum. Such algorithms improve the sensitivity to investigated parameters minimizing the influence of extraneous factors affecting canopy reflectance.

This study summarizes the development of more than 10 narrow-band VIs and their advantages and disadvantages for estimation of the vegetation biophysical variables and physiological stage of several crops under biotic stress (different viral infections). Hyperspectral reflectance data were collected by means of a portable fiber-optics spectrometer in the spectral range 350-1100 nm with a spectral resolution of 1.5 nm. Different classes of VIs have been calculated: ratio based VIs such as simple ratio vegetation index (SRI), normalized difference vegetation index (NDVI), modified NDVI, photochemical reflectance index (PRI); chlorophyll/pigment related indices such as Green Vegetation Index (GVI), Yellow Vegetation Index (YVI), chlorophyll indices (ChIs), pigment index (PI), chlorophyll absorption ratio index (CARI), modified CARI. Statistical analyses (Students' T-test, F-test, cluster analyses) were applied for assessment of the VIs which best suited for change detecting in biophysical parameters and physiological stage of individual crops under stress. Comparative analyses of advantages and disadvantages of analysed VIs for all crops were carried out. Perspectives on using these VIs for plant stress detection are discussed.

**Key words:** Hyperspectral vegetation indices, biophysical variables, leaf reflectance, viral infection

# CHANGE IN ACID ERITHROGRAM OF LABORATORY ANIMALS IN CONSTANT ELECTRIC AND MAGNETIC FIELD

**Anna V. Novikova, Anna A. Oleshkevich, Viktor E. Novikov**

Moscow State Academy of Veterinary Medicine and Biotechnology, Moscow, Russia

UV-autohemotherapy may sometimes be effective in veterinary medicine practice while treatment of chronic and subacute diseases of infectious and invasive etiology (/International Agricultural Journal (Mezhdunarodnyy sel'skokhozyaystvennyy zhurnal), 2002, No 5, pp. 58–59). For small animals, the procedure is carried out according to the pendulum type. It is possible to modify the type of physical effect on the animal's blood, namely, the replacement of UV radiation with electromagnetic radiation (EMR). During the development of EMR-modifications, we conducted a study of the effect of a constant electric and magnetic field on the suspension of red blood cells of laboratory rats. As a criterion of susceptibility, a change in the distribution of erythrocytes with respect to acid stability was used. Erythrocytes were obtained by triple washing in 0.15 M NaCl (600 g / 5 min).

Erythrocyte suspensions in isotonic NaCl-solution were subjected to an electrostatic field with an intensity of $8.3 \times 10^2$ V/m, with an exposure of 5, 10 and 15 minutes, in a preselected optimum concentration of $3 \times 10^9$ cells per 1 ml. Time chose was based of the technological duration of the proposed therapeutic procedure. To do this, a glass cuvette with a suspension of erythrocytes was placed in the field of the condenser to which the appropriate voltage was applied. Similarly, the suspension of erythrocytes was affected by a constant magnetic field. For this purpose, a plastic tube with a suspension was placed inside a solenoid with strength in the middle of the coil 70 E ($5.5 \times 10^2$ A/m). After irradiation with EMF, the acid erythrograms were examined. 4 n $CH_3COOH$ was chosen as a hemolytic. The resulting distribution of erythrocytes by acid resistance (histogram) was further analyzed by mathematical modeling. It was carried out by the histogram decomposing into the sum of 7 normal distributions series. To each private distribution corresponds one age group of erythrocytes.

Treatment of erythrograms showed that in all cases the significant changes in the stability of cells occurred. The percentage of cell groups with high acid resistance reduced against the increase of the portion of cell groups with reduced acid resistance. These changes were more well-defined when the RBC were exposed to a magnetic field. In all cases, a dose-dependent effect was observed.

# EFFECT OF CONSTANT ELECTRIC FIELD ON THE CHANGE OF ERITHROCITE MEMBRANE PERMEABILITY FOR GLUCOSE

**Anna A. Novikova, Anna A. Oleshkevich, Viktor E. Novikov**

Moscow State Academy of Veterinary Medicine and Biotechnology, Moscow, Russia

In parallel with the study of changes in the acid permeability of erythrocytes [*Change in Acid Erithrogram of Laboratory Animals in Constant Electric & Magnetic Field* // Anna V. Novikova, Anna A. Oleshkevich, Viktor E. Novikov] authors studied the effect of a constant electric field on the permeability of red blood cell membranes for glucose. The erythrocyte production and the conditions of electrostatic field affect were described in the mentioned above report. To determine the permeability of membranes, the phenomenon of reversal of plasmolysis was used which was recorded by the turbidimetric method.

The turbidimeter was a two-beam photoelectric colorimeter connected to a computer. For the electric field creation to the plates of the capacitor were attached to the side walls of the optical measuring cell of the colorimeter. In each dish of the colorimeter 16 ml of the erythrocyte suspension ($3 \times 10^9$ cells per ml) in a 0.15 M-NaCl solution were placed. Then, the reference photoelectric signal resulted in a zero value by compensating the reference beam. Further, an electric field with a strength of $8.3 \times 10^2$ V/m was applied for 5, 10 and 15 minutes. After the electric field was turned off, 1 ml of glucose 2.5 M-solution was added to the measuring (irradiated) cuvette, and 1 ml of 0.15 M NaCl was added to the cuvette of the comparison. In the measuring cuvette a rapid decrease in turbidimetric attenuation was followed by a relatively slow return to baseline. Changes in the turbidimetric attenuation corresponded to changes in the photoelectric signal according to the scheme: fast (2–5 sec) transition from zero to maximum and subsequent slow (60–300 sec) return to zero. The *rapid phase* is the release of water from the cells due to a sharp increase in the osmotic pressure of the medium. *Slow return* to the initial state corresponds to the leveling of glucose concentration in the medium and cells caused by incomplete osmotic activity of glucose.

