2012

RAD

The First International Conference on Radiation and Dosimetry in Various Fields of Research

APRIL 25 - 27, 2012
FACULTY OF ELECTRONIC ENGINEERING | NIŠ | SERBIA

BOOK OF ABSTRACTS

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INVITED PAPERS

The First International Conference on Radiation and Dosimetry in Various Fields of Research

APPLICATION OF MICRODOSIMETRY FOR RADIATION PROTECTION IN AVIATION AND SPACE

Peter Beck

Austrian Institute of Technology (AIT), Vienna, Austria

The paper presents the basics of microdosimetry in comparison to conventional dosimetric methods. It discusses the historical development of microdosimetry by H. Rossi (1917-2000) a physicist, born in Vienna. The site-size concept and measurement methods of microdosimetry are discussed. It describes applications of microdosimetry in radiation protection for aircraft crew and human in space, carried out during several research projects funded by the European Commission as well as the European Space Agency. Furthermore, an outlook is given of the future development in microdosimetry towards track structure analysis of neutrons, protons, as well as light and heavy ions.

DOSIMETRY FOR MEDICAL APPLICATION OF IONIZING RADIATIONS: CALIBRATION REQUIREMENTS AND CLINICAL APPLICATIONS

Olivera Ciraj-Bjelac, Milojko Kovacevic, Danijela Arandjic

Vinca Institute of Nuclear Sciences, Belgrade, Serbia

Diagnostic and interventional procedures involving x-rays are the most significant contributor to total population dose form man made sources of ionizing radiation. This is particularly evident for examinations using computed tomography equipment and interventional radiological and cardiological procedures. However, x-ray imaging generally covers a diverse range of examination types, many of which are increasing in frequency and technical complexity. This has resulted in the development of new dosimetric measuring instruments, techniques and terminologies which affect e work in the clinical environment and calibration facilities.

Calibration is an essential part of any dose measurement, in particular if these activities are related to human health. The European Directives 96/29 and 97/43 Euratom stress the importance of accurate dosimetry and require calibration of all measuring equipment related to application of ionizing radiation in medicine. The paper gives and overview of current system of dosimetry in diagnostic and interventional radiology that is relevant for metrology and clinical applications. It also reflects recently achieved international harmonization in the field promoted by International Commission for International Units and Measurements (ICRU) and International Atomic Energy Agency (IAEA).

Presented requirements for calibration facilities, in particular for the Secondary Standards Dosimetry Laboratories (SSDL) are given in terms of necessary equipment for generation of beam qualities, dosimetry and auxiliary equipment necessary for operation of SSDL. With respect to the trend in metrology in the field of diagnostic radiology to calibrate dosimeters in the conditions that are similar to the clinical environment, routines for calibration in terms of air kerma, kerma-area product and kerma-length product for dosimeters used in conventional radiography, fluoroscopy, mammography and computed tomography are described, with emphasis on specific radiation qualities, calibration set up and uncertainty assessment.

Objectives of clinical dose measurements in diagnostic and interventional radiology are multiple, as assessment of equipment performance, optimization of practice trough establishment of diagnostic reference levels or assessment of risk emerging from use of ionizing radiation. Therefore, from the clinical point of view, the requirements for dosimeters and procedures to assess dose to standard dosimetry phantoms and patients in clinical diverse modalities, as radiography, fluoroscopy, computed tomography and mammography are presented. Finally, examples of typical dose levees with assessed uncertainties are given.

CORRELATION OF LDH ENZYME ASSAY WITH RADIOACTIVE CHROMIUM ASSAY FOR DETERMINATION OF NK CELL ACTIVITY IN TUMOR PATIENTS

Vladimir Jurisic[1], Gordana Konjevic[2]

[1] University of Kragujevac, Faculty of Medicine, Serbia
[2] Institute of Oncology and Radiology Serbia, Belgrade

Natural killer (NK) cells play a role in the innate and adaptive antitumor immune responses. Determination of NK cell function is essential parameter for estimation immune function in different tumor type. By NK cell function we can estimate degree of immune system in patients with tumor at presentation as early marker, depending on tumor progression. Also we can analyze this parameter during applications diverse therapy protocols, especially immunotherapy.

Recently, there has been a trend in medicine to replace radioactive assays with calorimetric procedures, regarding decrease radiation during laboratory diagnostic procedure in laboratory workers.

This report describes how the LDH enzyme release assay originally described by Korzeniewski and Callewaert, 1983 for measuring NK cell cytotoxicity has been re-evaluated in order to compare it to the widely used standard 5'Crrelease assay. We here reported that several discrepancies exist between radioactive assays and originally described enzymatic assay for NK cell activity in several details. Principe of assays is release intracellular molecules after membrane damage in-vitro condition, after killing of tumor cells in contact with patients NK lymphocytes. However, the enzymatic LDH release method in original version previously described, gave higher values of NK cell cytotoxic activity for healthy controls than did the chromium-51 release assay. We here reported that discrepancy reflecting spontaneous LDH release from the cultures peripheral blood lymphocytes of tumor patients present in the assay. Separate cultures of lymphocytes prepared at the various concentrations used in the assay (8.0 X 106/ml, 4.0 X l06/ml. 2.0 X 106/ml of culture medium), exhibited substantial and concentration dependent spontaneous LDH release following 2 h assay. On average this release was 34% of the experimental LDH activity for an E:T ratio of 80:1) ,24% for an E:Tof 40:1 and 12% for an E : T of 20 : 1.

So, further research indicated that separated cultures of lymphocytes needed, and that LDH release obtained from our separated cell cultures also can be incorporated into formula for exact interpretation of NK cell activity by enzymatic NK cell assay. After incorporation these values in formula, NK cell assay can be used for estimation of NK cell activity in patients with different cancer.

EFFECTS OF RADIATION ON PARTICLE DETECTOR PERFORMANCE

Michael Moll

CERN RD50 collaboration

In order to increase the physics potential of the CERN Large Hadron Collider (LHC), it is foreseen to significantly increase the LHC luminosity by upgrading the LHC towards the HLLHC (High Luminosity LHC). Especially the final upgrade (Phase-II Upgrade) foreseen for 2021 will mean unprecedented radiation levels, exceeding the anticipated LHC fluences by roughly an order of magnitude. Due to the radiation damage limitations of the silicon sensors presently used, the physics experiments will require new tracking detectors for HL-LHC operation. All-silicon central trackers are being studied in ATLAS, CMS and LHCb, with extremely radiation hard silicon sensors to be employed on the innermost layers.

Within the CERN RD50 Collaboration, a massive R & D programme is underway across experimental boundaries to develop silicon sensors with sufficient radiation tolerance. One research topic is to gain a deeper understanding of the connection between the macroscopic sensor properties such as radiation-induced increase of leakage current, effective doping concentration and charge carrier trapping, and the microscopic properties at the defect level. Several clear links between the macroscopic behaviour and the underlying microscopic defects have meanwhile been established and will be presented. Special emphasis will be given to differences in proton and neutron damage with respect to microscopic defect production, NIEL (Non Ionizing Energy Loss) scaling and macroscopic detector performance degradation.

Finally, a brief overview about new sensor developments will be given. This entails the study of sensors made from p-type silicon bulk, which have a superior radiation hardness as they collect electrons instead of holes, exploiting the lower trapping probability of the electrons due to their higher mobility. Another sensor option under investigation is the use of Czochralski silicon. The high oxygen content in the Czochralski-Silicon has been shown to have a beneficial influence on some of the effects of radiation damage. A further area of activity is the development of advanced sensor types like 3D silicon detectors designed for the extreme radiation levels expected for the vertexing layers at the HL-LHC. These detectors in general have electrodes in the form of columns etched into the silicon bulk, which provide a shorter distance for charge collection and depletion, which reduces trapping and full depletion voltage. We will present results of several detector technologies and silicon materials at radiation levels corresponding to HL-LHC fluences.

FUKUSHIMA, DESCRIPTION OF THE ACCIDENT AND CONSEQUENCES TO THE ENVIRONMENT

Dragoslav Nikezic

University of Kragujevac, Faculty of Science, R. Domanovica 12, 34000 Kragujevac, Serbia

As it is well know, large scale nuclear accident was occurred in nuclear power plant Fukushima in Japan. The main cause was large water wave, “tsunami” followed by strong earthquake. All nuclear reactors in Fukushima Daichi power plant were involved in accident. Pools with nuclear waste were also damaged. In this work, the nuclear accident in Fukushima was described in details. Due to this accident, some amount of radioactive material was released in environment, which caused severe contamination of air, ocean water and neighboring land. Contamination level in Europe due to Fukushima accident was discussed with more details. A review of published data about contamination was presented.

SOME ADVANCES IN DOSE MEASUREMENT WITH MOSFET FOR PORTABLE INSTRUMENTATION

Alberto J. Palma

Electronics Department, ETSIIT, University of Granada, Granada (Spain)

Although the dosimetry systems based on MOSFETs developed up to now show remarkable specifications and performances, there are certain issues that can be improved upon, such as cost, range of use, and technology of the sensor, together with a reader unit able to extract the corresponding parameters with suitable measurement algorithms. The aim of this work is to exploit the possibilities in this direction.

The pMOS used in the dosimetry system developed here was irradiated in unbiased mode, and the transistor was connected to the reader unit only during the readout process, which allowed us to calculate the V_T and obtain the dose. The theoretical basis of these calculations has been reported in previous works [1, 2]. Measuring $\Delta|V_T|$ at two different drain currents, I_{D1} and I_{D2}, one obtains [1]:

$$\Delta|V_T| = \Delta V_{S1} + \frac{\Delta V_{S2} - \Delta V_{S1}}{1 - \sqrt{\frac{I_{D2}}{I_{D1}}}}, \qquad (1)$$

where ΔV_{Si} is the source voltage shift measured at constant drain current I_{Di}. Equation (1) allows one to extract the exact value of $\Delta|V_T|$ using two currents only and not considering the increase in the source-voltage due to $\Delta\beta$. As a consequence, the linear range of pMOS dosimeters in unbiased mode is enhanced. In addition, if a third drain current, I_C, is considered, both the thermal compensation and the linear range enhancement can be obtained simultaneously. In fact, this is done by sequentially applying the following expressions [2]:

$$\Delta V_{S1}^0 = \Delta V_{S1} + \left(\Delta V_{SC} - \Delta V_{S1}\right)\frac{\sqrt{I_{D1}} - \sqrt{I_{ZTC}}}{\sqrt{I_{D1}} - \sqrt{I_C}},$$
$$\Delta V_{S2}^0 = \Delta V_{S2} + \left(\Delta V_{SC} - \Delta V_{S2}\right)\frac{\sqrt{I_{D2}} - \sqrt{I_{ZTC}}}{\sqrt{I_{D2}} - \sqrt{I_C}}, \qquad (2)$$

$$\Delta|V_T^0| = \Delta V_{S1}^0 + \frac{\Delta V_{S2}^0 - \Delta V_{S1}^0}{1 - \sqrt{\frac{I_{D2}}{I_{D1}}}}. \qquad (3)$$

A dosimetry system that implements the measurement method described above has been designed, built, and tested. This electronic measurement system consists of a reader unit and a set of wireless sensor modules whose block diagrams are shown in Figure 1. In Table 1, measured dose sensitivities are also written.

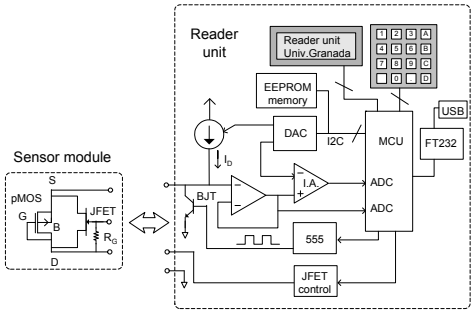

Fig.1. Block diagrams of dosimeter

Energy	Build-up	Sensitivity (mV/Gy)
^{60}Co	None	24.3±1.8
6 MV	0.3 mm	20.8±1.6
6 MV	0.5 mm	20.7±3.6
18 MV	0.5 mm	21.4±2.8

Table 1. Average global sensitivity for different radiation sources

References:

[1] M.A. Carvajal et al., Sensors and Actuators A 157 (2010) 178–184

[2] M.A. Carvajal et al., Phys. Med. Biol. 56 (2011) 3535–3550.

SURFACE AND BULK RADIATION INDUCED DEFECTS IN SI-BASED SENSORS

Ioana Pintilie

National Institute of Materials Physics, Atomistilor Str. 105 bis, 077125 Magurele-Ilfov, Romania

One of the most challenging applications for silicon detectors is given by their use in the inner tracking region of forthcoming colliding beam experiments (Large Hadron Collider at the European research centre CERN) and its planned upgrade (SLHC), International Linear Collider (ILC) or high brilliance photon sources like XFEL. The limiting factors for their practical application are the radiation induced changes in their electrical properties. In this work the understanding of radiation damage effects (bulk and surface effects) is addressed. The detailed relation between the "microscopic" reasons as based on defect analysis and their "macroscopic" consequences for detector performance are presented.

a) Bulk radiation damage resulting from the non-ionizing energy loss (as e.g. LHC and SLHC)

Comparative studies of the defects induced by irradiation with Co60- γ rays, 23 GeV protons and 1 MeV equivalent reactor neutrons revealed the existence of some point defects and cluster related centers having a strong impact on Si diodes. The TSC defect investigations were used to predict the annealing effects and to compare the results with the evaluations of C-V measurements– see Fig.1 (for neutron irradiation).

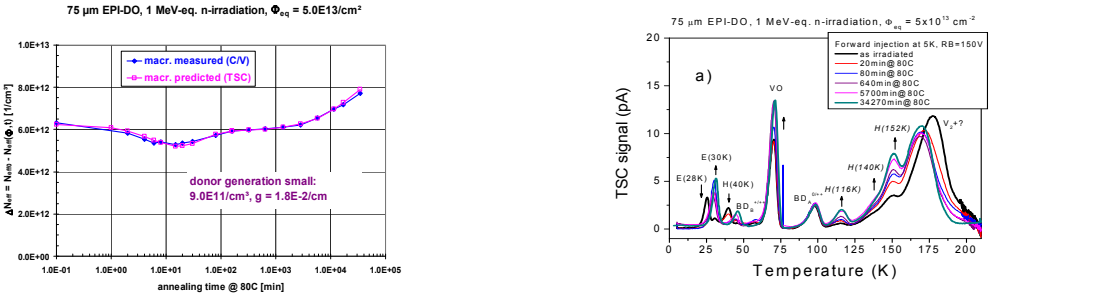

Fig. 1: a) TSC spectra after neutron irradiation as function of annealing at 80°C; b) Comparison between C/V measurements and predictions as given by TSC results

b) Surface and interface related effects caused by ionization in environments with high X-ray doses (as e.g. in XFEL). Results on the densities of oxide charges and Si-SiO_2-interface traps in MOS capacitors built on high-ohmic n-type silicon as function of the 12 keV X-ray dose up to 1 GGy are presented.

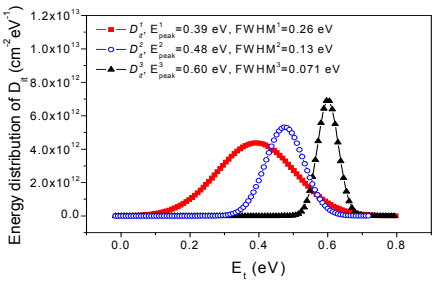

Fig. 2. The shapes of the three dominant interface trap levels caused by X-rays in MOS capacitors as function of their position in the silicon band gap

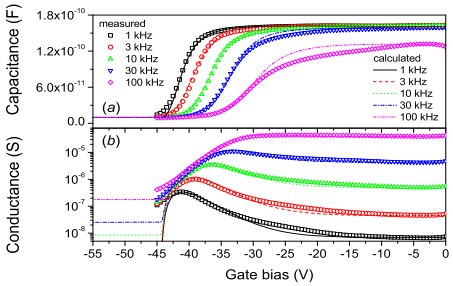

Fig. 3. Comparison of the measured to the calculated C-V and G-V curves (parallel mode) of a MOS capacitor irradiated to 10 MGy (12 keV X-rays) for frequencies between 1 and 100 kHz (*a*) C-V curves, (*b*) G-V curves.

RADIATION DOSIMETRY ON THE INTERNATIONAL SPACE STATION

Guenther Reitz

Division of Radiation Biology, Institute of Aerospace Medicine, German Aerospace Center (DLR), Linder Hoehe, 51147 Koeln, Germany

On board the International Space Station (ISS) continuous measurements of the radiation environment have been performed as part of the space agency's radiation health program to ensure that the exposure of astronauts remains well below established limits. A first mapping of the radiation distribution inside the US lab and Node 1 could be provided in the DosMap experiment which was flown as part of NASA's Human Research Facility in Increment 2 of the ISS(1). Since this time several instruments were flown on ISS to provide further information on the radiation environment in dependence of the solar activity, the altitude and attitude and the varying shielding distributions during the construction of the ISS and later on due to rearrangement of the interior (2-5). Most recently, the experiment DOSIS consisting of a suite of passive and active detectors was performed to provide a mapping of the radiation environment inside the new installed ESA COLUMBUS module. These measurements will be continued in near future with the experiment DOSIS 3D. In addition, Astronauts are equipped with personal dosimeters, which they have to wear during the whole mission. The readings from these dosimeters are private data and are listed in their exposure records.