From the processing of the curves obtained with mathematical modeling technique, the permeability constants of erythrocyte membranes for glucose were revealed. Constants were used as a quantitative criterion of the electric field affect on the permeability of membranes for glucose.

Because of the comparison of the constants, it was found that when the permanent electrostatic field is applied for 5 and 10 minutes, the permeability of the membranes for glucose decreases slightly. And when RBC were exposed to 15 minutes, the membrane permeability increases 4–5 times the reference level.

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# Biomaterials

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# PHOTOSTABILITY STUDIES OF BIOCHANIN A IN THE METHANOL SOLUTION

**Ivana Nikolic, Ivana Savic-Gajic, Ivan Savic**

Faculty of Technology, University of Nis, Leskovac, Serbia

The phytoestrogen biochanin A (5,7-dihydroxy-3-(4-methoxyphenyl)chromen-4-one) is a natural isoflavone derivative with the expressed anti-inflammatory, antioxidative, antimicrobial and antiproliferative activities. The main natural resource of biochanin A is red clover (*Trifolium pretense*). Due to poor literature data about its photostability, the objective of this study was to investigate the impact of UV irradiation on the photostability of biochanin A in the methanol solutions. The methanol solutions of biochanin A transferred in the quartz cells (1×1×4.5 cm) were put on the circular rotating bracket and irradiated in the photochemical reactor "Rayonet". The UVA, UVB or UVC lamps symmetrically placed in the reactor had the maximum emission at the wavelength of 350 nm, 300 nm and 254 nm, respectively. The concentration of biochanin A was monitored using UHPLC-DAD-ESI-MS/MS method. The content of biochanin A was higher after UVA irradiation in relation to the content after UVB and UVC irradiation. These results were expected, because the total energy flux of UVC and UVB irradiation were higher than the total energy flux of UVA irradiation. The quantitative results of UHPLC-DAD-ESI-MS/MS analyses provided the determination of the kinetic parameters of biochanin A photodegradation and to determine the photodegradation products.

**Keywords:** Stability, photodegradation, irradiation

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# GRAPHENE OXIDE AMINO ACID BASED NANOSTRUCTURES: SYNTHESIS, CHARACTERIZATION AND SENSITIVITY TO Co-60 IRRADIATION

**Ana Rajkovic, Mirjana Radenkovic,**
**Srboljub Stankovic, Radovan Dojcilovic**

Vinča Institute of Nuclear Sciences, Belgrade, Serbia

Graphene-based nanostructures have been recognized as a promising material for a variety of applications ranging from bio- and life-sciences to materials science. In this paper, we present results of the study on the synthesis, functionalization and sensitivity to irradiation of graphene oxide and amino acid based hybrid nanostructures in the gamma radiation field. Modified Hummers method was used for the fabrication of graphene oxide. Structural properties of the obtained material had been investigated by the scanning electron microscopy (SEM). The morphology of the graphene layers was preserved and high oxygen content had been found by the energy dispersive X-ray spectroscopy (EDS), verifying successful process of oxidation. In the second phase, a reduction of graphene oxide was conducted in the presence of sodium borohydride or ascorbic acid and related changes in optical properties induced by the reduction process have been monitored by UV-vis absorption spectroscopy. In the final phase, stable intermediate forms of the reduced graphene oxides (rGO) with preserved hydrophilicity have been isolated for conjugation with selected amino acids: tryptophan and phenylalanine. The UV-vis spectra of graphene oxide and reduced graphene oxide water solutions before and after functionalization with amino acids were recorded. The observed changes in characteristic absorption bands of graphene oxide after conjugation proved that the amino acids interacted with the graphene oxide and reduced graphene oxides while maintaining its initial optical properties. Photoluminescence emission spectra of amino acids before and after conjugation have shown that the presence of graphene materials influenced the emission intensity of amino acids and the appearance of new emission maxima. Taking into account possible applications of the obtained graphene-based hybrid nanostructures research was carried out regarding its behavior during irradiation in Co-60 gamma radiation field.

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Biopharmaceuticals

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# INFLUENCE OF LED-LIGHT ON THE PHARMACOLOGICALLY SIGNIFICANT TERPENOID INDOLE ALKALOIDS BIOSYNTHESIS IN *CATHARANTHUS ROSEUS* PLANTS

**Olga Molchan, Ekaterina Zaprudskaya**

The State Scientific Institution "V.F. Kuprevich Institute of Experimental Botany of the National Academy of Sciences of Belarus", Minsk, Belarus

*Catharanthus roseus* G. Don is an important medicinal plant producing pharmacologically significant terpenoid indole alkaloids (TIA). Ajmalicine, vinblastine and vincristine are the most valuable among *C. roseus* TIA. Ajmalicine is used for arterial hypertension treatment. Vinblastine and vincristine are well known as antineoplastic drugs used in chemotherapy of cancer diseases.

Plant growth and development are strongly controlled by specific light wavelengths. LED unique spectra could stimulate vegetative growth, flower or fruits formation. However regulation of TIA biosynthesis in *C. roseus* under different LED-lighting regimes remains poorly investigated.