Having the environmental measurements together with measurements at the Astronaut's body, organ doses, which are needed to calculate radiation risk, can be calculated using appropriate transport models. Another approach to determine organ doses is the use of human phantoms. The ESA multi-user facility MATROSHKA was designed to provide accurate measurements on the radiation doses in human organs during ISS EVA and IVA activities (6). The key part of MATROSHKA is a human phantom upper torso, equipped with numerous radiation detectors at the surface and inside the phantom. The MATROSHKA facility has been flown from 2004 to 2011 and allows the determination of the empirical relations between measurable absorbed doses at the skin and the tissue absorbed doses in different depth inside the phantom. Once the ratios for the tissue- and surface absorbed doses are known for a given radiation field around the human body, these values may be used in future exposures to determine the required tissue absorbed doses from measurements of surface absorbed doses.

This paper intends to give a short summary of the instrumentation used on ISS and inside the MATROSHAKA facility and on the results received from environmental and phantom measurements.

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RESEARCH FOR RADIOTHERAPY WITH HADRONS

Aleksandra Ristić-Fira[1], Ivan Petrović[1], Pablo Cirrone[2], Giacomo Cuttone[2]

[1] Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
[2] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy

The secret of modern radiotherapy is to place the beam on the target with the desired dose, while sparing surrounding normal tissue. Conventional radiotherapy is practiced for more than hundred years with the main goal to increase precision in targeting the tumour volume and to obtain greater biological effectiveness of the applied doses.

Particles like protons and heavier ions have advantages compared to conventional radiation: well defined range, small lateral scattering, high energy deposition just before the end of the range - the Bragg peak. The Bragg peak results from the increased ionization density or linear energy transfer (LET), leading to the rise of biological effectiveness toward the end of the particle range. Since the Bragg peak is very narrow, for the needs of cancer therapy to encompass the treatment volume, it has to be broadened by modulating the particle energy, thus producing the spread-out Bragg peak (SOBP). Protons and heavier ions are considered as high LET radiation, heavier ions having higher LET. Therefore, the effect on DNA of heavier ions with respect to protons can be compared as the effect of “cannon ball” to “bullet”. In the case of high LET radiation the density of the ionization tracks are at the size of DNA structure. The spectrum of induced lesions, as well as their spatial distribution depends on radiation quality. Low LET radiation usually induces reparable single DNA damages, while high LET radiation provokes multiple irreparable DNA breaks. For the tumour cells this gives an increased efficiency of killing, while for the neighboring healthy tissue results in an increased collateral damage (acute effects, late effects and secondary cancer induction).

The relative biological effectiveness (RBE), assessing biological efficiency of the specific type of radiation in comparison to the reference radiation (X- or γ-rays), increases with LET to reach its maximum value in the range from ~ 30 to ~ 200 keV/μm. It depends on the relative dose, ion species, initial energy of the beam, tissue and the analyzed biological end-point. Radiobiological studies of monoenergetic protons or other heavier ions can provide useful information on the biological effectiveness of these particles on different cell lines. For the improvement of radiotherapy, investigations of the effects obtained within SOBP are of particular importance. For more than thirty years protons are commonly used for the treatment of different types of tumours, especially for ocular tumours, such as iris melanoma, choroidal melanoma or retinoblastoma. Carbon (12C) ions, that have recently stared to be used, have advantages, not only with respect to γ -rays, but also to protons. The main advantage of carbon beams with respect to protons is a favorable depth profile of the RBE. The RBE values for 12C ions, due to higher LET attain larger values than for protons. Another important advantage of carbon ions is smaller lateral and longitudinal scattering than for protons. Clinical results have shown that 12C ion therapy can provide a sufficient dose to the tumour volume with a rather low destruction of the surrounding normal tissues. Carbon ions are used for the treatment of the advanced tumors such as adenocarcinoma, head and neck tumors, lung, prostate and pancreatic carcinoma, as well as soft tissue sarcoma.

SUN EXPOSURE PATTERNS; LESSON LEARNT USING TIME-RESOLVED PERSONAL ELECTRONIC UV DOSIMETRY

Elisabeth Thieden, Peter A. Philipsen, Hans Christian Wulf

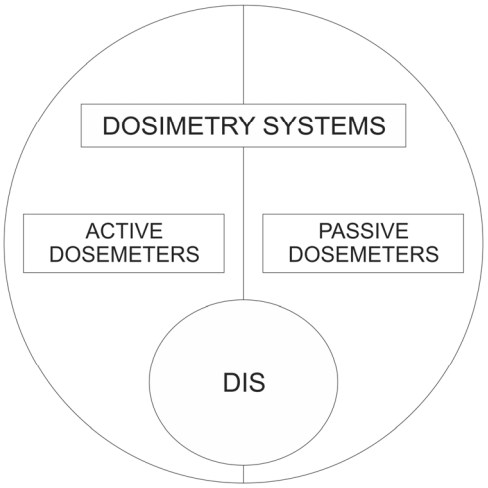
Department of Dermatology D92, Bispebjerg Hospital, University of Copenhagen,Copenhagen, Denmark

To assess individual time-related (time-stamped) UV radiation (UVR) dose pattern and sun exposure behaviour in an open prospective observational study. METHODS: *Subjects* Two hundred eighty-five Danish volunteers with apparently healthy skin: children, adolescents, indoor workers, sun worshippers, golfers, and gardeners (age range, 4-68 years) participated in total 346 sun-years (1 subject in 1 summer half-year). We developed a personal electronic UVR dosimeter in a wristwatch (SunSaver) and measured continuously time-related UVR doses in standard erythema dose (SED) and corresponding sun exposure behaviour from diaries, resulting in total 39068 days analysed. The estimated yearly UVR doses were calculated based on personal and ambient measured doses. RESULTS: The median estimated yearly UVR dose was 173 SEDs (range, 132 SEDs [indoor workers]-224 SEDs [gardeners]), with no significant difference by age (P =.25) or sex (P =.75). The difference in UV dose was greater within the groups than among the groups. Sunbathing or exposing shoulders was defined as risk behaviour. Female subjects had significantly more days with risk behaviour compared to male subjects (17 days; IQR, 9-29 days vs 9 days; IQR, 3-19 days). On days off with risk behaviour, which represented 9% of the participation days, 36% of the total measured UVR dose was received. Children, adolescents and sun worshippers received even respectively 51%, 68% and 60% of their UVR dose during days off with risk behaviour. Children and adolescents received more than half their total UVR dose at the beach. Sunburning doses above 10 SEDs per day were connected with risk behaviour. Of the UVR dose, 50% was received between noon and 3 PM. Only the gardeners received most of their UVR dose (55%) on working days. CONCLUSIONS: High UVR doses are connected with risk behaviour, except for outdoor workers. There is no need to change sun exposure habits on days without risk behaviour. Campaigns on sun protection should be addressed to adolescents and sun worshippers especially females with high intermittent UV exposure.

EVOLVEMENT OF DOSIMETRY SYSTEMS

Matti Vuotila

Mirion Technologies (RADOS), Finland



Typically the dosemeter systems have been thought to be divided into two main categories: Active and passive dosemeter based systems.

While the active dosemeters have evolved during the time of existence in large leaps the technology changes of the passive dosemeters have not really made any significant progress as such. Mostly the read-out systems have been evolving and the performance of the dosemeter systems has progressed.

Even when the passive dosemeters have not gone through very dramatic changes over long period of time, today some updates to these has been made in such a manner that the performance of the modern passive dosemeters have approached quite a bit closer to active dosemeter performance and maybe a third type of dosemeters has been created semi-active dosemeters and systems.

In this talk a short walkthrough from the first active electronic dosemeters till the modern electronic dosemeter of today is given. In addition the new, third type of dosemeter and system is presented with some highlights on measuring capabilities

Keywords:

Passive dosemeters: Film badges, TLD, RPL, OSL

Active dosemeters: GM-detector based, Silicon diode based, multiple diode detectors

Third generation dosemeters: Direct Ion Storage (DIS), instadose

SPACE EEE COMPONENT RADIATION HARDNESS ASSURANCE AND DOSIMETRY

Ali Zadeh

European Space Agency, ESTEC, The Netherlands

The European Space Agency successfully develops and flies state-of-the-art spacecraft in accordance with its member states requirements. The ESA spacecraft fulfil many functions ranging from Scientific, Earth Observation, Manned Space Flight, and Navigation to Telecommunication missions. ESA spacecraft are flown in orbits spanning Low Earth, Geostationary, Interplanetary and even orbits bringing spacecraft to explore other planets and bodies in our solar system.

The launch environment and the space environment in which spacecraft operate are harsh. Spacecraft structure, systems, subsystems and EEE components have to endure severe conditions throughout their mission lifetime but still function according to application specifications. Spacecraft systems have to survive large shock and vibration levels, extreme temperature variation, vacuum conditions and not least be exposed to the harsh natural space radiation environment.

The natural Space Radiation Environment is pervaded by highly energetic particles. These particles constitute different species and energy levels. The major source of the radiation is trapped particles in the Earth's magnetic field, the Sun, Galactic and extra-galactic cosmic rays. This environment is often highly dynamic with a strong Sun / Earth interaction. The composition of the radiation environment for which spacecraft are exposed to varies depending on their orbit location. Spacecraft in Low Earth Orbit are predominantly exposed to protons while spacecraft in Geostationary Orbits are predominately exposed to electrons (when considering cumulative Dose Effects). The population of heavier element particles increases further away from the Earth where the shielding effects of its magnetic field is reduced.

The radiation environment may adversely affect the functionality of EEE components. Radiation effects may present themselves as cumulative or transient effects. There are three major effects to be considered, these are Total Ionising Dose (TID), Displacement Damage (DD) and Single Event Effects (SEE). Radiation Effects in EEE components manifest themselves as non-destructive (e.g. electrical parameter degradation with increasing dose) or destructive (e.g. due to SEEs) effects. Radiation effects, if not accounted for may result in the loss of equipment or in the worst case an entire spacecraft.

To ensure that EEE components selected for flight on ESA missions are suitable, a rigorous Radiation Hardness Assurance (RHA) programme is developed and implemented. The RHA process deals with environment definition, part selection, part testing, spacecraft layout, radiation tolerant design, and mission/system/subsystems requirements. EEE components frequently undergo irradiation testing to determine their resilience to the space radiation environment. An important part of RHA and in particular related to irradiation testing is the availability of accurate dosimetry procedures. The dosimetry procedures need to be reliable, repeatable and traceable to ensure high confidence in the results of irradiation tests on EEE Components flown on ESA missions.

PAPERS

The First International Conference on Radiation and Dosimetry in Various Fields of Research

STUDY OF GAMMA RADIATION INDUCED EFFECTS IN GE-RICH CHALCOGENIDE THIN FILMS

Mahesh Ailavajhala[1], Diana Nesheva[2], Ping Chen[1], Dmitri A. Tenne[3], Hugh Barnaby[4], Maria Mitkova[1]

[1] Department of Electrical and Computer Engineering, Boise State University, Boise, ID 83725, USA
[2] Institute of Solid State Physics, Bulgarian Academy of Science, 1784 Sofia, Bulgaria
[3] Department of Physics, Boise State University, Boise, ID 83725-1570, USA
[4] School of Electrical, Computer, and Energy Engineering, Arizona State University, Tempe, AZ 85287-5706, USA

Chalcogenide glasses receive constant research attention due to the wide range of spectacular properties and externally induced effects they display. Their light sensitivity has been applied in the field of optical recording, as photoresists, phase change memory, etc. The studies of the radiation induced effects in chalcogenide glasses did not finish with visible light. Significant progress has been made to date related to the effects caused by irradiation of amorphous selenium with X-rays which led to the formation of highly effective arrays for digital radiology. However, the amount of research conducted to date related to the effects caused by irradiation with γ-rays in the chalcogenide glasses is quite scarce. The reported effects of γ-irradiation on the electrical conductivity or long-wave shift of the fundamental optical absorption edge of bulk chalcogenide glasses suggest active interaction of the radiation with the chalcogenide glass structure which gives meaning to the importance of these studies.

The presented work reports data from Raman spectroscopy and photoelectrical investigations of amorphous $Ge_{40}Se_{60}$ thin films (100-150 nm thick) before and after γ-ray irradiation. In essence, there are two types of effects occurring – such that are reversible and decay after the cession of radiation and others which are non-reversible and are stable with the time. The reported measurements have been carried out after the radiation has been stopped, so that they can be regarded as capturing only the non-reversible changes caused by radiation. The films were irradiated in a closed cylindrical cavity by concentrically established ^{60}Co (E_{av} = 1.25 MeV) radioisotope capsule at a dose rate of 12 rad/sec. The applied γ-ray doses were ranging from 20 krad(Si) to 3 Mrad(Si). The effect of γ-radiation over the structure is well evidenced on the Raman spectra of the films; there is a change in the relative intensity of the Raman bands which suggests a disorder increase for the low doses (<200 krad) and some structural ordering for the higher doses. The relative ratio of the corner-sharing/edge-sharing structural units decreases which implies some opening of the structure after radiation. A significant increase of the film photoconductivity upon irradiation has been observed which confirms the conclusion for the γ-irradiation ordering. These effects are expected to be used in a radiation sensor in which both – the radiation induced changes in the materials' structure and Ag diffusion are applied for obtaining of significant increase of the conductivity of the irradiated material which can be easily measured for registration of the radiation doses.

Acknowledgements:
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INFLUENCE OF GAMMA IRRADIATION ON SILICON NITRIDE MIS CAPACITORS AND RADIATION HARDNESS

Ercan Yilmaz[1,2], Evrin Tugay[3,4], Aliekber Aktag[1,2], Rasit Turan[3,4]

[1] Physics Department, Abant Izzet Baysal University, 14280 Bolu, Turkey
[2] Center for Nuclear Radiation Detector Research and Applications (NÜRDAM), Abant Izzet Baysal University, Bolu, Turkey
[3] Physics Department, Middle East Technical University, 06531 Ankara, Turkey
[4] Center for Solar Energy Research and Applications (GÜNAM), Middle East Technical University, 06531 Ankara, Turkey

SiN_x thin films with thickness of 100 nm were deposited on p-type (100) silicon wafer by using plasma-enhanced chemical vapor deposition (PECVD) method. After deposition the samples annealed at 500 and 700 °C for 1h at N_2 ambient. The chemical bonds and their densities inside the films were investigated by Fourier transform infrared (FTIR) spectroscopy. The as-deposited and annealed samples with $Al/SiN_x/Si$ structure as metal-insulator-semiconductor (MIS) capacitors were exposed to a 60-Co gamma radiation source with a dose rate of 0.015 Gy/S. Capacitance-voltage (CV) measurements were performed for frequencies of 10, 100 and 1000 kHz before and after radiation exposure with doses of up to 40 Gray. It was found that before gamma irradiation compared with as-deposited sample, the annealed samples exhibit less negative flatband voltages (V_{fb}) shift indicating the relative reduction in positive charge in the SiN_x:H samples. After gamma irradiation for all samples a negative shift has been observed in V_{fb}, being more pronounced in the samples annealed at higher annealing temperature of 700 °C. The more streaking feature is that the amount of shift doesn't change by increasing radiation dose after first irradiation, in which we attributed to the radiation hardening in $Al/SiN_x/Si$ MIS capacitors which can be used in space and nuclear applications as a radiation hardened device.

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POSITIVE BIAS TEMPERATURE STRESS IN IRRADIATED AND NON-IRRADIATED THIN FILM TRANSISTORS (TFTS)

Emil V. Jelenković[1], S.K. Jha[3], K.Y. Tong[1] , G.S. Ristić[3]

[1] Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong, PR China
[2] Center of Super-Diamond and Advanced Films, Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong, PR China
[3] Faculty of Electronic Engineering, University of Niš, Serbia

There are only few reports on irradiation stability of TFTs, while advanced TFTs show promises for their application under the irradiation conditions [1]. Generally, TFTs show instability under positive or negative bias temperature tests (PBT or NBT) and it is of technological interest to understand their behavior after irradiation if exposed to such tests. In this report we compare irradiated TFTs with non-irradiated after PBT stress.

Fully sputtered fluorinated-hydrogenated TFTs were used in the course of this investigation [2]. The irradiated samples, with total dose of 2000 Gy, were exposed to PBT stress a year after irradiation. The PBT test was conducted with Vgs=5V and with drain-source electrodes shorted in the temperature range from 100 °C to 150 °C.For each stress test a fresh TFT was used. A typical threshold voltage (Vt) vs stress time is shown in Fig. 1. The rate of Vt change is higher for the irradiated TFTs and it is valid for lower stress temperatures, as well, but with a smaller gradient. The finding is explained qualitatively in terms of grain trap boundaries, positive oxide charge and interface states generation [2].

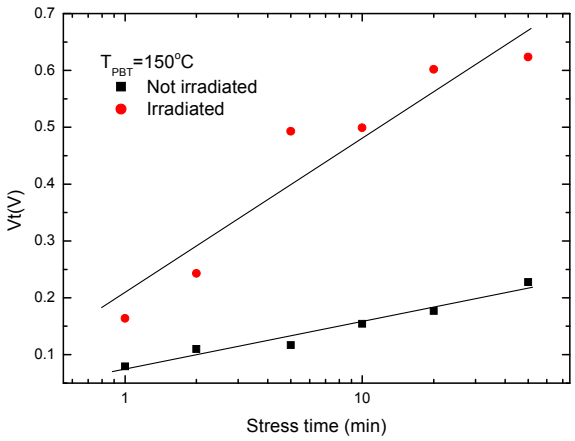

Fig.1 Threshold voltage change of irradiated and non-irradiated TFTs after different stress times of PBT.

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POST-IRRADIATION CONSTANT CURRENT STRESS STABILITY IN SPUTTERED GATE OXIDES

Emil V. Jelenković[1], Milojko Kovačević[2], S.K. Jha[3], K.Y. Tong[1], D. Nikezić[4]

[1] Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong, PR China
[2] Vinča Institute of Nuclear Science, Belgrade, Serbia
[3] Center of Super-Diamond and Advanced Films, Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong, PR China
[4] University of Kragujevac, Faculty of Science, Kragujevac, Serbia

With advances in thin film transistors (TFTs) technology, there is great interest to study their performance under irradiation conditions [1,2]. In TFTs gate insulator can be deposited by LPCVD, PVD or sputtering. Post-irradiation stability of MOS devices is particularly important in their application as radiation dosimeters. This investigation compares stability of irradiated and non-irradiated sputtered oxide in MOS structures under constant current stress.

The irradiated MOS capacitor on p-type Si were exposed to gamma irradiation of 2 Mrad and subsequently stored for 12 months. The constant current stress was performed with electron injection from metal electrode. The gate oxide was prepared under optimal condition described in Ref. 3.

A significant frequency dispersion of C-V curves was observed after constant current stress.

The generated fixed oxide charge and interface states were evaluated using the approach described by Alexandrova. et.al. [4]. For illustration, the change of interface states after the stress is shown in Fig. 1. The irradiated samples show grater instability regarding the flat band voltage and interface states. To improve the post-irradiation stability of sputtered oxide its nitridation or fluorination is suggested.

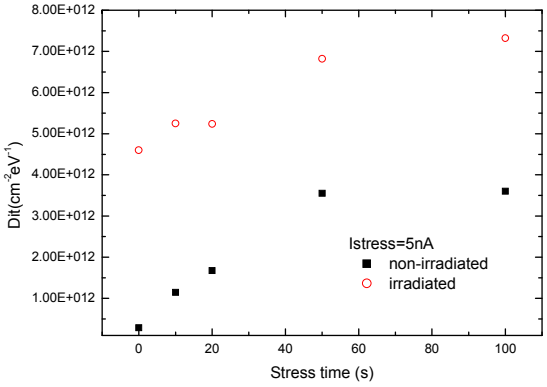

Fig.1 Interface states generation in non-irradiated and irradiated sputtered oxide after constant current stress; electron injection from aluminium; gate area is 1.4×10^{-4} cm^2

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ONLINE RADIATION DOSE MEASUREMENT SYSTEM FOR ATLAS EXPERIMENT

Igor Mandić

Representing ATLAS collaboration, Jožef Stefan Institute, Jamova 39, Ljubljana, Slovenia

Particle detectors and readout electronics in the high energy physics experiment ATLAS at the Large Hadron Collider at CERN operate in radiation field containing photons, charged particles and neutrons. The particles in the radiation field originate from proton-proton interactions as well as from interactions of these particles with material in the experimental apparatus. In the innermost parts of ATLAS detector components will be exposed to ionizing doses exceeding 100 kGy. Energetic hadrons will also cause displacement damage in silicon equivalent to fluences of several times 10^{14} 1 MeV-neutrons per cm^2. Such radiation doses can have severe influence on the performance of detectors. It is therefore very important to continuously monitor the accumulated doses to understand the detector performance and to correctly predict the lifetime of radiation sensitive components. Measurements of doses are important also to verify the simulations and represent a crucial input into the models used for predicting future detector performance.

The online radiation monitoring system in ATLAS experiment measures ionizing dose in SiO_2, displacement damage in silicon and fluence of thermal neutrons at several locations in ATLAS detector. The on-line measurement of the Total Ionizing Dose (TID) is done with radiation sensitive MOS transistors (RADFETs). Displacement damage in silicon is monitored with diodes. Fluences of thermal neutrons are estimated from gain degradation in dedicated npn bipolar transistors.

In this contribution the design of the online radiation monitoring system, results of measurements and comparison of measured integrated doses and fluences with predictions from FLUKA simulation will be shown.

A COMPACT MONOCHROMATIC ELECTRON SOURCE TO CALIBRATE RADIATION DETECTORS

J.M. Cornejo, A.M. Lallena, D. Rodríguez

Departamento de Física Atómica Molecular y Nuclear, Universidad de Granada, Spain

Monochromatic electron beams in the energy range of 1-20 MeV are important to measure very precisely the response function of radiation detectors to be used in fundamental physics, in β decay experiments, or in applications as, for instance, to determine the energy profile of an electron clinical accelerator. The production of these beams is however not straight forward, as natural monochromatic electron sources do not exist for energies above 1 MeV. In this contribution we present the results of a first experiment carried out at a tandem accelerator using a prototype of a device built at the University of Granada. This device is based on a set of electromagnets and has several features regarding the cooling of the coils, the calibration of the magnetic field and the portability.

THERMOLUMINESCENCE (TL) AND OPTICALLY STIMULATED LUMINESCENCE (OSL) IN NATURAL SCIENCES AND ENGINEERING

George S. Polymeris[1,2], Nestor C. Tsirliganis[2], Konstantinos M. Paraskevopoulos[1], George Kitis[3]

[1] Physics Department, Solid State Section, Aristotle University of Thessaloniki, GR-54214 Thessaloniki, Greece
[2] Laboratory of Radiation Applications and Archaeological Dating, Department of Archaeometry and Physicochemical Measurements, Cultural and Educational Technology Institute, Athena Research and Innovation Center in Information, Communication and Knowledge Technologies, Tsimiski 58, GR-67100 Xanthi, Greece
[3] Physics Department, Nuclear Physics Lab, Aristotle University of Thessaloniki, GR-54214 Thessaloniki, Greece

Thermoluminescence (TL) and optically stimulated luminescence (OSL), has been increasingly used for dosimetric purposes presently constituting an important part of solid-state dosimetry. The luminescence that is emitted from an irradiated material during the thermal or optical stimulation period provides a measure of the radiation dose absorbed by the dosimeter. Through calibration of the signals against known doses of radiation, the absorbed dose can be obtained. Luminescence dosimetry has been actively developed in the past 3 decades thanks to its successful applications. Among them, the most widespread is radiation monitoring of personnel working in any kind of radiation environment. Also, in recent years, luminescence dosimetry has been used on ever growing scale in radiation therapy. The aforementioned successful applications of luminescence dosimetry stemmed from the search, development, and analysis of properties of artificial materials which were fabricated for detectors of ionizing radiations. A brief overview of the properties of those artificial luminescent dosimetric materials will be presented, along with some general approaches to the search for and the development of new efficient dosimetric materials.

Nevertheless, luminescence dosimetry is also applied by using naturally occurring dosimeters, a typical example being the sterilization dosimetry. Herbs, spices and medicine are sterilized by the use of large doses (of the order of 1-20 kGy). Luminescence stands as a unique tool to assess these doses. Several examples will be presented. Moreover, applications of the so called retrospective dosimetry fall in two major categories, namely the geo-archaeological dating and the accidental dosimetry. The target material in these cases consists of grains of naturally occurring minerals, usually quartz and/or feldspar; however in some cases salt works also, very efficiently. A separate determination of the environmental dose rate is required in order the age of the sample to be specified. A number of successful luminescence applications to dating aspects will be presented, while special attention will be paid to some ongoing trends towards dating of megalithic structures, paintings, marbles and glasses.

Nevertheless, the traditional field of applications of luminescence has been considerably expanded besides dosimetry. TL is also an established tool of engineering towards the solid-state characterization of several materials as well as the detection of phase transitions. In the framework of this presentation, special emphasis will be given to a number of alternative and pioneer applications of TL as a probe for:

- Study of ancient pottery manufacturing technologies by assessing their firing temperature in the past.
- Provenance studies in the cases of crystalline quartz, amorphous silica glasses, obsidian and gemstones of archaeological interest.
- Study of crystallization conditions of geological quartz and feldspars.
- Bioactivity study of artificially manufactured bioactive glasses for osteo-inductive and osteo-conductive purposes.
- Characterization studies of properties of nano-structured materials, such as dosimetric Al_2O_3:C as well as thermoelectric Mg_2Si.

ANOMALOUS EFFECTS IN THERMOLUMINESCENCE

Arkadiusz Mandowski[1], Jacek Orzechowski[2], Ewa Mandowska[1]

[1] Institute of Physics, Jan Długosz University, Armii Krajowej 13/15, 42-200 Czestochowa, Poland
[2] Stanislaw Staszic High School, ul. Szkolna 12, 27-200 Starachowice, Poland

Thermoluminescence (TL) is a widely known technique, frequently used for characterization of traps and recombination centers (RCs) in insulating materials. Commercial applications include dosimetry of ionizing radiation and dating of archeological and geological objects. Prior to the measurement a sample is excited at appropriately low temperature to fill traps and RCs with charge carriers. Then, the sample is heated, usually with a constant rate. During heating emitted luminescence is recorded. The luminescence is related to recombination of charge carriers, which were thermally released from traps and then moved to RCs.

Since many decades, researchers studying TL properties often find unexpected TL behaviour. Most known examples include:

- the occurrence of very high frequency factors
- the occurrence of dose-rate effect
- first order shape of most TL glow curves
- anomalous heating-rate effect

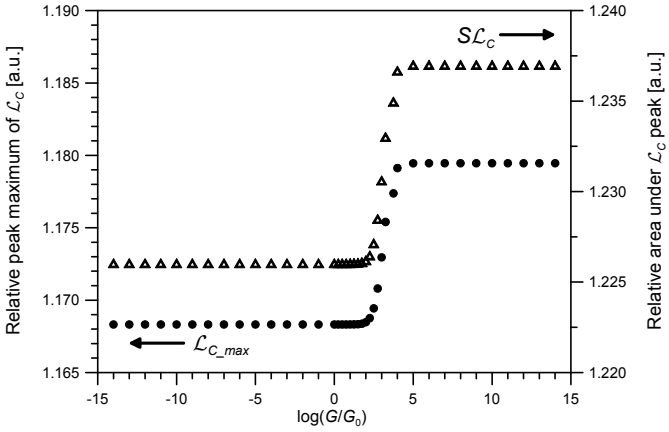

Fig. 1. Dose-rate effect in the SLT model

Most of these properties could not be explained in the framework of already known theories, i.e. the simple trap model (STM) and the model of localized transitions (LT). Recently, a more general theory was suggested [1-3]. The model of semi-localized transitions (SLT) describes TL and optically stimulated luminescence (OSL) kinetics unifying the STM and LT models. This paper shows how SLT predicts all of these 'anomalous' phenomena. Despite mathematical complexity, the physical interpretation is very clear and coincides with experimental data [4,5].

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NEUTRON SPECTROMETRY WITH HE-3 PROPORTIONAL COUNTERS

M. Manolopoulou[1], M. Fragopoulou[1], S. Stoulos[1], W. Westmeier[2], M. Zamani[1]

[1] School of Physics, Aristotle University of Thessaloniki, Thessaloniki 54124, Hellas
[2] Philipps-Universität, 35032 Marburg, Germany

Application of He-3 counters in neutron detection and spectrometry has been long proposed mainly due to high cross section of ^{3}He interaction with neutrons, though for spectrometry applications the complexity of the spectrum as well as several other causes like the wall effect, recombination and space charge make response function calculation a difficult task. In this work the response of a proportional He-3 counter is studied experimentally and simulated with the Geant4 code. The calculated response of the system is used to determine neutron energy distribution in an unknown neutron field.

The counter was irradiated with monoenergetic neutron beams for various operating voltages in the proportionality region to specify the optimum operating settings as well as to examine the linearity of the pulse height with neutron energy. The irradiations were realized in Tandem, NCSR "Demokritos", Athens, Hellas, with nearly monoenergetic neutron beams in the energy range from 230 keV up to 10.7 MeV, for different operating voltages in the proportionality region [1].

Regarding energy calibration, the full-energy peak position is linearly correlated with neutron energy, while the position of the ^{3}He recoil peak deviates from a linear response, especially in the lower energy region. By means of the linear full-energy peak calibration, recoil peak energies are found to be significantly lower than those resulting from the kinematics of the reaction, due to recombination effect. Using the Bragg curve of the recoiling nucleus in the counter gas mixture, the recombination coefficient is determined 33.5 ±1.3 % of the fraction of energy deposited by a ^{3}He nucleus traversing the gas mixture with a stopping power higher than 450 eV/μm. The energy calibration equation for the recoil peaks is derived using: i) the range-energy relation and the stopping power function for a ^{3}He nucleus in the gas mixture where the coefficients of both functions were determined via Monte Carlo (SRIM code) calculations, and ii) the experimentally determined recombination coefficient [2].

To determine the efficiency of the system, irradiations with neutron beam energies 565 keV, 1.2 MeV and 2.5 MeV were performed in a calibrated neutron field in PTB, Braunschweig, Germany. The response of the counter is calculated with GEANT4 simulation kit, taking into account the different energy calibration for the events coming from different reactions. The simulated spectra are compared with the pulse height distributions obtained in the calibrated neutron field.

The calculated response of the system is used to determine neutron energy distribution from the spallation set-up "Energy+Transmutation". Neutron fluencies in the energy region from 0.1 to about 7 MeV are determined with an uncertainty of about 10% while they are found in acceptable agreement with those calculated with Dubna Cascade Model code.

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EFFECT OF SYNTHESIS METHODS, DOPING METHODS, METALS AND METAL CONTENTS ON THE DOSIMETRIC PROPERTIES OF LITHIUM TETRABORATE

A. Yilmaz[1], G. Özbayoğlu[2]

[1] Department of Chemistry, Middle East Technical University, 06800 Ankara, Turkey
[2] Dean Faculty of Engineering Atılım University Kizilcasar Mahallesi, Incek-Golbasi 06836 Ankara, Turkey

Thermoluminescent dosimeter (TLD) needs to have some features such as; a simple glow curve structure, a high gamma ray sensitivity, low fading of TL signal, linear dose-response relationship, simple annealing procedure for reuse, chemical stability and inertness to extreme climatic variations, insensitive to daylight, suitable effective atomic number (Zeff), close to that of soft tissue which is 7.42 [1]. The effective atomic number of lithium tetraborate is (7.42), which is almost the same as that of the biological tissue [2, 3]. Due to that reason, in this research, Lithium tetraborate: $Li_2B_4O_7$, has been synthesized by different methods, such as, high temperature solid state synthesis and solution assisted synthesis methods. After preparing the host material, Cu and Mn were doped with different concentrations, such as 0.1–3.0% by mass. TL glow curves of Mn and Cu doped LTB samples produced by using different synthesis and doping methods and Ag, P and Mg co-doped samples were investigated for comparison. Structural and morphological analyses of products were done by using Fourier Transform Infrared spectroscopy (FTIR), Powder X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM) and Raman Spectroscopy. All samples prepared displayed TL response and the best TL signal was obtained from the sample produced by solid state synthesis and doped by solution assisted method with 0.1% Cu and 0.004% Ag. High temperature solid-state synthesis of LTB and high temperature solid-state doping of Mn gave better glow curves with 1 wt% Mn content than other products with different synthesis and doping methods and than other percentages of Mn in LTB with two separable glow peak at 350 and 553 K with high intensity. The addition of Ag as co-dopant shifted the main glow peak to 473 K. P increased the intensity of glow peak at 553 K. Mg increased the glow curve complexity.

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NEUTRON DIFFRACTION ASSISTED INVESTIGATIONS IN CONDENSED MATTER PHYSICS AND MATERIALS SCIENCE AT INRNE - BAS

K. Krezhov

Institute for Nuclear Research and Nuclear Energy, Bulgarian academy of sciences, 72 Tzarigradsko chaussee, 1784 Sofia, Bulgaria

The quest for novel materials with potential for the development of new technologies is one of primary topics in modern multidisciplinary scientific research. This article is motivated by the recent resurgence of interest in complex oxides owing to their coupling of electrical, magnetic, thermal, mechanical, and optical properties, which make them suitable for a wide variety of applications. Solving the structure property problems for 21st century materials is requiring characterization tools that keep pace with advances in synthesis. Neutron scattering methods (diffraction, small angle scattering, reflectometry, inelastic scattering) have proven to be a highly informative tool in both fundamental and applied science. For 60 years these methods have been used for materials characterization. Although other techniques measure structure and dynamics, the neutron has a number of properties that make neutron scattering so important means for materials research. Among the specific properties distinguishing the neutron from other elementary particles are: absence of electric charge, presence of magnetic moment, different scattering amplitude for different isotopes of one atom, large penetrating depth and energy comparable to that of dynamic lattice excitations. Undoubtedly, neutron scattering will continue to play a central role in meeting the challenges in the world of nanomaterials, biomaterials, and soft materials. It appears that the physical properties of nanosystems and nanostructured materials can be markedly different from those in bulk, opening up new prospects for scientific research and the development of nanotechnologies.