Influence of LED light on the growth and biosynthesis processes in *C. roseus* was studied. Plants were grown under artificial illumination using different LED-lighting regimes or luminescent lamps as control. Our experiments demonstrated that some LED light regimes strongly stimulated *C. roseus* growth and biomass production. Moreover, we found contrast effects of LED's light spectrum on TIA accumulation in plant leaves and roots. The highest ajmalicine accumulation was observed in leaves and roots of plants grown under LED light with highest Red/Blue ratio and intensity. Plants grown under light with low Red/Blue ratio and intensity had low ajmalicine level, but the highest vindoline and catharanthine (precursors of vinblastine and vincristine) accumulation. L-tryptophan decarboxylase is the key enzyme involved in the TIA biosynthesis. On the other hand, dimerization of the vindoline and catharanthine are catalyzed by peroxidase. The activity of peroxidases and TDC in *C. roseus* seedlings and leaves were depended on the of Blue and UV light intensity of LED-lighting.

Nitric oxide (NO) donors sodium nitroprusside (SNP) and S-nitrosoglutation (GSNO) were shown to demonstrate contrast effects on TDC activity in *C. roseus* seedlings under different LED lighting regimes. L-arginine (0.1-1 mM) caused a similar stimulation of TDC activity and tryptamine accumulation. Effects of SNP, GSNO and L-arginine were inhibited by the NO scavenger cPTIO. Our data suggest that the enzymatic production of NO (NOS-like activity) might be involved in the regulation of TDC activity and tryptamine accumulation in *C. roseus* under LED lighting.

The results of this work could be used in development of ornamental and medicinal plants cultivation techniques.

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# SKIN PHOTOPROTECTION BY NATURAL POLYPHENOLS: EXTRACTS OF WILD ROWANBERRY

**Milica Stanković[1], Vanja Tadić[2], Ivana Arsić[1]**

1 University of Niš, Faculty of Medicine, Department of Pharmacy, Niš, Serbia
2 Department for Pharmaceutical Research and Development, Institute for Medicinal Plant Research , Belgrade, Serbia

Rowanberry (*Sorbus aucuparia* L.), family Rosaceae, especially fruits from this plant, have been used in traditional medicine in the treatment of many different conditions, as well as for food preparations. Nowadays, the plant is used as decorative tree throughout the Europe, and its beneficial potential is underutilized. Plant polyphenols are natural antioxidants and prevent oxidative stress damage by neutralization of free radicals. Recent studies about skin protection from the harmful solar radiation showed the importance of usage of polyphenols from natural sources as a substitutes for the synthetic ones.

The aim of our work was to prepare different fruit extracts from rowanberry plant and to examine the content of total phenols (TPC) and total flavonoids (TFC). Fruits were collected randomly at ripening stage from the wild locality of Vlasina region in Southeastern Serbia. The extracts were prepared by maceration method, at room temperature 21 ± 1°C, by mixing fruits with four different solvents (drug:extract ratio was 1:5): methanol, 45% (w/w) propylene glycol, 70% (v/v) ethanol and distilled water. TPC was determined according to the Folin-Ciocalteau method. The amount of TF was analyzed by aluminium chloride colorimetric method.

The extract with 45% propylene glycol showed the highest phenolic content (4.89 ± 0.24 mg GAE/g of dry extract), while extracts obtained by using 70% ethanol and water had lower contents of total phenols, 3.88 ± 0.16 and 2.22 ± 0.09 mg GAE/g of dry extract, respectively. As far as content of total flavonoids was concerned, the 70% ethanolic and methanolic extracts showed the maximum levels of 6.23 ± 0.05 mg RE/g of dry extract and 5.48 ± 0.07 mg RE/g of dry extract, respectively. The similar values for TFC were for both extracts with water (3.32 ± 0.03 mg RE/g of dry extract) and 45% propylene glycol (3.27 ± 0.04 mg RE/g of dry extract).

The results suggest that rowanberry extracts have the potential for usage as natural source of polyphenols in skin preparations for UV radiation protection. Fruit extracts with 70% ethanol might be the most effective due to the high content of both phenolics and flavonoids fractions.

**Key words:** photoprotection, skin, natural polyphenols, rowanberry, fruit extracts

**Acknowledgements:** Authors would like to thank to the Serbian Ministry of Science and Technological Development for financial support (Project No. 45017).

# EXTRACTS OF BLACKTHORN FRUITS AS POTENTIAL ACTIVE SUBSTANCES IN SKIN PHOTOPROTECTION PREPARATIONS

**Milica Stanković[1], Vanja Tadić[2], Ivana Arsić[1]**

1 University of Niš, Faculty of Medicine, Department of Pharmacy, Niš, Serbia
2 Department for Pharmaceutical Research and Development, Institute for Medicinal Plant Research , Belgrade, Serbia

One of the main causes for the development of photoaging and skin cancer is UV radiation. Oxidative stress generates free radicals which lead to the biochemical changes in the skin structure and skin aging. Utilization of plant extracts for photoprotection is a novel preventive and therapeutic strategy against photoaging. Current researches are based on the new advances of bioactive compounds from plants for skin photoprotection. Plant extracts are mixtures of wide variety of anioxidants, with synergistic action to prevent skin damage. Tannins and anthocyanins are among the most important natural antioxidant compounds.

The aim of our work was to prepare different fruit extracts from blackthorn (*Prunus spinosa* L., family Rosaceae) plant and to examine the content of total tannins (TTC) and total anthocyanins (TAC). Fruits were collected randomly at ripening stage from the wild locality of Vlasina region in Southeastern Serbia. The extracts were prepared by maceration method, at room temperature 21 ± 1°C, by mixing fruits with four different solvents (drug:extract ratio was 1:5): methanol, 45% (w/w) propylene glycol, 70% (v/v) ethanol and distilled water. The contents of total tannins (TTC) and total anthocyanins (TAC) were determined according to the methods described in European Pharmacopoeia 9th edition. The content of tannins was expressed as percentage of pyrogallol (% w/w), while the percentage content of anthocyanins was expressed as cyanidin-3-glucoside chloride (CG).

The extract with 70% ethanol showed the highest content of tannins (0.27 ± 0.05 %), while the extracts with methanol had the highest content of anthocyanins (1407.87 ± 85.85 mg CG/100g of dry extract weight - dw). Extract obtained by using 45% propylene glycol had lower contents of tannins and anthocyanins, 0.23 ± 0.02% and 413.06 ± 53.32 mg CG/100 g dw, respectively. As far as other extracts were concerned, the TTC values for methanol and water extracts were 0.16 ± 0.02 % and 0.11 ± 0.01 %, respectively. The TAC values for extracts with water and 70% ethanol were 517.23 ± 59.88 mg CG/100 g of dw and 197.26 ± 43.80 mg CG/100g of dw, respectively.

Our results demonstrate that tannins and anthocyanins are quite abundant in blackthorn extracts (the characteristic fruit color is evidence for their presence). Future development of sunscreen formulation with blackthorn extracts that might protect the skin from the harmful effects of ultraviolet radiation is completely justified.

**Key words:** tannins and anthocyanins, UV protection, skin, dog rose, fruit extracts

**Acknowledgements:** Authors would like to thank to the Serbian Ministry of Science and Technological Development for financial support (Project No. 45017).

# UV PROTECTION CREAM WITH STANDARDIZED WILD APPLE FRUIT EXTRACT - INVESTIGATION OF POLYPHENOLS AND FRUIT ACID CONTENT AND IN VIVO EFFICIENCY

**Dragana Stojiljković[1], Ivana Arsić[2], Vanja Tadić[3], Aleksandra Bogdanović[4]**

1 Health Care Institution Pharmacy, Niš, Serbia
2 Department of Pharmacy, Faculty of Medicine, University of Niš, Niš, Serbia
3 Department for Pharmaceutical Research and Development, Institute for Medicinal Plant Research "Dr Josif Pančić", Belgrade, Serbia
4 State University of Novi Pazar, Novi Pazar, Serbia

Wild apple fruit (*Malus sylvestris* (L) Mill., Rosaceae) contains a large number of bioactive substances (including polyphenols and fruit acids). Their extracts can be potentially used in cosmetic and dermatology products for prevention and/or treatment of many skin's diseases. Therefore, the aim of this study was to investigate a content of polyphenols and fruit acids, as good antioxidant, hydrating and lightening active substances, in cream with wild apple fruit oil extract, as well as *in vivo* efficiency of this cream which could be used for UV skin protection. Cream was made with 6% of wild apple fruit oil extract (obtained by sunflower oil as solvent and digestion as extraction method) and stabilized with natural biodegradable mixed emulsifiers. Content of polyphenols and fruit acids into formulated cream after preparation was investigated using HPLC analysis, while *in vivo* investigation was carried out employing the biophysical methods on the skin of 10 healthy volunteers (by measuring hydration efficiency, transepidermal water loss-TEWL, skin pH, erythema-EI and melanin index-MI) after 180 minutes of cream application. Formulated cream demonstrated satisfying content of polyphenols (content was 54.86 mg/100g of cream) and fruit acids (141.39mg/100g of cream). Content of these bioactive substances induced positive effects on human skin after short-term cream application during 180 minutes. Increase of skin hydration after 60 min. was 9.10±2.54 and after 180 min. 13.30±16.77. In addition, TEWL and pH values remained unchanged during cream application, while *in vivo* measurements revealed decrease of EI (-29.40±9.15 after 60 min. and -9.40±5.27 after 180 min) and MI (-0.60±9.61 after 60 min. and -2.20±9.78 after 180 min). Cream with 6% of standardized wild apple fruit oil extract and stabilized with natural biodegradable emulsifiers was rich in polyphenols and fruit acids. Synergistic action of these antioxidant, hydrating and lightening bioactive substances induced good anti-irritating, hydrating and lightening effects of UV cream on human skin after cream application. Therefore, cream with wild apple fruit oil extract might be used for prevention of oxidative stress-related skin damages, for dry skin hydration, for skin hyperpigmentation lightening and for UV skin protection.

**Keywords:** wild apple fruit oil extract, UV protection cream, polyphenols and fruit acids, *in vivo* efficiency

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Biotechnology

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# ENGINEERING ROBUSTNESS OF INDUSTRIAL MICROORGANISM *ESCHERICHIA COLI* BY INTRODUCING THE STRESS-RESPONSE GENES FROM *DEINOCOCCUS RADIODURANS*

**Sangyong Lim, Jong-Hyun Jung, Ho Seong Seo, Min-Kyu Kim**

Korea Atomic Energy Research Institute, Jeongeup, South Korea

*Deinococcus radiodurans* (*D. radiodurans*) is well known for its ability to survive multiple extreme stresses, including gamma-radiation, UV light, ROS, and other DNA-damaging agents. Various enzymatic and non-enzymatic anti-oxidative systems, redundancy in DNA repair genes with a unique DNA repair machinery called extended synthesis dependent strand annealing (ESDSA), and some physical characteristics of nucleoids, which are advantageous to DNA repair, contribute to the extreme resistance of *D. radiodurans*.

*Escherichia coli* (*E. coli*) is one of the most frequently used bacterial hosts for the industrial production of recombinant proteins, biofuels, and pharmaceuticals. Thus its cellular robustness should be enhanced for the wide spread application of *E. coli* in biotechnology. However, the production and accumulation of recombinant proteins, fuels, and chemicals can induce a variety of stresses in *E. coli*, such as an unsuitable pH, temperature, osmotic pressure, and oxidative stress, all of which reduce the production from this bacterium.