We present results from the recent neutron diffraction assisted studies carried out at INRNE-BAS. The neutron diffraction experiments convey information about both the structural arrangement of the atoms and the ordering scheme of their magnetic moments and have been used to tackle with complex structural problems. The systems we studied were perovskites from the $ReFe_xMn_{2-x}O_3$ and $ReFe_xMn_{2-x}O_5$ series (Re is a rare earth ion or Bi), double perovskites $Sr_2FeMoO_{6-x}N_x$, mixed oxides $YFe_xCr_{1-x}O_3$, and some completely structurally unrelated materials like $Ba_2Mg_2Fe_{12}O_{22}$, which are Y-type hexaferrites. The experiments were aimed at improving of the understanding of some fundamental aspects of the mechanisms giving rise to intrinsic effects such as orbital and charge order and multiferroicity. Such effects are manifestation of the strong interplay between the orbital, charge, and spin degrees of freedom in these systems and similarly to high-temperature superconductivity after 20 years of investigations, the elucidation is not yet completed. Neutrons feel hydrogen and light atoms in general, can detect isotopic substitutions, and are highly sensitive to magnetism. In contrast to other probes utilized in structural investigations such as electrons and X-rays the neutrons have the ability to reveal nuclear positions and mean displacements without bias from the effects of electron distribution. The structural findings are combined with results from magnetic and electrical measurements and Mössbauer spectroscopy.

RETROSPECTIVE RADON AND THORON MEASUREMENTS BY HOME STORED CDS/DVDS - RESEARCH AND PRACTICE

Dobromir S. Pressyanov

Faculty of Physics, University of Sofia "St. Kliment Ohridski", Sofia, Bulgaria

After twelve years of dedicated experimental and theoretical work, the method for retrospective radon measurements by home stored CDs/DVDs is becoming a valuable tool for radon surveys in Bulgaria. The key concept of the method (in the version for ^{222}Rn) is to combine the high radon absorption ability of the bisphenol-A based polycarbonate material of commercial CDs/DVDs with its track-etch properties. In 2011 a pilot research revealed that it is possible to expand the method also for retrospective measurements of thoron (^{220}Rn). In this report an overview of the methodology for combined retrospective measurements of ^{222}Rn and ^{220}Rn is comprehended. It includes issues related to the influence of different environmental factors, calibration and quality assurance, automatic track counting and application for real surveys. In the last years several real radon/thoron problems in buildings have been identified after measurements of CDs/DVDs provided by the stakeholders. This experience is discussed in the light of the real prospects for wide scale practical applications of the method.

DEVELOPMENT OF A DIFFUSION CHAMBER FOR THE DISCRIMINATIVE MEASUREMENT OF RADON / THORON USING LEXAN SSNTD

Farzaneh Torabi Nabil[1], Seyed Mahdi Hosseini Pooya[2,3], Mojtaba Shamsaie Zafarghandi[1], Mehran Taheri[2]

[1] Nuclear Engineering and Physics Faculty, Amirkabir University of Technology, Tehran, Iran
[2] Iran Nuclear Regulatory Authority, Tehran, Iran
[3] Radiation Application Research School, Nuclear Science and Technology Research Institute, Tehran, Iran

A new passive system has been developed for the discriminative measurement of radon and thoron. It consists of a diffusion chamber with approximately 250 cm^3 in inner volume closed with two fiber glass filters (with a gap) on one end, and a polycarbonate lexan nuclear track detector (film) placed at the bottom of the chamber. Another lexan polycarbonate detector covered with an optimized thickness of an attenuator is placed outside the chamber to measure only the long-life thoron progeny (i.e., ^{212}Po). Because of the short physical half-life of thoron (55.6 s), the filters prevent the thoron to diffuse the chamber, so the inner detector only measures the amount of radon that entered the chamber.

The sensitivity of the system has been measured by 8.95 [tracks cm^2 (Bq lit^{-1} $day)^{-1}$] and 6.89 [tracks cm^{-2} (Bq m^{-3} $day)^{-1}$] values for radon and ^{212}Po (or thoron) respectively. So the system can be used successfully for separated measurement of radon/thoron in dwellings (next to the walls) where the high mixed concentrations of the isotopes may exist.

FIRST MOBILE LINEAR ACCELERATORS IN SERBIA - PRELIMINARY TLD RESULTS

Olivera Marinkovic[1], Vedrana Prokic[2], Stefan Rafailovic[1], Zoran Mirkov[2]

[1] Serbian Radiation Protection and Nuclear Safety Agency, Belgrade
[2] Serbian Institute of Occupational Health "Dr Dragomir Karajovic", Belgrade

More than billion travelers and pieces of baggage undergo scans each year; but, many millions of cargo containers cross borders with little screening at all [1]. Serbian ministry responsible for cross border control had invested in modern technology buying mobile linear accelerators (linacs). Surprising information from producer [2] tells about three decades of mobile linear accelerators in human medicine in China!

Being quite new unit in our practice mobile linacs have been licensed under several conditions in order to collect and analyze dosimetry results *in situ*.

Preliminary results given in the paper open wide area for discussion, especially TLD results.

A set of TL dosemeters (two crystals per card packed in standard filtered holders, [3]) has been placed around NUCTECH MT1213LH Mobile Container/Vehicle Inspection System at different distances to collect radiation during a month. At the same time, eight TL dosimeters which were exposed to three scans were read-out three hours later (Table 1). Crystal (ii) has position below 1 cm tissue equivalent filter and crystal (iii) has position below skin equivalent filter.

Table 1: TLDs surrounding NUCTECH MT1213LH Mobile Container/Vehicle Inspection System

No.	TLD bar-code	Three scans (TLD in air) (ii) (nC)	(iii) (nC)	Distance from spot (different angles)	Check crystals (*) (nC)	(nC)
1	11039	0.9709	1.75959	11 m right back	13.25	12.85
2	4232	1.0630	7.64617	19 m left front	13.52	13.86
3	2510	0.8061	1.60664	9 m left front	13.16	13.84
4	2985	1.0260	5.64319	9 m central back	13.60	12.85
5	4158	0.8874	7.79779	8 m right front	13.15	13.91
6	4033	1.9780	11.6002	13 m left back	14.12	14.07
7	4223	1.0360	1.33133	6 m central front (beam)	12.68	13.21
8	10244	1.1740	2.01362	25 m left front	12.37	12.74
9	5537	0.8372	2.60281	Not exposed (background)	13.35	12.40
10	4113	0.8786	1.24128	Not exposed (background)	13.74	13.54
	average	1.06572	4.324269		13.294	13.3286
	stdev	0.340241	3.628713		0.505573	0.592033

(*) Signal of TLD exposed to Sr-90, 10 s (after exposing in linac surroundings and after annealing)

Results indicate very high doses in scattered radiation field with extremely low level of energy, close to ultraviolet radiation (TLD (iii) No. 2, 4, 5 and 6). Complete results will be discussed in full paper.

A lot of recommendations for protection against ionizing radiation can easily be applied to mobile linacs radiation protection demonstrating compliance with legal regulations. But, can we be sure that ionizing radiation control area preserves the same risk of low energy radiation for possible damage of as sensitive tissues as skin and eye are?

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ASSESSMENT OF DOSE DISTRIBUTION IN HUMAN EYE PROTON THERAPY BY MONTE CARLO METHOD

M. Tavakol[1], A. Karimian[2], S.M. Mostajab Aldaavati[1]

[1] Department of Physics, Faculty of Science, University of Isfahan, Isfahan, Iran
[2] Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran

Nowadays proton therapy is used to treatment the cancers inside the eye, because of its benefits in comparison to the other radiation therapy methods. This research represents the assessment of absorbed dose in human eye and its components during treatment the tumors in choroid and sclera regions and also healthy tissues of eye by Monte Carlo method. To assess the absorbed dose in different parts of eye, the proton therapy system, the nuzzle aperture, modifier, different parts of eye such as choroid and sclera, retina and etc, also vision sense parts such as optic nerve, cornea, lens and anterior chamber have been simulated by Monte Carlo method. To reduce the absorbed dose of healthy cells as well as maximum delivery of dose to the eye tumor, the important parameters in proton therapy such as: proton beam radius size, energy of proton particles and the thickness of the modifier were calculated and modified by simulation study. The results showed by setting the amount of proton beam radius equal to 0.8 cm, proton energy beam of about 53.5 MeV and the modifier thickness of about 1.5 cm , the best treatment planning for a tumor inside the cell No. 23 (Fig. 1) would be achieved. By setting the above parameters to the mentioned values, the absorbed dose in the different cells of eye during the treatment of tumor in the choroid and sclera regions (cell No.23) were calculated and have been shown in Fig.2. The results showed the maximum absorbed dose in the tumor and healthy regions are 6.21 and 5.94 MeV/g respectively. Also the minimum absorbed dose in the healthy tissues was found about 44 eV/g. These results showed in spite of the advantages of proton therapy in comparison to the other radiation techniques, selecting the treatment planning parameters are very important and also the absorbed dose in the healthy cells which are very close to the tumor cells, such as cell No.22, are still considerable.

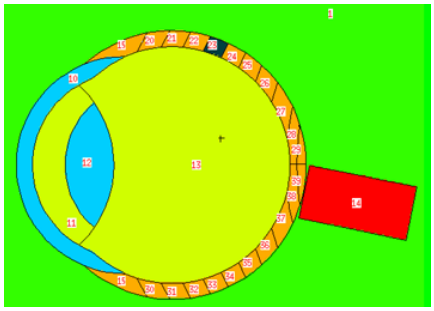

Fig. 1: Simulation of the human eye by Monte Carlo method.

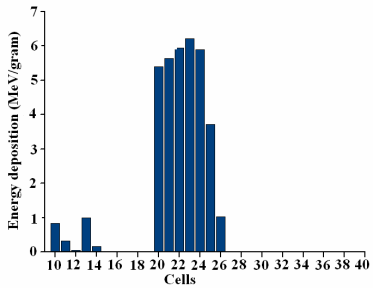

Fig. 2: Calculated absorbed doses inside the specified eye cells during proton therapy

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EARTH AND MOON IONIZING RADIATION DISTRIBUTION AS OBTAINED WITH BULGARIAN BUILD INSTRUMENTS

Ts. P. Dachev

Space and Technology Research Institute, Bulgarian Academy of Sciences (STRI-BAS), Sofia Bulgaria

Since 2000, scientists from Solar-Terrestrial Influences Institute (Now part of STRI-BAS) at the Bulgarian Academy of Sciences have contributed with Bulgarian build instruments in a wide number of experiments for the measurements of the flux and dose rates on the incoming Space radiation from the Earth's Surface to the Moon Orbit. This paper summarizes the results obtained by the following Liulin type instruments: (1) Mobile Dosimetry Unit (MDU) MDU-2 was used on French balloon flight up to 29 km on 14th of June 2000; (2) MDU-5 was used for more than 8000 h between 2001 and 2011 on an aircraft of Czech Airlines (CSA) at different routes. Most significant results were the measurements during the SPE and Ground level event (GLE-15) on 15th of April, 2001 and the use of the instrument to prove the results for the individual monitoring of the aircrew. Similar and more sophisticated instruments (see Fig. 1.) were used for aircraft radiation monitoring (3) Mobile Radiation Exposure Control System – Liulin-E094 containing four active battery-powered dosimeters worked successfully between May and August 2001 on the board of US Laboratory module of the International Space Station (ISS). Very important results are the validation of HZETRN model and the time serial analysis of the induced LEO environment; (4) R3D-B2 Radiometer-Dosimeter with 256 channels ionizing radiation spectrometer and four UV channels spectrometer was flown in the period from May 31–June 16, 2005 inside of the ESA Biopan 5 facilities on Foton M2 satellite; (5) Liulin-ISS contains four MDU with displays and Control and the interface unit and will be used for 15 years in the Service Radiation Monitoring System of the Russian segment of ISS; (6) 3 battery-powered MDUs were operated during the June 8, 2005 certification flight of the NASA Deep Space Test Bed (DSTB) balloon at Ft. Sumner, New Mexico, USA; (7) R3D-B3 and Liulin-Photo instruments were used from September 14–29, 2007 inside of the ESA Biopan 6 facilities on Foton M3 satellite. Good agreement with GEANT4 Monte-Carlo code and experimental observations was obtained; (8) Liulin-R was launched successfully on HotPay2 rocket January 31, 2008 up to 380 km altitude from Andoya Rocket Range (ARR) in Norway; (9) R3DE instrument worked on EuTEF platform outside of the European Columbus module of ISS between February 20, 2008 and September 1, 2009. Major results of the experiment are: the proof of the Liulin ability to characterize the near Earth radiation environment, the first time observed fluxes and dose rates by relativistic electrons on ISS and the observed drops down of the ISS radiation environment during the Space Shuttle dockings; (9) on October 22, 2008 RADOM instrument was launched successfully on Indian Chandrayaan-1 satellite and worked inside of the Earth's radiation belts and on 100/200 km circular lunar orbit; (10) R3DR instrument worked on EXPOSE-R platform outside of the Russian Zvezda module of ISS between March, 2009 and January, 2011; (11) Liulin-6I, Liulin-6R and Liulin-6MB are internet based instruments, which generate web pages. They work online at Jungfrau (Switzerland) http://130.92.231.184/), Moussala (Bulgaria) http://beo-db.inrne.bas.bg/moussala/ and Lomnicky Stit (Slovakia) http://147.213.218.13/ peaks. Main advantages of the Liulin type spectrometers are their low weight (~100 g), low power consumption (~100 mW) and low cost (~10,000 Euro). The high scientific and application value of the obtained data is coming mainly from the extensive calibrations at different accelerators and from well-developed data analysis procedures. Data from all experiments mentioned above are analysed, compared and plotted to reveal harmonized picture how the different ionizing radiation sources contribute and build the distribution from the earth surface to the Moon orbit.

Figure 1. Liulin with a LCD display

BAYESIAN ANALYSIS FOR NEUTRON DOSE ESTIMATION FROM BONNER SPHERE MEASUREMENTS

G. Medkour Ishak-Boushaki, M. Allab

Laboratoire SNIRM-Faculté de Physique, Université des Sciences et de la Technologie Houari Boumédiène, BP 32 El-Alia BabEzzouar, Algiers-Algeria

Neutron spectrometry measurements are often carried out for determining some physical quantities characterizing the neutron field and generally, the measuring devices do not provide a direct measurement of the quantity of interest.

In the standard approach, the data collected from the spectrometer are first unfolded and the quantities of interest are extracted from the computed spectrum. However, in the unfolding process it is not simple to quantify the uncertainties associated with the derived quantities due to the fact that the solution spectrum is not unique.

This paper underlines the use of a Bayesian approach to overcome these difficulties,. As an example, some integral quantities of interest in the radiation protection field have been determined in the vicinity of an Am-Be source of low activity (~37 GBq). From a set of measurements carried out using a Bonner sphere spectrometer, the neutron fluence has been determined using this approach and the neutron ambient dose equivalent has been deduced with a good accuracy.

Keywords: neutron spectrometry, Bayesian approach, neutron dose.

NUMERICAL ANALYSIS OF THE SHIELDING ENERGY DEPENDENCE FACTOR OF THE MOSFET DOSIMETER IN ELECTRON-BEAMS IRRADIATION

S.J. Stanković[1], R.D. Ilić[1], D. Nikolić[1], D. Čekerevac[1], B. Lončar[2], M. Živanović[1]

[1] Vinča Institute of Nuclear Sciences, Belgrade, Serbia
[2] Faculty of Technology and Metallurgy, University of Belgrade, Belgrade, Serbia

In recent years, an increasing number of research works have been addressed to the study of the characteristics and applications of MOSFET detectors in the field of nuclear industry, medical applications and space research. At a time when the stormy development of technology, a new type of solid state dosimeter, the MOSFET detector, has been introduced into the radiotherapy, primarily for in vivo patient dosimetry in electron-beam irradiation.

One of the major goals of our work was the presentation of the shielding energy dependence factor which assesses the impact of the lid with different shielding materials to MOSFET response for different energies of electron-beam irradiation into range 4 MeV – 20 MeV. In doing so, the established Monte Carlo numerical method for analysis influence of the packaging to energy dependence, carried out prior to any experimental testing.

The bare MOSFET is encapsulated in epoxy glue which mechanically protects the chip. To trace the influence of the lid is the one intended by the physical protection, on the other hand, it can also be used for the protection against radiation, is introduced that defines the shielding energy dependence factor (SDEF) for different electron energies and for different constructional materials of lid.

Factor SDEF is defined as the ratio of values of the absorbed dose, which in fact means that it is equal to the energy deposited when the MOSFET is shielded with protection, and the MOSFET without a lid. When we know the energy dependence factor for SDEF MOSFET with and without armor can be carried out and the analysis of whether and to what extent the energy required compensating the electronic components.