Extremophiles living under harsh environmental conditions could serve as reservoirs of genes/regulators that could confer robust phenotypes on industrial strains. Recently, it has been reported that the introduction of genes from *D. radiodurans* enhances the robustness of host cells. In this study, we demonstrated successful enhancement of stress tolerance of *E. coli* by introducing stress response genes from *D. radiodurans*. First, a small heat shock protein (Hsp20) of *D. radiodurans*, enhanced tolerance to hydrogen peroxide ($H_2O_2$) stress when expressed in *E. coli*. Second, a response regulator in two component signal transduction system (TCS) of *D. radiodurans*, DR1558, conferred multi-stress tolerance against $H_2O_2$, low pH, high temperature, and high NaCl to *E. coli* by increasing catalase (KatE) activity and alternative sigma factor (RpoS) expression. In addition, *E. coli*introduced with a cold shock domain-containing protein, PprM, from *D. radiodurans* exhibited significant increase of tolerance to $H_2O_2$ by elevating the expression of several OxyR-dependent genes, which play important roles in oxidative stress tolerance. Particularly, manganese transporter gene (*mntH*) was activated by 9-fold in PprM overexpressing cell which affected the increase of cellular Mn/Fe ratio by 2-fold and resulted in the protection of cells from $H_2O_2$ stress. Our findings clearly show that the use of deinococcal stress response genes can improve the robustness of industrially useful microorganisms.

RAD 2018

Biomedical Engineering

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# COMPUTER ANALYSIS OF OCCLUSION IN FIXED DENTAL IMPLANT REPLACEMENT

**Daniela Djurovic Koprivica, Tatjana Puskar, Milica Jeremic Knezevic, Bojana Milekic, Milica Paut Kusturica**

Medical Faculty, Novi Sad, Serbia

Due to the biomechanical specificity of dental implants and the specificity of the surrounding tissues the success key of prosthetic-implant therapy with fixed dental restorations is to provide axial load of implants and physiologically optimal and stable occlusion. Since it can be achieved by the proper positioning of the implants, and the conditions for implantation are rarely ideal, it is often necessary to establish a proper occlusion, in addition to the special implant restorations design, by subsequent reocclusion. In contrast to the qualitative, widespread, analytical procedures where the therapist determines the nature of contact using standard articulation papers and other auxiliary materials, T-scan is a specially engineered computer system that, besides recording contact schedules, gives information on the number and order of establishing contacts, their duration and the relative intensity of the force at each individual contact. This system has undergone several development phases and the latest generation T-scan III system consists of: manual data converter, personal computer, T-Scan III Windows software, small and large holders for ultra-thin sensor foils that are directly connected to a computer. Handling this system is easy due to the simple application and very accurate schematic presented results in a very short time. Due to faster and simpler application, more accurate registration of occlusal contacts and many other advantages compared to qualitative methods of occlusal analysis, the T-Scan system represents a great potential in the diagnosis and treatment of occlusion disorders, especially for restorations on dental implants where adequate occlusion is extremely important.

# VISUALIZATION AND MORPHOLOGICAL CHARACTERIZATION OF INTEGRAL SKIN CELLULAR POLYMERIC COMPOSITES USING X-RAY MICROTOMOGRAPHY

**Remon Pop-Iliev, Wing Yi Pao, Pedram Karimipour-Fard, Ghaus Rizvi**

UOIT- University of Ontario Institute of Technology, Oshawa, Canada

This paper focuses on 3-dimensional non-destructive characterization of the morphologies of integral-skin cellular polymeric composites using X-ray Microtomography. Rapid Rotational Foam Molding (RRFM) is a polymer processing technology that is capable of creating composites with intricate shapes that have a foamed core surrounded by an integral solid skin layer (similar to the structure of a bone). The analyzed specimen were extracted from composites processed in RRFM having a solid skin made of polypropylene (PP) grades combined with foamed cores made of both polyethylene (PE) and PP grades by implementing a suitable chemical blowing agent (CBA) in extrusion. The resulting cellular structures pertaining to the foamed core and the near-skin area were visualized and their morphological quality was evaluated in terms of cell size distribution and cell density. The stress-strain behaviour and 3-dimensional structural changes were monitored and characterized with in-situ compression testing.

# SUPERCRITICAL CARBON DIOXIDE EXTRACTION IN FUNCTION OF STEROIDAL SAPOGENINS ISOLATION FROM *TRIGONELLA FOENUM-GRAECUM* L. SEEDS: PROCESS OPTIMIZATION USING RESPONSE SURFACE METHODOLOGY

**Aleksandra Bogdanovic[1], Vanja Tadic[2], Ivana Arsic[3], Milica Stankovic[3], Slobodan Petrovic[4]**

1 State University of Novi Pazar, Novi Pazar, Serbia
2 Institute for Medicinal Plant Research "Dr Josif Pančić", Belgrade, Serbia
3 Faculty of Medicine, Nis, Serbia
4 Faculty of Technology and Metallurgy, Belgrade, Serbia

Steroidal sapogenins have been known for their activities as hypercholesterolemic, cardiotonic, anticancer, antidiabetic and virostatic substances. Therefore, their medical application is widespread. The aim of this study was to analyze supercritical carbon dioxide extraction of steroidal sapogenins from fenugreek, as green solvent technique, in addition to organic solvent extraction. Defining optimal conditions of supercritical carbon dioxide extraction according and expressed through the yield and content of steroidal sapogenins was observed in order to achieve the acceptable extraction efficiency. The yield of obtained total extract and content of steroidal sapogenins were determined at different conditions of SC-$CO_2$ extraction. Estimation of different SC-$CO_2$ process parameters influence on total extract yield and steroidal sapogenins content was achieved in order to find the optimal working condition for obtaining the SC-CO2 extracts rich in steroidal sapogenins. The response surface methodology (RSM) and central composite design (CCD) were applied to define optimal conditions of SC-$CO_2$ in extraction of steroidal sapogenins.

RAD 2018

Biomechanics

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# KINETIC ENERGY OF HOMOLOGUE CHROMOSOME PAIRS IN BIOMECHANICAL OSCILLATORY MODEL OF MITOTIC SPINDLE

**Andjelka Hedrih[1], Katica (Stevanovic) Hedrih[1,2]**

1 Department of Mechanics, Mathematical Institute SANU, Belgrade, Serbia
2 Faculty of Mechanical Engineering, University of Niš, Niš, Serbia

The ways in which chromosomes move within the cell during the cell division process is called functional genomic architecture. Weise et al (2016) postulate that functional genomic architecture is not only present in interphase but also in metaphase stage of cell division cycle.

The aim of this work was to study how different oscillatory behavior of centrosomes as well as chromosomes' mass arrangement affects kinetic energy of pairs of homologue chromosomes in the system of mitotic spindle during metaphase. The analyses were done through biomechanical oscillatory model of mitotic spindle. In biomechanical oscillatory model of mitotic spindle mitotic spindle is presented as a system of coupled oscillators where coupling is made over two rheonomic centers – centrosomes. One oscillatory pair consists of a centrosome, a microtubule and a related chromosome and these are interconnected with their homologous pair. Each element in the model has its mechanical counterpart.

Analytical expressions for kinetic energy of oscillating pair of homologues chromosomes are given for the case that biomechanical system of mitotic spindle is conservative, linear and oscillate under external single frequency oscillation. Numerical analyses with some approximation for mouse chromosomes were done.

Our numerical experiment reveals that kinetic energy of oscillating pair of homologue chromosomes has oscillatory character and is affected by chromosomes' mass arrangement and frequency of centrosome excitation. If centrosomes oscillate with different frequencies, energy of pairs of homologue chromosomes has non-linear oscillatory character. Maximum value of amplitudes of kinetic energy of pair of same homologue chromosomes are equal in the case of equal frequency of forced centrosome excitation but differ over time in a case of different frequency of forced centrosome excitation.

Regardless the distribution of chromosome masses (central or peripheral position of chromosomes with heavier masses) kinetic energy for each particular pair of homologue chromosomes are lower in the central zone of mitotic spindle, but amplitudes of kinetic energy for each pair of homologue chromosomes subsystems are lower when chromosomes with heavier masses are positioned in central zone of mitotic spindle compare to the case when they have peripheral positions in mitotic spindle.

This difference in energy distribution regarding different centrosome oscillatory frequency in the same cell and mass chromosomes arrangement may carry additional epigenetic information and could be important for process of cell differentiation.

**Key words:** Kinetic energy, chromosomes, centrosome, mitotic spindle, oscillations, biomechanical model

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# Other Topics 34

# THE LARGE ANGLE QUASI-ELASTIC SCATTERING CROSS SECTIONS AND THE EFFECTIVE WEIGHT FUNCTION BASED ON THE BARRIER DISTRIBUTION FOR $^{32}S+^{92,94,96,98,100}Mo$ REACTIONS

**Z. Merve Cinan, A. Hakan Yilmaz**

Faculty of Science, Department of Physics, Karadeniz Technical University, Trabzon, Turkey

We studied quasi-elastic scattering and the effective weight function for the barrier distribution for $^{32}S+^{92,94,96,98,100}Mo$ reactions have been calculated simultaneously in a wide range of bombarding energies around the Coulomb barrier. The quasi-elastic angular distribution data are analyzed using the optical model code with phenomenological Woods-Saxon potentials. It is shown that the calculations taken into account, for these reactions can explain the experimental data of the quasi-elastic cross-section and the quasi-elastic barrier distribution. These results indicate that the coupled-channels formalism can still valid even for the various mass systems. The large-angle quasi-elastic scattering reactions were studied with the same nucleus-nucleus potential recommended for designating fusion reactions. With an empirical barrier distribution establish on the modified Woods-Saxon potential and taking into account the influence of nucleon transfer, the calculated quasi-elastic scattering cross sections of a series of reactions are in good harmony with the experimental data.

**Key words**: Quasi-elastic scattering; coupled-channels formalism; effective weight function; barrier distribution

# THE APPLICATION OF THE SEMIEMPIRICAL METHODS TO DETERMINE THE PROTON TRANSFER OF SOME BENZOYL HYDRAZONES

**Mirjana S. Jankulovska[1], Vesna Dimova[2], Milena Jankulovska[3]**

1 Ss. Cyril and Methodius University, Faculty of Agricultural Sciences and Food in Skopje, Skopje, Macedonia
2 Cyril and Methodius University, Faculty of Technology and Metallurgy in Skopje, Skopje, Macedonia
3 University St. Kliment Ohridski, Chemical-Bromatological-Toxicological Analysis Laboratory, Higher Medical School in Bitola, Bitola, Macedonia

There is a great interest in applying semiempirical methods to predict proton transfer at a given pH for different types of organic molecules. The object of our investigation was five different aromatic p-nitro-p-substituted hydrazones. Optimization of the geometry of investigated hydrazones and calculation of total energy, binding energy, enthalpy of formation, Gibbs energies of formation atomic charge, proton affinity and deprotonation enthalpy values was performed using AM1 (Austin Model 1) and PM3 (Parametric Method 3) semiempirical methods. These parameters were further used for prediction of deprotonation site in the hydrazone molecule in basic media and the site of protonation in acidic media.

Possible protonation sites of investigated p-nitro-p-substituted hydrazones are the azomethine nitrogen atoms i.e. the sp2 (imino) and sp3 (amino) hybridized nitrogen atoms which can exist as cations in acidic media. The obtained results of the proton affinity values suggested that probable protonation site in hydrazone molecule is imino hybridized nitrogen atom with higher proton affinity. The exact place where the molecule can lose a proton can be predicted knowing the values of the deprotonation enthalpy. Hydrazone which possesses two dissociable groups (amide and phenolic group) dissociate in two steps, the first dissociation step was a result of dissociation of the phenolic group, while the second dissociation step was due to dissociation of amide group.