In order to use the Monte Carlo numerical methods in this paper, the appropriate geometry form of the MOSFET dosimeter was defined using the adequate software. The electron transport Monte Carlo code FOTELP-2K10 has been adopted to analyze the influence of the MOSFET package on its energy response. FOTELP-2K10 code, uses RFG and PENGEOM6 software modules for dosimeter geometry description.

Observations indicate that the MOSFET response is dependent on electron energy as well as varying with the package configuration. The packaging effect was investigated by comparising the total energy deposited in zones of the MOSFET structure. In this work presented, the ratio between values of total energy deposited in the sensitive volume (thick SiO_2 layer) for cases of MOSFET structure with and without a package lid. For this purpose is defined the shielding energy dependence factor (SDEF), and is given its value for kovar and Ti-24Al-11Nb and Ti-13Nb-13Zr alloys as lid materials. Further, we have done the identification of the dependence of the total energy deposited with varying of photon energy, for all zones of interest with specially selected type of the MOSFET dosimeter.

MONTE CARLO MODELING OF THE MEDICAL LINEAR ACCELERATOR AND EXPERIMENTAL VERIFICATION OF THE MODEL.

P.V. Kazantsev

N.N. Blokhin, Russian Cancer Research Center, Moscow, Russia

With advances in technology and improved treatment delivery techniques of high-precision radiotherapy such as stereotactic radiosurgery (SRS), intensity-modulated radiation therapy (IMRT) and image-guided radiation therapy (IGRT), requirements for dosimetry control and quality assurance became much stronger. In particular, this is connected with usage of small fields in all modern techniques [1]. Relative dosimetry of small fields constitutes rather complicated problem due to absence of common protocol and exact recommendations. The problem is strongly connected with radiation detectors available in specific clinic, as standard 0.125 cm^3 semiflex chambers supplied with all the motorized water phantoms proved to be unsuitable for narrow beams measurements due to volume averaging effect. This effect smears the penumbra of the beam and makes the measured data unusable for precise beam modeling in treatment planning systems, which require this data for SRS/IMRT calculations.

The measured data could be mathematically processed to exclude the effect; this idea is well-known in image processing and based on the assumption that the measured profile is the product of convolution of real profile and detector kernel. The only possibility to obtain the real profile without any impact of detector is to exactly simulate the head of linear accelerator.

In this study we used the EGSnrc/BEAMnrc [2] system for Monte Carlo modeling of Varian Clinac iX medical linear accelerator (Varian Medial Systems, Palo Alto, CA). The structure of the linac head was taken from Varian (Confidential) The first step of model verification was comparison of the data obtained with the phase-space files distributed by IAEA; it was proved that we get similar data in terms of spectrum and energy fluence distribution. Several specific parameters of the initial electron source such as energy and beam size were changed during verification. The second step of verification was modeling of the ionization chamber (PTW 31010 0.125 cm^3 semiflex, PTW, Germany) in narrow beam produced by the simulated linac. The profiles obtained were checked against the measurement data. Gamma method was used for comparison (2%/2mm criteria) and it was found that profiles match each other with more than 90% of points passed the criteria. Finally, the verified model of the linac was used for simulating the profiles of narrow beams in pure water without detector included. The profiles obtained will be used as "real profiles" for deconvolution of the detector kernel. This kernel will be used for extraction of unperturbated profiles from the measurement data. The results of using this approach are pending.

Eventually, the medical linear accelerator head was modeled and this model was verified against the measurement data. The model obtained could be used as source for precise particle transport simulation for any purposes. Further work is needed for using the profiles obtained for reconstruction of the real profiles from the measurement data.

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CHARACTERISATION OF RADFET DEVICES IN THE DIAGNOSTIC ENERGY RANGE

A.M. McGarrigle[1,2], N. Vasovic[1], A. Jaksic[1], A. Mathewson[1]

[1] Tyndall National Institute, University College Cork , Lee Maltings, Dyke Parade, Cork, Ireland
[2] Cork University Hospital, Wilton, Cork, Ireland

X-rays are frequently used in Diagnostic Imaging, with both the number and complexity of examinations growing annually. This trend has resulted in patients receiving increased radiation exposure, an occurrence which has been reported on in the media recently. Patient dose estimation presents a significant challenge to medical physicists and is often subject to a large degree of error with current methods.

Manufacturers have addressed dose concerns with the introduction of dose reduction measures on their imaging modalities. While this development is essential for optimal radiation protection of patients, evaluation of the efficacy of such measures are difficult to quantify. A need was identified to address the current deficit in dosimetry technology and methodology.

The purpose of this work was to carry out a full characterisation of Radfet devices at the diagnostic energy range. The devices available had previously been fabricated for potential use in Radiotherapy but had not been considered for diagnostic imaging. The energy range of interest is 40 kV-120 kV and the known threshold for detection was approximately 100 mGy. Typically, 100 mGy is higher than radiation doses expected in imaging; however, this is acceptable in the context of a preliminary study of the device performance.

OSL PROPERTIES OF NATURAL SODIUM CHLORIDE

Magdalena Biernacka, Arkadiusz Mandowski

Institute of Physics, Jan Dlugosz University, ul. Armii Krajowej 13/15, 42-200 Czestochowa, Poland

Common salt (NaCl) is a very popular and cheap material which may be used in retrospective dosimetry of ionizing radiation as well as luminescence dating material. Various forms of NaCl could be used for this purpose – e.g. household salt or a rock salt (halite). Previous studies showed linearity of dose response up to 100 Gy. Irradiated sodium chloride crystals exhibit pronounced thermoluminescence (TL) and optically stimulated luminescence (OSL) phenomena. Typical OSL decay curves are shown in Fig. 1.

This paper presents some properties of natural and rare earth doped NaCl. It is shown that this material exhibits quite complex luminescence decay characteristics. Most likely it may attributed to a multi-level system with several interacting traps and recombination. It seems to be responsible for a "regeneration mechanism" which could be seen while performing repetitive OSL measurements with a variable time delay between measurements. Surprisingly, with increasing delay, the OSL intensity increases also. Possible theoretical explanation of this phenomenon will be given.

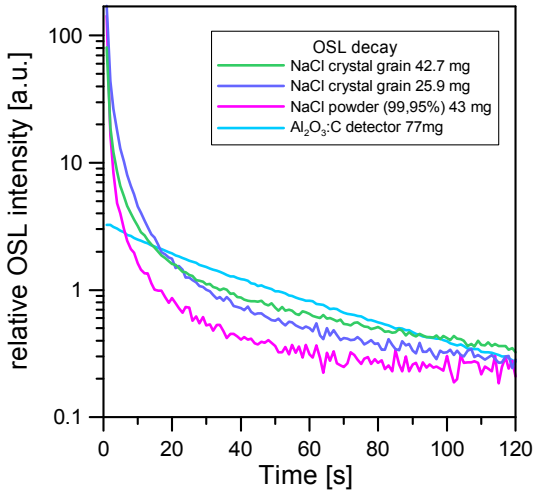

Fig. 1. OSL decay of various NaCl samples. OSL decay of Al_2O_3:C is shown for comparison.

NEW ANALYTIC METHOD FOR ASSESSMENT OF INGESTION DOSES FROM ^{3}H. APPROACH AT THE TERMS OF RADIOECOLOGICAL INFORMATION INCOMPLETENESS

A.P. Kravets

Institute of cell biology and genetic engineering of NAN of Ukraine, Kiev, Ukraine

New analytic method for assessment of human ingestion dose from 3H entering to food chains was developed. Anthropogenic tritium (T, ^{3}H) appears and enters into environment as result of nuclear energy production. An about 99% of natural tritium transforms into tritium water ($H^{3}HO$). The behavior of tritium water in soil and its mechanisms of plugging in a biological rotation are identical regular water. Researches of tritium behavior in biological objects testify possibility of its 1000-fold accumulation in living organisms and food chains. It results in a number of negative effects, related to induction of genome instability. In spite of the numerous detailed radiobiological researches, currently numerous data about tritium transfer in an agricultural produce and rate of its ingestion with food by human organism absent.

Therefore there is possibility to use information about water balance of different cultivated plants and take into account ecological features of agricultural lend soils at prognostication of agricultural produce with tritium contamination.

New method taken into account by a man reference human diet, water balance of agricultural plants, climate of agricultural lands for the nuclear power stations zone influence, half-time tritium decay. The series of referent estimations (annual dose, “life-time” dose) for different climatic zones are conducted.

THE WORLD UNDERESTIMATES THE CONSEQUENCES OF CHRONIC RADIATION EXPOSURE

A.P. Kravets

Institute of cell biology and genetic engineering of NAN of Ukraine, Kiev

In spite of a growing body of information, the question about biological efficacy of low dose is still under the discussion. Available data demonstrate that there are several aspects of this problem: the type of low dose endpoints is determined not only by interval dose and dose rate but also by the continuance of exposure. An organism is complex multilevel system that can repair the damages and formatted protective and adaptive reactions. Every of these reactions have specific threshold of induction and own time of formation. Effects of short-term exposure reflect system's sensitivity in the area of low dose, and show factors and mechanism determined by this sensitivity. Effects of protracted exposure are cumulative and reflect possible changes of radiosensitivity along all dose range. Present wide spectrum of non-linear effects of low dose varying from hormesis to hypersensitivity phenomenon had been demonstrated for mode of protracted exposure within low dose area.

Analysis of the current data permit to select 5 types of dynamic reactions on a chronic irradiation:

1. Early display negative effects with a subsequent monotonous growth their severity. Such type of reaction is typical for cytogenetic aberration and embryonic digenesis;
2. Early display of hormetic effects, transitory into growth of negative effects with following transitory into functional organism exhaustion;
3. Early display of hormetic effects with a subsequent transition to an adaptive response;
4. Display of negative effects at the first stages of influence, with a subsequent transition to an adaptive response;
5. Most difficult dynamic type of effect is shake mode with a trend to adaptation (at more low intensity of irradiation) or to - at more high intensity of irradiation - functional organism exhaustion.

These dynamic possibilities of chronic irradiation effect development must be taken into account at the radiation risks assessment.

CALCULATION OF EFFECTIVE DOSE IN ORNL PHANTOMS SERIES DUE TO NATURAL RADIOACTIVITY IN BUILDING MATERIALS

Dragana Krstic[2], Dragoslav Nikezic[1], Goran Ristic[2]

[1] University of Kragujevac, Faculty of Science, Kragujevac, Serbia
[2] University of Niš, Faculty of Electronic Engineering, Niš, Serbia

In this paper the effective dose in age-dependent ORNL phantoms, due to naturally occurring radionuclides in building materials, was calculated. The absorbed doses for various organs or human tissues have been calculated. MCNP computer code has been used for this purpose. The effective dose was calculated according to ICRP74 and ICRP103 recommendations. The obtained values of dose conversion coefficients for a standard room are: 1.033, 0.752 and 0.0538 nSv/h per Bq/kg for elements of the ^{238}U, ^{232}Th series and the ^{40}K isotope, respectively. The values of effective dose coefficients for ^{40}K and ^{232}Th isotope conform well to literature data. The values for elements of the ^{238}U series are greater than those in literature data.

Key words: effective dose; gamma radiation; building materials; Monte Carlo

MODELING OF ORNL THYROID PHANTOM AS AN INPUT FILE FOR MCNP

Dragana Krstic[2], Dragoslav Nikezic[1], Goran Ristic[2]

[1] University of Kragujevac, Faculty of Science, Kragujevac, Serbia
[2] University of Niš, Faculty of Electronic Engineering, Niš, Serbia

Protection against ionizing radiation requires information on the absorbed doses in organs of human body. Computational models of human anatomy called "*phantom of a human body*" are mathematical representations of the human body, designed to be used in dosimetry calculations. They have been used in dosimetry calculations for radiotherapy, nuclear medicine, radiation protection etc. Series of mathematical phantoms of the human body, given by the Oak Ridge National Laboratory (ORNL), were programmed as input files for MCNP-4B code. All organs of the human body were represented with analytical equations of various three dimensional geometrical bodies. One of the most complicated organs for modeling is the thyroid. However, this organ is very important because the radioactive isotope iodine ^{131}I, which is abundantly released in nuclear accident, is deposited in the thyroid, causing cancer. In this paper modeling of a thyroid of ORNL phantom as an input file for MNCP is presented.

CHANGES IN METHYLATION PATTERN OF FUNCTIONALLY DIFFERENT DNA PARTS UNDER VARIOUS IRRADIATION MODES

D.A. Sokolova, A.P. Kravets

Institute of Cell Biology and Genetic Engineering, National Academy of Science of Ukraine, Department of Radiobiology, Vasilcovskaya st. 31/17, Kiev - 03022, Ukraine

Currently radiobiology disposes of extensive information about the constitutive and inducible mechanisms of biological systems' protection and repair from irradiation damage. However, its potential and correlation in forming of post-radiation system response remains insufficiently known.

One of the approaches for assessment of inducible mechanisms and their functions in radiosensitivity changes is associated with investigation of methylation pattern of transcribed DNA part transformations for different irradiation modes.

Methylation is a unique form of covalent DNA modification; it occurs without alterations in nucleotide sequences. Also it is one of basic epigenetic mechanisms in control of gene expression. At the same time, methylation is a polyfunctional process implicated in stabilization DNA structure.

Correlations between changes in methylation pattern of functionally different DNA parts and radiosensitivity under various types of radiation exposure have been investigated. Fractionated UV-C exposure, «adaptive-challenger» mode of irradiation and combination of chronic-acute exposure have been used.

The changes in methylation pattern were detected using a restriction assay with enzymes HpaII, MspI, MboI and subsequent polymerase chain reaction (PCR) assay with internal transcribed space - ITS1(19b), ITS4(20b), inter-simple sequence repeat - ISSR(14b) primers.

Obtained data indicate specific changes in methylation pattern of transcribed and satellite DNA under various modes of irradiation. Possible role of these changes in progressing irradiation damage and generation inducible protection reactions is discussed.

ANALYSIS OF PROTON TRACKS ETCHED IN REVERSE DIRECTION IN PADC DETECTOR USED FOR NEUTRON IRRADIATION

B. Milenković, N. Stevanović, D. Nikezić, V. Marković, J. Stajić

University of Kragujevac, Faculty of Science, R. Domanovic 12, 34000 Kragujevac, Serbia

A computer program called Neutron_CR-39.F90 written in Fortran 90, for neutron simulation through a PADC detector and its detection was described and developed. In this work the neutron Am-Be source was considered for simulation. It was shown that the most intensive secondary particles, created in neutron interactions with the detector, are protons. Protons are emitted in different directions and their latent tracks are oriented randomly within the detector. Some tracks will be etched from the point where the particle was created in the direction of the particle motion – this is direct etching. Other tracks will be etched from the point where the particle was stopped, or from where it exited from the detector, in opposite direction of particle movement – this is the etching in reverse direction. There are a lot of these tracks and they need be treated specifically as has been done in this work. Not all latent tracks can be revealed after an etching procedure. Several factors influence the track revealing. The energy threshold and the critical angle are the most important ones. In differ to other authors we calculated contribution of reverse etched tracks to total neutron dose

The programming steps are outlined with detailed description of neutron simulation, determination of latent tracks of created protons, as well as, their development after detector etching in same and opposite direction of particle motion. The computer code Neutron_CR-39.F90 contains three subroutines. First, Neutron.f90 which simulates neutron through CR-39 detector and store parameters of secondary particles in output file. Second, Trackfdmsame.f90 which calculates profiles of tracks emitted in same direction as etchant progression. Third, subroutine Trackfdmback.f90 which calculates profiles of tracks emitted in opposite direction then etchant progression.

The outputs of the code are parameters of created protons (coordinates of starting and stopping points, direction angles of particles, initial and deposited energies) and number of visible tracks per incident neutron. It enables calculation of neutron detection efficiency for different input parameters and may be used for further analyses.

GAMMA DOSE EVALUATION OF ITER BASED ON NEUTRON ACTIVATION CALCULATION

Amir Korang Beheshti[1], Ali Reza Karimian[2], Mohammad Reza Abdi[1], Iraj Jabbarib[1]

[1] Department of Nuclear Engineering, Faculty of New Sciences and Technologies, University of Isfahan, Isfahan, Iran
[2] Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran

ITER (International Thermonuclear Experimental Reactor) is an international nuclear fusion research and engineering project, which is currently building the world's largest and most advanced experimental tokamak nuclear fusion reactor at Cadarache in the south of France. The machine is expected to demonstrate the principle of getting more energy out of the fusion process than is used to initiate it, something that has not been achieved with previous fusion reactors.

Dose rates assessment was only considered by transport of particles emitted from the plasma in previous analyses by Arione Ara´ujo. The gamma radiation due to the neutron activation of the solid structures in ITER is important from the radiological point of view therefore the gamma dosimetry considered in this case is the neutron activation due to the Deuterium-Tritium (DT) plasma burning with neutrons production rate at 14.1 MeV. The goal of this research is assessment the gamma dose rate by considering neutron activation and delay gammas in ITER system. To achieve this goal, the ITER system and its components were simulated by Monte Carlo method. Also to increase the accuracy and precision of the absorbed dose assessment the activation of walls around the ITER system were considered in the simulation.