Furthermore, the influence of the substituents in the p-position in the benzene ring of benzoylhydrazones was discussed. The similarity of the proton affinity values of both nitrogen atoms indicated that the influence of the substituents present in the investigated hydrazone molecules is not significant. The same situation was observed with the deprotonation enthalpy values. The stability and the proton affinity of the isomers (E and Z) and their protonated forms were predicted, too. The E isomer has bigger proton affinity compared with Z isomer. The stability of E isomer is greater in neutral media, while there were no difference in stability of protonated forms of both isomers.

**Key words:** p-nitro-p-substituted benzoylhydrazones, protonation affinity, deprotonation enthalpy, semiempirical methods AM1 and PM3, E and Z isomers

# A QUANTUM CHEMICAL INVESTIGATION OF N1-SUBSTITUTED 1,2,4-TRIAZOLE

**Vesna Dimova[1], Mirjana S. Jankulovska[2], Milena Jankulovska[3]**

1 Ss Cyril and Methodius University, Faculty of Technology and Metallurgy in Skopje, Skopje, Macedonia
2 Ss. Cyril and Methodius University, Faculty of Agricultural Sciences and Food in Skopje, Skopje, Macedonia
3 University St. Kliment Ohridski, Chemical-Bromatological-Toxicological Analysis Laboratory, Higher Medical School in Bitola, Bitola, Macedonia

The 1,2,4-Triazole system is a structural element of many drugs that have antimycotic activity such as fluconazole, itraconazole, voriconazole. Because of the synthetic utility and broad range of pharmacological effects, the 1,2,4-triazole nucleus is an important five member ring, and the interest in the synthesis and microbiology of this pharmacophore continues to be fuelled by its analgetic, antiasthmatic, diuretic, antihypertensive, antibacterial, antifungal and anti-inflammatory properties.

One of the methods of preparing derivatives of 1,2,4-triazole is the Mannich reaction (aminomethylation), a well know process. N-hydroxymethyl derivatives of heterocycles such as: benzotriazoles and benzimidazoles under the influence of amines, can also give corresponding Mannich bases. It is also known that some aminomethyl heterocycles, that possess biological and corrosion-inhibition activity can be used as additives in greasy oils as well as photopolymerizing paints to improve adhesion.

A group of five N1-(p-substituted phenyl)aminomethyl-1,2,4-triazole derivatives (PhAMT) was synthesized by condensation of the hydroxymethyl derivative of 1,2,4-triazole and the appropriate aromatic amines.

The aim of our work was geometry optimization of investigated PhAMT and calculation of: atomic charge, bond length and angle between characteristic atoms in triazole molecule, using Austin Model 1 (AM1) and Parametric Method 3 (PM3) semiempirical methods.

The study of the geometry of PhAMT is important because of the possible usefulness of such information as an aid to the understanding of mode of action of PhAMT as acid as and base and co-coordinative species.

**Key words:** N1-substituted 1,2,4-triazole, semiempirical methods, AM1, PM3, geometry optimization, atomic charge, bond length

# CASE STUDY: ERGONOMIC PROJECT

**Osman Çelen[1], Yonca Yahşi Çelen[1], Kemal Fırat Oğuz[2]**

1 Afyon Kocatepe University, Afyonkarahisar, Turkey
2 Maltepe University, İstanbul, Turkey

**Business Selection.** Bigadiç Boron Operations Directorate has observed that the operation concentrator unit can not obtain the required efficiency in the triage belt conveyor, the working conditions are based on labor power and are not ergonomic. It has been observed that the observed working conditions are not appropriate, that there are defects in the body axial stiffness and that this causes a decrease in performance on the workers. Improvements have been made to these factors.

**Materials and Methods.** The average height, which is one of the frequently used variables in anthropometric studies, was found to be 168.88 cm for males and 155.3 cm for females. The weight average was 74.74 kg for males and 67.12 kg for females. In general, sexual dimorphism, which is observed in height and weight, is also one of the important results in the length measurement.

Anthropometric body measurements have been taken as reference to determine the body measurements of the employees of the operating triage band.

**Ergonomic Design.** After taking the required measurements in the area to be designed, 3 appear in the AutoCAD program. Ergonomic design emerged after the improvements to be made were identified.

**Results.** Under the current conditions, it was determined that the working conditions were not ergonomic and the final score was 7 points in the rula test of body axial stresses. This is a situation where urgent action must be taken. It was determined that the final score decreased to 3 when the system was re-raly analyzed after the technical regulations were made.

# INVESTIGATION OF NOISE POLLUTION AND ITS EFFECTS ON COGNITIVE PERFORMANCE OF WORKERS IN OPEN-PLAN BANK OFFICES IN SERBIA

**Selena Samardžić[1], Robert Lakatoš[1], Milan Cvijanović[2], Aleksandra Mihailović[1], Uranija Kozmidis Luburić[1], Tomas Nemeš[1]**

1 Faculty of Technical Sciences, Novi Sad, Serbia
2 Clinical Centre of Vojvodina Novi Sad, Novi Sad, Serbia

Empirical research on the impact of environmental conditions, such as noise, on worker performance has been conducted since the early 20th century. On the other side, open-plan offices, invented in 1950s Germany, are introduced in order to improve productivity and increase communication among coworkers. However, many studies have shown that this type of spatial organization adversely affect the working capacity of employees. Noise affects our health and well-being, our mental state and performance. In order to investigate impact of noise on workers, survey questionnaire and noise measurements were done in six bank offices in Serbia. 66 employees were examined about their subjective impression of environment noise. For data analysis, software for statistical data analysis (SPSS) was used. It has been determined that noise greatly affects the occurrence of stress, psychophysical changes and in the most part to the ability to perform work. Also, it was found that the noise affects the expression of those factors to a greater extent in women, older respondents and to those who have more work experience. The extent of noise was determined using TES-1358A Sound Analyser. The data on equivalent A-level (dBA), as well as, maximum and minimum sound pressure levels were also collected. It was found that Leq levels in open plan offices fluctuate between 55 and 61 dB. Differences in measurement techniques made it difficult to make quantitative comparisons between the various studies. However, this research is the starting point for further deeper analysis on the basis of which could bring significant conclusions.

# INVESTIGATION OF OCCUPATIONAL NOISE EXPOSURE IN ELECTRO INDUSTRIES

**Selena Samaradžić, Uranija Kozmidis Luburić, Milan Cvijanović, Aleksandra Mihailović, Robert Lakatoš**

Faculty of Technical Sciences, Novi Sad, Serbia

It is well known that occupational noise is harmful to health and leads to a whole number of diseases and various other physical or mental losses**.** In addition, the noise indirectly influences the results of the work, regarding reduction of productivity, injuries and the increase in the number of errors. There is causal relationship between workplace noise and hearing loss and the other health problems of the workers. The mechanism of noise generation depends on the particular noise operations and equipment including: electromechanical devices, pumps, compressors, etc. The situation is very much worse when it comes to industry which uses outdated equipment and technology. Mostly, the noise is a result of different types of shock, friction, dynamic imbalance in the work of machine, variable magnetic field, and interference in the flow of fluids. In order to investigate noise in Electro Industry, noise measurements were done with Bruel-Kjaer 2260 Investigator. It was found that sixty percent of the machines produced noise levels above the limiting threshold level of 85 dBA. The dBA of $L_{eq}$ at 1/1 octave bands for pumps and compressors in comparison with NR-80 curve at 1/1 octave bands have been done. The noise rating curves (NR) are developed by International Organization for Standardization to determine the acceptable indoor environment for hearing preservation, speech communication and annoyance. The frequency analysis revealed that the noise was dominated by higher frequency noise, and the maximum level mostly appeared between 1 and 4 kHz. This result represent a worrying fact, having in mind that given the physiology of the oral channel, the human ear is the most sensitive at the frequency of about 3000 Hz. The present investigation showed that most of facilities are not located in work space standardized to adequate acoustic criteria and the workers do not wear hearing protectors.

# STUDY OF GAMOW-TELLER TRANSITIONS FOR GERMANIUM ISOTOPES

**Şadiye Çakmak**

Program of Medical Monitoring Techniques, Osmangazi University, Eskişehir, Turkey

The field devoted to study of exotic nuclei is nowadays one of the most productive in Nuclear Physics. Weak rates in nickel isotopes play an integral role in the dynamics of supernovae. Electron capture and β-decay of germanium isotopes, dictated by Gamow–Teller transitions, significantly alter the lepton fraction of the stellar matter. In this study, Gamow-Teller Transitions (GT) for $^{60\text{-}80}$Ge are calculated using QRPA methods. Also, /EC half-lives to deformation are discussed. The GT strength distributions were calculated using five different QRPA models. QRPA models namely pn-QRPA, Pyatov Method (PM) and the Schematic Model (SM). All three models are further divided into two subcategories: (A) Nuclei are treated as spherical and only particle-hole (ph) interaction is taken into account. The resulting model is referred to as Model (A) in this manuscript. (B) The particle-particle interaction is usually thought to play a minor role in decay but has shown to be of decisive importance in decay and electron capture reactions (Hirsch et al. 1993) in pn-QRPA models. Particle-particle (pp) interaction is then incorporated into the Model (A) to get our Model (B). The SM is further classified into a third category in order to study the effect of deformation of the nucleus on the GT strength functions. In other words, Model (C) takes into account nuclear deformations and also perform the calculation in *both* pp *and* ph channels. Our model's results are also compared with previous theoretical calculations and measured strength distributions wherever available.

# THE STUDY OF THE INFLUENCE OF ADDITIVES IN THE CRYSTALLINITY OF RECYCLED LDPE BY IR AND XRD ANALYSIS

**B. Papajani[1], E. Vataj[2], A. V. Hasimi[3], A. Sinanaj[1]**

1 Faculty of Natural Science, University "Aleksander Xhuvani", Elbasan, Albania
2 Institute of Applied Nuclear Physics, University of Tirana, Tirana, Albania
3 Institute of GeoSciences, Energy, Water and Environment, Polytechnic University of Tirana, Tirana, Albania

In this study it was analyzed the influence of additives used during the recycling process, to the crystallinity of Low-Density PolyEthylene (LDPE). The usage of LDPE recycled is growing up, as other types of recycled plastics, due to its flexibility and other properties. Spectroscopic method of infrared vibration is used for microstructure analysis of the samples. The presence of low-intensity peaks to infrared spectrum at 1300-800 $cm^{-1}$, for all samples indicates the presence of additives. Additives used in the recycled polymers influence their degree of crystallinity that is closely linked with their physical and mechanical properties. Due to the different rates of crystallinity the samples show different intensities of peak at 726 $cm^{-1}$. X-Ray diffraction (XRD) techniques are used to calculate the degree of crystallinity and to study the phase compound of recycled LDPE. By diffractgrams analyses were identified rutile's and calcite's peak, as additives added in the recycled LDPE.

**Key words:** Spectroscopic methods, polarized light microscopy, X-Ray diffraction, crystallinity, phase compound

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