The Tokamak hall has been shielded by a 2 meters thick bio-shield made up of removable specific concrete and neutron activation calculation is very important inside this bio-shield. The results of this research showed that the gamma dose rate level near to the bio-shield wall of the Tokamak hall is not close to the allowable limit dose. This result may come from the fact that photons from the activated vacuum vessel, cryostat and bio-shield which have contribution in dose rate at this location have increased the dose rate and should be considered in shielding calculations.

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ABSORBED DOSE ASSESSMENT OF BREAST, CARDIAC AND OTHER TISSUE DURING BREAST IMAGING BY SPECT

M. Basij, A. Karimian

Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran

Absorbed doses of internal organs can be estimated, using Monte-Carlo technique [1-3]. In this research work, the absorbed doses of breast, cardiac, lung, breast cancer cells and other tissues around breast were evaluated by Monte Carlo method and by employing 140 keV photons of technetium-99m as radio nuclide tracer.

In this search, Monte Carlo simulation was utilized to set the geometry of left side of torso. The used phantom in this work was considered as in Fig.1. The torso and breast phantom have been represented by parallelepiped with the dimensions of 350×240×50 mm^3 and 60×50×50 mm^3 respectively. The cardiac was modeled as a sphere with 80 mm in diameter and the volume of about 268 cm^3[4]. The study was done for a tumor with the radius of 5mm.

All tissue compositions were taken from the ORNL MIRD phantom [5].The activity concentration inside the cardiac, tumor, lung and all other healthy soft tissues were considered as the ratio of: 15:6:2:1 respectively [6]. The total activity inside the phantom was considered as about 15mCi.

The results showed maximum absorbed dose rate inside the cardiac, breast, lung and other healthy tissues respectively (Fig.2). The maximum and also the minimum absorbed dose rate in the cardiac and healthy tissue were much higher than the published limits of ICRP 60. So to overcome this problem, the patients should drink liquids as much as possible after scan. The other important point of view is the calibration of the SPECT system. When the system is well calibrated the quality of the images are good enough and the technicians do not need to increase the injected activity.

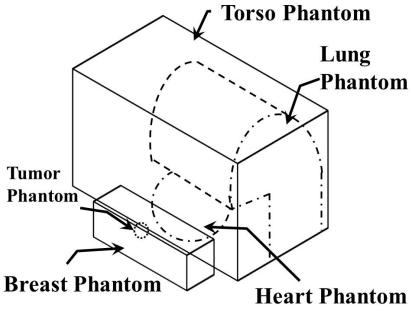

Figure 1: The geometry of the used phantom in this work

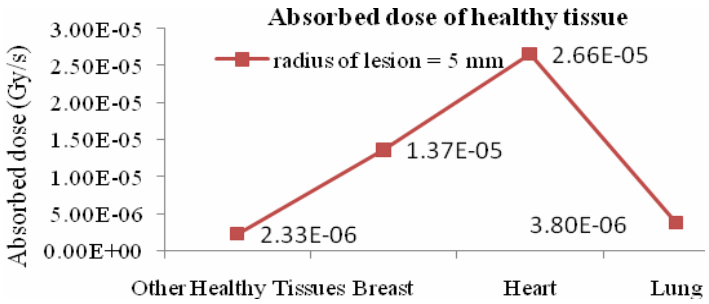

Figure 2: Total absorbed dose in each tissue during SPECT imaging of a breast with a 5 mm tumor

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FUNDAMENTAL LAWS OF EFFICIENCY OF ISOTHERMAL PROCESSES UNDER IONISING AND NON-IONISING ELECTROMAGNETIC RADIATION

Yu.P. Chukova

Krasnopresnenskiy Ecological Fund. Moscow, Russia

Electromagnetic radiation contains 22 order of frequency. This range can be divided by some parts according to different problems (purposes) and according techniques of scientifically-practical research (for instance, ionizing and non-ionising radiation). Thermodynamic law of efficiency of isothermal processes for full frequency range of electromagnetic radiation was formulated in second part of 20th century and is presented in work. Functional dependence of efficiency on absorbed energy for a range of high and low frequencies which is observed by experimenters is presented in work too [1,2].

In the field of high frequencies (the Wien region) there is a logarithmic dependence (the Weber-Fechner law), and in the field of low frequencies (the Rayleigh-Jeans region) there is a "step" (the Devyatkov law). The thermodynamic prognoses of development of experimental researches of isothermal processes is stated and expected difficulties are analyzed

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EVALUATION OF DMOS TRANSISTORS AS ELECTRON BEAMS DOSIMETER

M.A. Carvajal[1], F. Simancas[2], D. Guirado[2], J. Banqueri[1], S. Martínez-García[1], A.M. Lallena[3], A.J. Palma[1]

[1] Electronics Department, ETSIIT, Spain
[2] Atomic, Nuclear and Molecular Physics Department, Science Faculty, University of Granada, Spain
[3] Universitary Hospital "San Cecilio" Granada, Spain

Intra-operative radiotherapy (IORT) is a complementary technique used just after cancer extraction. IORT aims to destroy the remaining tumoral cells on the cancer edges using electron beams. The dose must be applied in a single session and just after surgery with the patient lying on the stretcher. To determine the dose in this type of treatment should be suitable and some works have presented MOSFETs (Metal-Oxide Semiconductor Field Effect Transistors) as dosimeters that could be useful for this purpose [1]. In this communication, a preliminary study of different general purpose DMOS transistors used as dosimeters for electron beams is presented.

BS250F, ZVP3306 and ZVP4525 are p-channel Vertical DMOS transistors manufactured by Zetex Semiconductors (Plano, USA). We have tested them as dosimeters, using the Siemens Mevatron KDS LINAC of the University Hospital "San Cecilio" of Granada (Spain). Four transistors of each model were irradiated with electrons of 6 MeV (normal incidence) in various sessions, with doses per fraction ranging between 2.1 and 5.6 Gy, up to a total accumulated dose of 56 Gy. MOSEFTs were placed at the isocentre of the LINAC (at 100 cm from the source) and irradiated with a field of 25x25 cm^2. The sensor response was measured using a reader unit developed by our research group that provide the threshold voltage shift (ΔV_T) biasing the transistor with three different currents in a sequential way [2]. DMOS transistors were soldered on a PCB for connecting them to the reader unit (Figure 1).

ΔV_T versus dose was measured and calculated, finding a lineal dependence for all studied transistor models. Table 1 summarizes the average sensitivity and the standard deviation for the set of irradiated transistors in a session. As can be observed, ZVP3306 model presents a slightly higher sensitivity than the other two models. Figure 2 shows ΔV_T as a function of the accumulated dose for this transistor model. Our preliminary results indicate that ZVP3306 DMOS transistor could be a possible candidate as dosimeter for radiotherapy with electron beams. However, a deeper study with more transistors per group is needed for a definitive choice. The characterization of the temperature, angular and dose rate dependences of the devices are future tasks for our group in this research field.

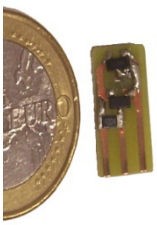

Fig.1. Sensor Module

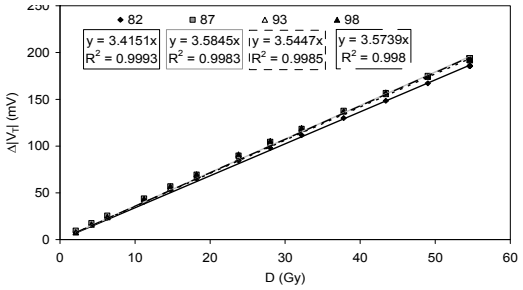

Figure 2. ΔV_T for ZVP3306

Table 1. Sensitivity (mV/Gy)		
	Average	σ
ZVP3306	3.71	0.27
BS250F	3.14	0.37
ZVP4525	3.38	0.44

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POSITRON DETECTOR FOR RADIOCHEMISTRY ON CHIP APPLICATIONS

Russell Duane, Nikola Vasovic, Pierre LeCoz, Nikolai Pavlov, Carl Jackson, Aleksandar Jaksic

Tyndall National Institute, University College Cork , Lee Maltings, Dyke Parade, Cork, Ireland

Positron Emission Tomography (PET) procedure requires that a drug with a known biological activity is labelled with a positron-emitting nuclide and injected into a patient; the in vivo imaging of the radioactivity allows monitoring several biological pathways, hence assessing the health of the patient undergoing the exam. The radiopharmaceutical needs to be produced immediately before the analysis due to the short half-life of the positron emitting species. Presently, large, expensive and complex devices are required for labelling the drug with the positron emitting nuclide which makes the process very expensive and prevents the widespread use of this technique.

As part of a European funded project called Radiochemistry On a Chip (ROC) whose aims were to perform all of the necessary radiochemistry steps using micro-fluidic chips, a novel miniature positron detector to qualitatively monitor the produced positron activity inside the small shielded chamber was developed. The probe consists of a silicon photomultiplier coupled with thin scintillator and preliminary characterisation has shown that the positron probe could selectively monitor changes in positron activity whilst rejecting the effect of large gamma concentrations in the small shielded enclosure.

Work is continuing to optimise the positron probe in terms of material selection to increase light output in order to obtain acceptable signal to noise levels. More characterisation using high activity sources is required to validate the new material combinations.

ULTRA-THIN 3D SILICON DETECTORS FOR ACTIVE NEUTRON DETECTION

C. Fleta[1], C. Guardiola[1], D. Quirion[1], J. Rodríguez[1], G. Pellegrini[1], J.P Balbuena[1], M. Lozano[1], F. Gómez[2], X. González[2], D. González[2], J. Pardo[2], F. García[3]

[1] Instituto de Microelectrónica de Barcelona, (IMB-CNM, CSIC), Bellaterra, Barcelona, Spain
[2] Universidad de Santiago de Compostela, Santiago de Compostela, Spain
[3] Helsinki Institute of Physics, University of Helsinki, Helsinki, Finland

In this work we propose to use a novel silicon-based detector, the ultra-thin 3D (U3DTHIN, [1]) as a neutron detector. The U3DTHIN is fabricated on a SOI wafer and the active volume is only 10 µm thick, as shown in Fig. 1. The collecting electrodes are columns etched through the silicon instead of being deposited on the surface like in the standard planar diodes, allowing for a much lower capacitance and electronic noise compared to a planar sensor of the same thickness. Most importantly, the ultra-thin active volume allows a high gamma rejection factor, a key requirement in order to discriminate the signal coming from the neutrons in mixed neutron/gamma radiation fields. The neutron sensitive element (not shown in the figure) is a boron-based converter layer deposited on the front side of the detector that detects low energy neutrons via the $^{10}B(n,\alpha)^{7}Li$ reaction. The thickness of this layer was optimized with simulations using the MCNPX Monte-Carlo software.

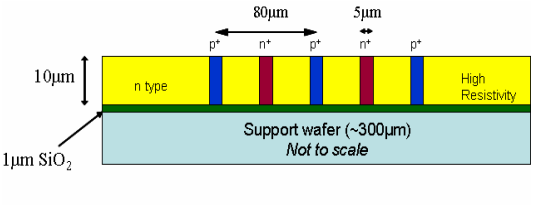

Figure 1. Cross-section of the U3DTHIN detector

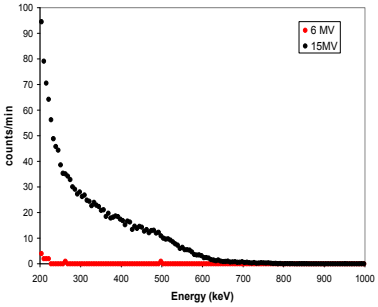

Figure 2. Energy spectra from the Elekta Synergy accelerator working at 15MV and 6MV. The U3DTHIN was covered with a H3BO3 (99% 10B) converter layer.

The detectors were tested with clinical linacs which produce a mixed, pulsed gamma/neutron radiation field. Figure 2 shows the spectra obtained with a 10×10 mm² detector with a H_3BO_3 (99% ^{10}B) conversion layer in an Elekta Synergy clinical linac. The detector was located on the ground, at 4 m from the vertical of the isocenter and the accelerator head had 0º orientation. With the accelerator working at 15 MV, above the threshold for photoneutron production, and delivering 400 MU/min, a total of 1755 counts/min·cm² were registered by the sensor. When the same detector was tested with the linac working at 6 MV (below the photoneutron threshold, emitting only gammas), only 3 counts/min·cm² were obtained, demonstrating the excellent gamma rejection performance of the ultra thin 3D structure. Furthermore, the system showed no signal pile-up up to at least 500 MU/min, which is higher than the standard treatment rates.

These results have shown the good signal discrimination and performance of the ultra thin 3D silicon detectors in a complex mixed gamma-neutron pulsed radiation field.

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Support by the Spanish Ministerio de Ciencia e Innovación and the European Regional Development Fund through project NeutorIII (CIT-300000-2009-011) is acknowledged.

CALIBRATION OF CURRENT INTEGRATORS USED WITH IONIZATION CHAMBERS

V. Spasić Jokić, I. Župunski, B. Vujičić, Z. Mitrović, V. Vujičić, Lj. Župunski

Faculty of Technical Sciences, University of Novi Sad, Serbia

Introduction: Verification of ionizing radiation detectors is a legal requirement in Serbia. Verification is a subject of accreditation according to SRPS ISO/IEC 17020 which should be preceded by laboratory accreditation for calibration in terms of SRPS ISO/IEC 17025 that confirms the competence of the laboratory. Laboratory for metrology at Faculty of Technical Sciences, University of Novi Sad is accredited in terms of SRPS ISO/IEC 17025 for verification of the detector readers, electronic devices capable to measure low currents in wide range from fA to μA as are electrometers, current integrators etc[1]. The common element to all these calibrations is the use of suitable direct current source that simulates the output from ionizing radiation detectors.

Methods: Current range is highly dependent of chamber type (well type, cavity and free-air chambers). Our Laboratory performs calibration of current integrators in range between 100 fA and 100 mA with expanded uncertainty better than 0.05 % (k=2) [2]. Calibration of current integrator is performed using method of direct measurement. Readings from integrator under the test are directly proportional to the current (or voltage) from the standard current (or voltage) source applied to the inputs either directly or through standard resistor or standard capacitor located in the integrator's feedback. Calibration factor can be expressed in terms of Gy/A; Sv/A; A/A or V/A or multiples of these units. Simplified calibration setup is presented at the Fig.1.

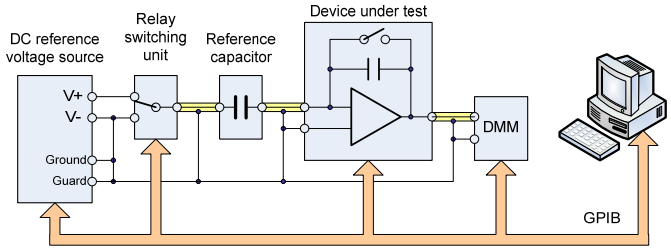

Fig. 1. Simplified calibration setup

Calibration is performed using standard high impedance DC source Keithley 6220, various standard resistors and capacitors and digital multimeter HP 3458 A. The main part of each calibration procedure is an uncertainty estimation and design of uncertainty budget. Model function for error estimation in the calibration procedure for current integrator can be expressed as: $E_x = (I_x + \delta I_x) - I_e$, where are: E_x - error of integrator under the test; I_x - current read by integrator under the test; δI_x - error of reading obtained by integrator under the test due to final resolution and I_e - preset current (on current or voltage source). Sensitivity coefficients for integrator under the test and standard source are derived from the following expressions, respectively : $c_{\delta Ix} = \partial E_x / \partial I_x = 1$ and $c_{\delta Ie} = \partial E_x / \partial I_e = -1$. Calibration uncertainty for current integrator can be calculated from: $u(E_x) = \sqrt{\left(c_{\delta Ix} \cdot u(\delta I_x)\right)^2 + \left(c_{\delta Ie} \cdot u(\delta I_e)\right)^2}$ where are: $u(E_x)$ - calibration uncertainty of integrator under the test; $u(\delta I_x)$ - uncertainty caused by final resolution and $u(\delta I_e)$ - uncertainty of preset current.

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FLUORESCENCE BASED FIBER-OPTIC UV SENSOR

A. V. Jože, D. Z. Stupar, J. S. Bajić, M. P. Slankamenac, M. B. Živanov

Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, Novi Sad

In this paper a novel large-core fiber-optic UV sensor based on the principle of fluorescence is presented. Fiber-optic sensor with one end covered with mixture of powder from mercury lamp and index matching gel is fabricated. In Figure 1 is shown experimental setup used for UV detection. As a UV light source solar simulator in UV spectrum is used. Spectrum of the light on the other end of the optical fiber is measured by using USB spectrometer. On the output of the sensor with powder from mercury lamp are obtained peaks of fluorescent emission in the visible spectrum of wavelengths.

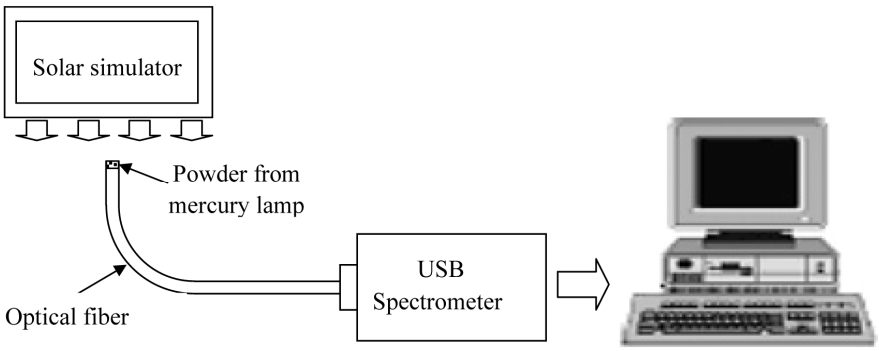

Figure 1. Experimental setup used for UV detection.

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Acknowledgement:

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AN ALTERNATIVE MEASUREMENT METHOD FOR MOSFET DOSIMETERS

J. Banqueri[1], M.A. Carvajal[1], M. Vilches[2], D. Guirado[2], S. Martínez-García[1], A.M. Lallena[3], A.J. Palma[1]

[1] Electronics Department, ETSIIT, Spain
[2] Atomic, Nuclear and Molecular Physics Department, Science Faculty, University of Granada, Spain
[3] Universitary Hospital "San Cecilio" Granada, Spain

In dosimetry with MOSFETs, dose is usually extracted from the threshold voltage (V_T) shift, but this is not the only transistor parameter changed by ionizing radiation [1]. In the present work, we propose a different method based on the intensity-voltage (I-V) curves in triode and in the sub-threshold ($|V_{GS}| < |V_T|$) regions, where the current is extremely low. This current for lateral MOSFET is proportional to [2]:

$$I_{DS} \propto \exp\left[\frac{qV_{GB}}{n\,k\,T}\right] \quad (1)$$

where q is the electron charge, T is the temperature, k is the Boltzman constant, V_{GB} is the gate-bulk voltage and n is a parameter that is proportional to the density of interface surface states, N_{it}. Taking logarithms in eq. (1) and carrying out a linear fit, it can be found that the inverse of the slope (p) is proportional to N_{it}: $N_{it} \propto (T \cdot p)^{-1}$. It is well known that increments of N_{it} are related to dose [3] and, therefore, it could be calculated from $D \propto \Delta\left((T \cdot p)^{-1}\right)$.

The responses of ten pMOS transistors 3N163 (Vishay Siliconix, USA) irradiated with a 60Co source (Theratron 780, University Hospital "San Cecilio", Granada, Spain) have been studied. IDS-VGS curves were measured before and after each irradiation with the semiconductor analyser HP-4145B from 1nA to 1□A. Temperature was registered with a NAW 880 EXL thermometer (Oregon-Scientific, USA) with accuracy of 0.1ºC. Figure 1 shows the logarithm of the current versus the gate-source voltage for the transistor number 1 for different accumulated doses. If the increment of the inverse of the slope times the temperature is plotted as a function of the dose, an excellent linear dependence is found (Figure 2). Therefore, the dose can be measured if the dosimeter is calibrated previously. Similar results were obtained for the remaining transistors and the average sensitivity obtained was $(4.1 \pm 0.3) \cdot 10^{-6} u.a. \cdot Gy^{-1}$, where the uncertainty is given with a coverage factor k=1. In summary, the new method proposed here could be an alternative or complementary method to measure the dose with MOSFETs.

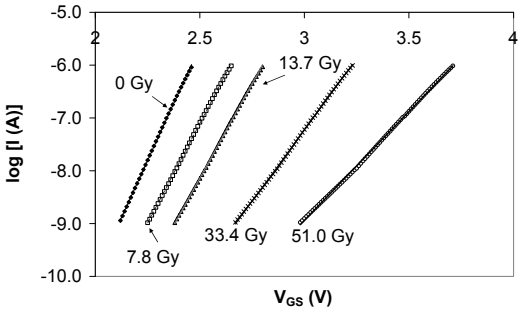

Fig. 1. Currents in sub threshold region.

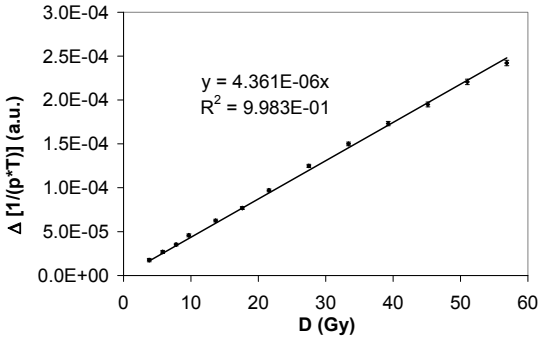

Fig. 2. Variation of the new dosimetric parameter as a function of the accumulated dose.

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GAMMA WASTE DETECTOR FOR RADIOCHEMISTRY ON CHIP APPLICATIONS

Nikola Vasovic, Russell Duane, Nikolai Pavlov, Carl Jackson, Pierre LeCoz, Aleksandar Jaksic

Tyndall National Institute, University College Cork , Lee Maltings, Dyke Parade, Cork, Ireland

Positron Emission Tomography (PET) procedure requires that a drug with a known biological activity is labelled with a positron-emitting nuclide and injected into a patient; the in vivo imaging of the radioactivity allows monitoring several biological pathways, hence assessing the health of the patient undergoing the exam. The radiopharmaceutical needs to be produced immediately before the analysis due to the short half-life of the positron emitting species. Presently, large, expensive and complex devices are required for labelling the drug with the positron emitting nuclide which makes the process very expensive and prevents the widespread use of this technique.

As part of a project whose aims were to perform all of the necessary radiochemistry steps using microfluidic chips, a novel miniature gamma detector to quantitatively monitor the waste gamma radioactivity inside the small shielded chamber was developed. The probe consists of a silicon photomultiplier coupled with an inorganic scintillator. Detailed characterisation has shown that the gamma probe can quantitatively predict the gamma concentration in the waste line.

Work is ongoing to increase the speed of the readout electronics in terms of faster sampling (decreasing the time stamp and spectrum integration). Custom low power electronics are being miniaturised to the same scale as the detector in order to target battery operated applications in other markets.

A PULSE MODE GAMMA RADIATION MONITORING SYSTEM

Marko Anđelković, Goran S. Ristić

Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Serbia

A prototype of a pulse mode gamma radiation monitoring system is presented in this paper. The proposed system is intended for detecting low level (low dose rate) gamma radiation in personal dosimetry applications. Its operation is based on detection of current pulses produced in the radiation sensor as a result of interaction with the incident gamma photons. The system has the capability of counting the number of pulses in the unit time and the total number of pulses in the predetermined time period. The block diagram and the physical appearance of the proposed pulse mode radiation monitoring system are illustrated on figure 1.

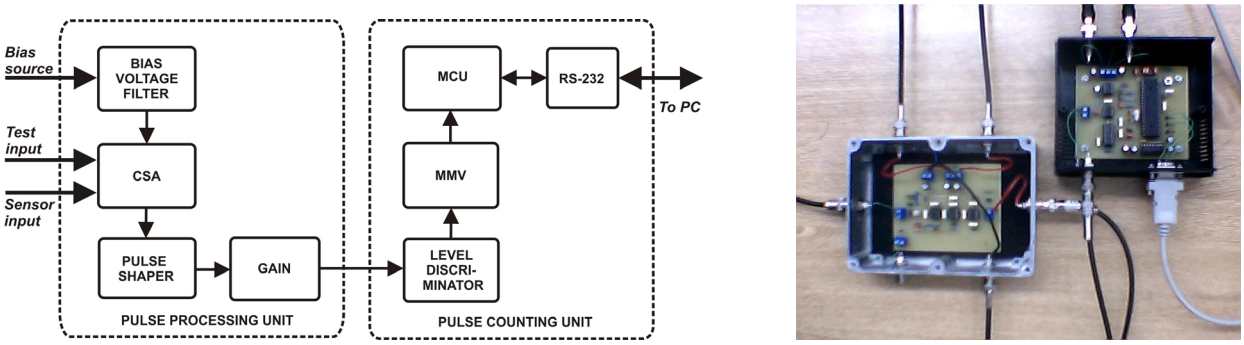


Figure 1: Pulse mode radiation monitoring system (left – block diagram; right – physical appearance)

For the purpose of monitoring the system operation in real-time, a serial interface for PC connectivity based on RS-232 standard was implemented and an appropriate software application was developed in Visual Studio 2005 software development tool. This application enables the control of the system operation as well as visualization and storage of the pulse count rate and the total number of accumulated pulses.

The performance evaluation of the realized system was conducted with pulsed signal excitation and with radiation source excitation. The purpose of the pulsed signal excitation was to estimate the conversion gain stability and the count rate capability when the sensor is not connected. For testing the response to radiation field, a ^{137}Cs was used as a source and a PIN photodiode PS100-6-CER2 PIN, manufactured by First Sensor, with 100 mm^2 active area, was utilized as the radiation detector. Results obtained by the pulsed signal excitation have shown good stability of the conversion gain while the maximum count rate capability of the proposed system is 100 000 counts/sec. The system has demonstrated ability to detect the presence of radiation source but due to very low activity of the used ^{137}Cs source it was not possible to fully evaluate the performance of the developed system as well as the sensitivity of the selected PIN photodiode. Therefore, further experimental research is required in order to obtain the optimal system design.

Acknowledgement. This work was supported by the Ministry of Education and Science of the Republic of Serbia, under the project No 43011, and European Commission, under the project FP7 No 207 122 RADDOS.

AN AUTO-RANGING ELECTROMETER FOR CURRENT MODE DOSIMETRY

Marko Anđelković, Goran S. Ristić

Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Serbia

This paper presents a design of an auto-ranging electrometer intended for low level direct current measurements in current mode dosimetric applications. Basically, the current mode dosimeters operate on the principle of linear dependence between the dose rate and the current induced by ionizing radiation into the sensing element. Therefore, by measuring the absolute value of the radiation induced current it is possible to estimate the dose rate, and if the current is integrated (measured continuously) over a predefined period of the time, the total absorbed dose for that specific time interval can be obtained. The block diagram and the physical appearance of the proposed electrometer design are illustrated on figure 1.

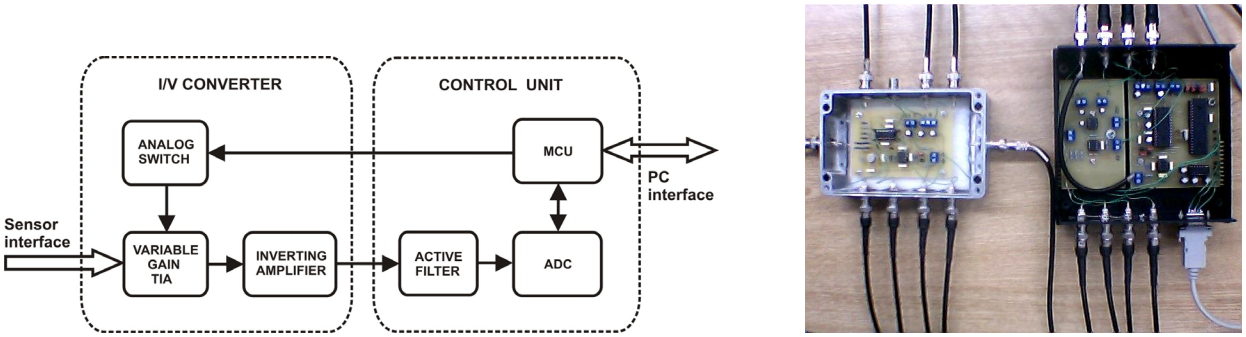


Figure 1: Electrometer (left – block diagram; right – physical overview)

Since the values of the radiation induced currents range from few picoamperes up to several microamperes, depending on the field intensity and the type of radiation sensor, it is necessary to use wide range electrometers for current measurement. The electrometer design proposed in this paper is based on low cost commercial components and it can be used very effectively for measuring currents in the range 50 pA – 10 μA with relative error below 2.5 %. The presented electrometer was realized for laboratory use and was calibrated with high precision source measuring unit Keithley model 2636A. It is suitable for real-time measurement of direct current response of unipolar high impedance radiation sensors such as PIN photodiodes, ionizing chambers, scintillation and luminescence based detectors, etc. The control of the measurement process is achieved by a personal computer equipped with custom made application software developed in Visual Studio 2005 software development environment.

The electrometer was used for testing the current response of two low cost commercial PIN photodiodes (S1223 and PS100-6-CER2 PIN) under gamma radiation exposure provided from ^{60}Co source, in order to investigate the possibility of using the proposed electrometer together with a suitable PIN photodiode as a current read-out dosimeter. Experimental results have shown excellent linearity between the dose rate and the measured photocurrent for dose rates from 0.9 Gy(Si)/h to 67 Gy(Si)/h, and very stable current response during irradiation.

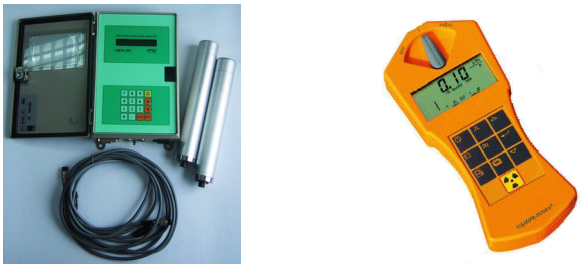
Acknowledgement. This work was supported by the Ministry of Education and Science of the Republic of Serbia, under the project No 43011, and European Commission, under the project FP7 No 207 122 RADDOS.

VALIDATION OF PORTABLE MONITORING SYSTEM FOR MEASUREMENT OF NATURAL BACKGROUND GAMMA RADIATION

Zoran Petrušić[1], Uglješa Jovanović[1], Vedrana Vuletić[2], Igor Jovanović[1], Dragan Mančić[1]

[1] Faculty of Electronic Engineering, University of Niš, Serbia
[2] Serbian Radiation Protection and Nuclear Safety Agency, Belgrade, Serbia

Main activites of research presented in this paper include measurement of natural background gamma radiation using two instruments, a MFM 203 and a GAMMA-SCOUT, result analysis and validation of the GAMMA-SCOUT's results. Both instruments were installed in meteorological station in city of Niš in Serbia (43.327°N, 21.898°E) where the measurements were performed from one meter above the ground. The MFM 203 served as a referent while the portable monitoring system GAMMA-SCOUT served as a working standard. Brief characteristics of both instruments are presented. Measurement setup is also presented as well as the results of both instruments obtained after measurement along with proper discussion and comparison between them. Physical appearances of both instruments used for measurement of natural background radiation are shown in figure 1.



(a) *(b)*

Fig. 1 Used instruments: (a) MFM 203; (b) GAMMA-SCOUT

Main purpose of this experiment was to make a comparison between measurements obtained from both instruments and to evaluate whether the GAMMA-SCOUT could be employed as a referent instrument for measurement of natural background gamma radiation in the meteorological station currently developed at Faculty of Electronic Engineering in Nis.

Based on the performed measurements it became obvious that there is a difference in obtained results between two instruments. This difference varies but it never exceeds 20% which is acceptable considering the performance differences between both instruments as well as their GM tubes.

After the measurements were performed the obtained results were sent to a PC using the PC application supplied by the manufacturer. This application creates an *Excel* file containing all relevant data (time and measurement results) used for error and deviation calculations. The *Excel* file could be loaded into specialized software (in this case *Matlab*) which can be used for further data processing and analyses, as well as for comparative graphical display with the results obtained from the referent system.

REALIZATION OF RADIATION LOW-COST MULTICHANNEL ANALYZER

Uglješa Jovanović, Goran S. Ristić

Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Serbia

A low-cost laboratory multichannel analyzer (MCA) operating in pulse height analysis mode pulses and built with commercial components is presented in this paper. It collects and analyses impulses coming from radiation detector. A basic block diagram of the proposed MCA is presented along with proper description of every block and basic operation principle.

The MCA is composed of a pulse shaper, a "sample and hold" circuit, an analog to digital converter (ADC), and a logic control circuitry. An analog pulse coming from the detector is amplified and shaped, and the height of the amplified pulse is digitized. Since the ADC output corresponds to the input analog voltage, therefore the obtained counts correspond to the deposited radiation energy. After digitization, a count in the corresponding memory bin is incremented.

The proposed MCA is based on a PIC18F8520 microcontroller (MCU). It integrates a basic CR-RC pulse shaper, a peak detector, a pulse stretcher, a parallel successive approximation register (SAR) ADC and a logic control circuitry built around the MCU composed of a non-volatile memory and a RS-232 interface. Block diagram of the proposed MCA is shown in figure 1.

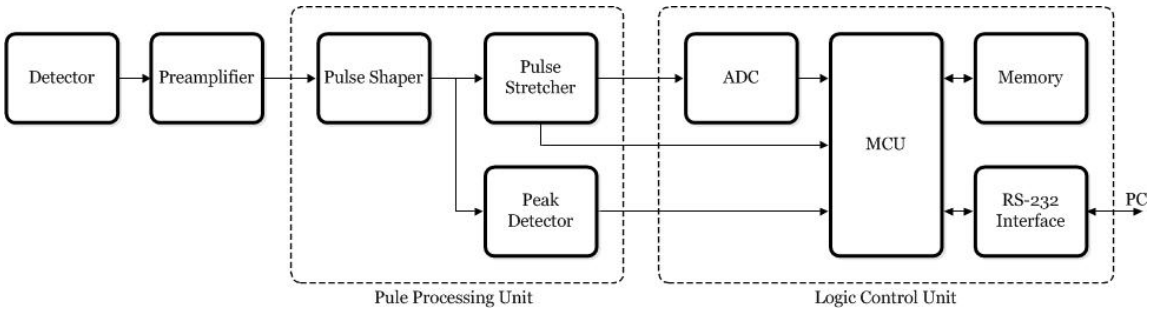


Fig. 1. Block diagram of the proposed MCA

The proposed MCA has a single analog input with 4096 channels in total and it can count up to 65535 counts per single channel. In order to store a number of counts associtated with the particular channel a zeropower parallel SRAM memory with 8KB is employed. Two memory locations are used to store a number of counts associted with an individual channel. At this stage of the MCA's development it can process up to 20 000 counts per second.

The radiation spectrum can be easily monitored on a host personal computer (PC) through a special application, developed in Visual Studio 2010 software development tool, which is also described. A connection between the PC and the MCA is carried out through the RS-232 serial interface.

In the stage of laboratory testing the MCA (without the detector and preamplifier) was tested with a signal generator in order to analyze the obtained histogram, to gain a better result insight and to evaluate the MCA's performance in detailed testing. The pulses from the signal generator were directly fed into the shaper. The results of laboratory testing have shown that the MCA has a good linearity and a small measurement error.

Acknowledgement. This work was supported by the Ministry of Education and Science of the Republic of Serbia, under the project No 43011, and European Commission, under the project FP7 No 207 122 RADDOS.

A NEW HEATING SYSTEM FOR THERMOLUMINESCENCE READER

Miomir Todorović, Goran S. Ristić

Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Serbia

A new heating system that could be used in thermoluminescence (TL) reader is developed and realized. The performances of the realized system, as well as the results of the temperature rise measurements for several heating profiles are presented.

For TL measurements it is necessary to provide linear temperature rise of examined irradiated thermoluminescent dosimeter (TLD), and the special heater construction is required. The TLDs have small mass, and the heater's shape and characteristics must provide desired heating profiles. A small kanthal strip is often used as a heater. It has very small resistance meaning a special driver and algorithm are needed for controlling the temperature rise of the heated sample.

The system is composed of a power converter circuit that was realized as a full bridge power converter and the control unit. Since the kanthal strip with low impedance is used as a heater, then the ferrite core transformer is used to adjust its impedance. The system control unit is realized using a PIC18F4550 microcontroller (MCU) made by Microchip. The MCU's program executes a fuzzy logic algorithm used for control of a temperature rise. The control unit has connection with a PC implemented through a USB protocol.

For data acquisition, the special software is designed using C# programming language and Visual C# Express 2005 software development environment. The data is transferred from control unit to the PC via USB interface and stored in appropriate files. The software creates three files after the measurement. Two data files contain the required and the measured temperature of the examined sample. Third data file contains PWM duty cycle value applied to power converter. These parameters are used for monitoring of examined sample temperature and assessment of the fuzzy logic algorithm used for control of temperature rise.

The heating system has very good heating profiles in temperature range from 30°C to 500°C with heating rate from 1°C to 10°C/sec.

Acknowledgement. This work was supported by the Ministry of Education and Science of the Republic of Serbia, under the project No 43011, and European Commission, under the project FP7 No 207 122 RADDOS.

MICROORGANISMS AS A MODEL SYSTEM FOR STUDYING THE BIOLOGICAL EFFECTS OF ELECTROMAGNETIC NON-IONIZING RADIATION

E.N. Gromozova, S.I. Voychuk, L.B. Zelena, I.A. Gretckey

Institute of Microbiology and Virology, Kyiv, Ukraine

The safe use of generators of non-ionizing radiation is becoming more relevant due to their intensive propagation in everyday life and because of the results of researches, which demonstrate their possible negative health effect.

Microorganisms are convenient objects for studying the effect of various stress factors, including EMF. In the yeast *Saccharomyces cerevisiae* (the model organism for the studies of eukaryotic cells behavior), we showed changes of physiological, biochemical, cytological, morphological and genetic parameters under the influence of electromagnetic radiation of EHF, UHF, VHF and generated with video display terminals. Similar effects, in comparison with the yeast, were observed in animal tissue cultures (HEp, pig testicular cells, mice fibroblasts) and plant tissue (Allium-test) during these experiments. Results obtained in our research were the basis for the development of the biosensor systems to visualize biological effects of non-ionizing electromagnetic radiation (Patent UA). The increasing of the luminescence value was detected in photobacteria after treatment with EHF and VHF. These results suggested that genetic structures containing *lux*-gene can be served as biomarkers to validate biological action of of non-ionizing radiation.

Studies using microorganisms are perspective not only for the detection of biological effects and mechanisms of action of non-ionizing electromagnetic radiation, but also have the great practical importance in environmental monitoring, normalization and standardization of EMFs exposure and for the testing of devices that should protect against the possible negative effects of EMFs and for the testing of devices that should protect against the possible negative effects of EMFs.

DIGITAL INTEGRATOR UNIT FOR IONISATION CHAMBER BASED DOSIMETERS

Z. Mitrovic, V. Spasic-Jokic, B. Vujicic, Lj. Zupunski, V. Vujicic

Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, Serbia

Purpose: In the paper proposed digital integrator eliminates, with even better performance, the key and technologically the most demanding component – a precision capacitor – from the integrator of the ionizing chamber based dosimeter, using the recently developed digital stochastic measurement method. Schematic diagram, theoretical analysis and results of simulation that confirm the estimated measurement uncertainty will be presented.

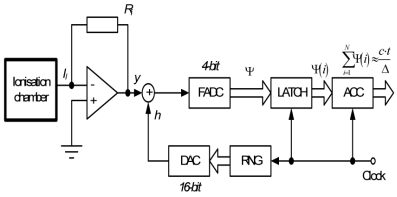


Figure 1. Proposed instrument based on stochastic digital integrator

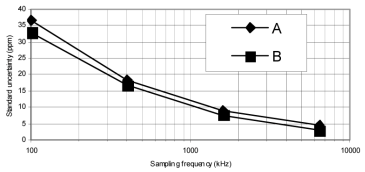


Figure 2. Upper theoretical limit of standard uncertainty (A) and results of simulation (B)

Results: Figure 1. presents proposed instrument based on stochastic digital integrator. The simulation results show that using the stochastic digital integrator we can replace five precision capacitors and provide much better performances in dosimeters based on ionizing chamber. Figure 2. shows comparation between upper theoretical limit of standard uncertainty (A) and results of simulation (B).

The significant Gaussian noise (SNR = 28 dB) at low dose rate, is used in calculations for all dose rates. It is shown by simulations that this noise is almost of no influence (the error is under $5x10^{-6}$) at clock frequencies of 6400 kHz. Using high clock frequencies, this instrument can be used for high-precision measurement of the radiation dose. The digital integrator presented can provide measurement of lower currents (lower dose rates) and larger doses (longer integrating periods) then usual analog integrator in dosimeters.

Conclusion: The proposed instrument presents significant improvement in development of ionizing chamber based dosimeters. The whole instrument besides ionisation chamber can be easily implemented in one ASIC integrated circuit, which can add to instrument reliability and lower susceptibility to electromagnetic and other sources of disturbances.

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Aknowledgement.
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MEMS CAPACITIVE SWITCH FOR SPACE APPLICATIONS

Oskar Z. Olszewski, Cormac Ryan, Ruth Houlihan, Conor O'Mahony, Russell Duane

Tyndall National Institute, University College Cork, Ireland

Microelectromechanical (MEMS) switches are micro-scale devices that, in their simplest form, include two metallic electrodes, of which one can move with respect to a fixed electrode. The up or down position of the moving electrode determines the open or closed state of the switch, allowing the radio-frequency (RF) signal to be transmitted or blocked in the device. RF MEMS switches have gained significant interest for various RF applications due to their superior RF performances, low dc power consumption, small size and weight and integration capability [1, 2]. One of the most immediate application for RF MEMS are satellite systems is space industry, which require the use of large number of switches and switch matrixes. Currently used RF switch technologies in space application are bulky and heavy (coaxial and waveguide switches) and can suffer from high power consumption and inferior RF performances (PIN diodes, MESFET transistors) [2, 3].

This paper describes the capacitive type RF MEMS switch technology being developed in Tyndall with the support of European Space Agency (ESA). A typical switch, the device cross section and measured actuation characteristics are shown in Fig. 1. In this paper the operation principle, design and fabrication of switches will be explained. The reliability issues of MEMS switches that are hindering commercialization of such devices will be discussed and experimental data demonstrated. The major reliability limiting mechanisms are mechanical degradation of the movable electrode and dielectric charging phenomenon that occur during the switch actuation. Both mechanisms distort the actuation characteristic of the switch and can cause device failure. A typical change in the switch characteristic is shown in Fig. 2. Moreover, initial experimental data on the influence of the ambient temperature (-50 to 100°C) and gamma irradiation (total radiation dose levels up to 72 krad) on the switch actuation voltage will be presented.

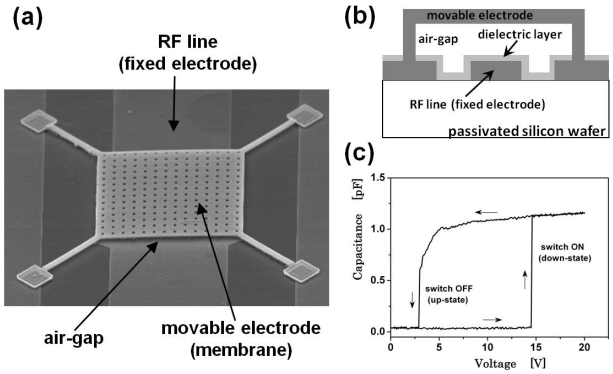

Fig. 1. (a) SEM image of a typical capacitive switch developed in Tyndall, (b) the switch cross section, and (c) typical C-V characteristic of the switch.

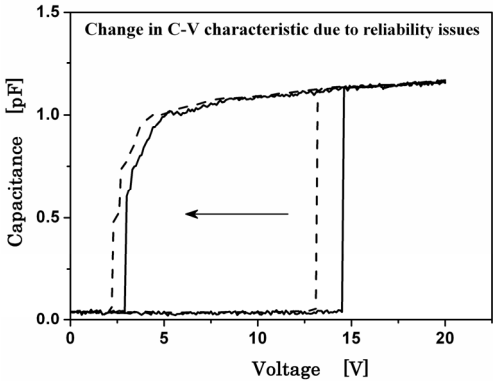

Fig. 2. A typical change in C-V characteristic of the switch that occurs due to reliability issues, i.e. mechanical degradation or dielectric charging phenomenon.

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SENSITIVITY OF pMOS DOSIMETERS WITH VARIOUS GATE OXIDE THICKNESSES

Goran S. Ristić[1], Marko Anđelković[1], Aleksandar B. Jakšić[2]

[1] Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Niš, Serbia
[2] Tyndall National Institute, Cork, Ireland

The p-channel metal-oxide-semiconductor (pMOS) dosimetric transistors are unique radiation dosimeters that have extremely small sizes (the dimensions of sensor elements are ≈ 1 mm × 1 mm) and allow the dose measurement in vivo in real time, which is especially important for radiotherapy.

The threshold voltage shift ΔV_T is caused by the radiation-induced oxide charge and interface traps. The irradiation results in the trapping of holes in the SiO_2, and the creation of interface states at the Si/SiO_2 boundary. The cross section of pMOS transistors with the defects created by radiation is shown in Fig. 1.

The sensitivity increasing can be achieved by increasing the gate oxide thickness or stacking more transistors. The investigation of pMOS transistors with a thick gate oxide has been intensified because of their enhancement radiation sensitivity. The pMOS dosimeter advantages, in comparison with other dosimetric systems, include immediate, non-destructive read out of dosimetric information, extremely small size of the sensor element, the ability to permanently store the absorbed dose, wide dose range, very low power consumption, compatibility with microprocessors, and competitive price (especially if cost of the read out system is taken into account). The disadvantages are a need for calibration in different radiation fields (”energy response”), relatively low resolution (starting from about 1 rad) and nonreusability.

The dependence of threshold voltage shift (ΔV_T) on dose (sensitivity to the ionizing radiation) of five dosimeter types with the oxide thicknesses of 400 nm and 1 μm has been investigated.

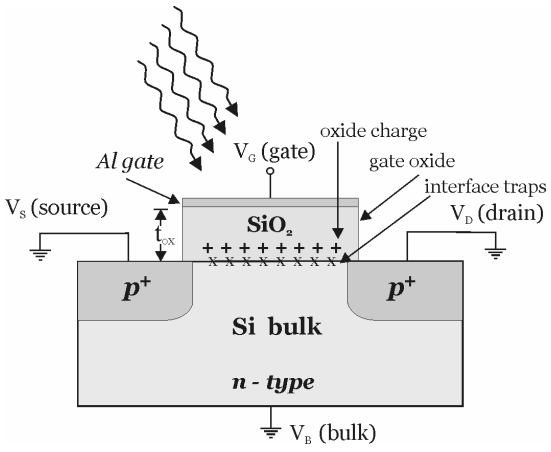

Fig. 1 Cross section of pMOS transistors after irradiation.

PLUTONIUM INTERACTIONS WITH CELLS IN CULTURE

Tatjana Paunesku [1], Baikuntha P. Aryal [2,3], Chuan He[3], Drew Gorman-Lewis[2], Stefan Vog[4], Barry Lai[4], Lynda Soderholm[2], Mark P. Jensen[2], Gayle Woloschak[1]

[1] Department of Radiation Oncology, Feinberg School of Medicine, Northwestern University, Chicago, IL USA
[2] Chemical Science and Engineering Division, Argonne National Lab, Argonne, IL USA
[3] Department of Chemistry, the University of Chicago, Chicago, IL USA
[4] X-ray Sciences Division, Argonne National Laboratory, Argonne, IL USA

Toxicity of plutonium for living organisms is an outcome of both its radioactive decay, and its properties as a heavy metal. Exposure of living organisms to Pu can lead to its accumulation and deposition which may last for decades; however specific biochemical interactions of Pu are poorly defined.

We have studied plutonium uptake by cultured cells (rat pheochromocytoma PC12 cells) using both synchrotron X-ray fluorescence microscopy (XFM) and micro-XANES (X-ray absorption near edge structure). Thus, we could investigate, in the same set of samples, Pu distribution, quantity and oxidation state. XFM was used to image and quantify plutonium at the L_3 or L_2 edge as well as lighter, biologically relevant elements. PC12 cells were exposed to the long-lived plutonium isotope ^{242}Pu which is localized principally in the cytoplasm. Micro-XANES was used to determine the oxidation state of intracellular plutonium in individual 0.1 μm2 areas within single cells. We found that regardless of the initial oxidation state or chemical form of Pu presented to the cells (Pu(III), Pu(IV), and Pu(VI), the XANES spectra of the intracellular Pu deposits showed only tetravalent Pu.

In a complementary set of experiments, we investigated plutonium-binding proteins from PC12 cells using a metalloproteomic approach. A combination of immobilized metal ion chromatography, 2D gel electrophoresis, and mass spectrometry were employed to analyze potential plutonium-binding proteins. Our results show that several proteins from PC12 cells show high affinity towards Pu4+-NTA (plutonium bound to nitrilotriacetic acid). Proteins from several different spots in the 2D gel were excised, analyzed and identified. These plutonium interacting proteins were found to have functional roles in downregulation of apoptosis as well as pro-proliferative roles. The MetaCore™ analysis based on this group of proteins produced a pathway with a statistically significant association with the development of neoplastic diseases.

RADIOBIOLOGICAL STUDIES OF THE 62 MEV CATANA THERAPEUTIC PROTON BEAM ON THE HUMAN MELANOMA CELLS

Danijela Todorovic[1], Ivan Petrovic[2], Lela Koricanac[2], Pablo Cirone[3], Giacomo Cutone[3], Aleksandra Ristic-Fira[2]

[1] Medical Faculty, University of Kragujevac, Kragujevac, Serbia
[2] Vinca Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia
[3] Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy

Presented experimental data are a part of an ongoing long term research program within the international collaboration of the Vinča Institute of Nuclear Sciences, Belgrade, Serbia and the Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy. The results are chosen segments of an extensive investigation of radiobiological parameters and viability levels of a very resistant melanoma cell line after exposure to radiations having quite different values of linear energy transfer (LET): conventional – low LET (gamma rays) and high LET (protons and carbon ions) radiation. Assessment of the effects of irradiations at the CATANA (Centro di Adro Terapia e Applicazzioni Nucleari Avanzati) treatment facility using two types of the 62 MeV proton beams were performed on the human HTB140 melanoma cells. Exponentially growing HTB140 cells were irradiated close to the full energy Bagg peak maximum and along the therapeutic spread-out Bragg peak (SOBP) at four positions: plateau, middle, distal end and distal declining edge. Gamma rays from a ^{60}Co source at the Vinča Institute of Nuclear Sciences in Belgrade were used as a reference radiation. The applied doses ranged from 2 to 16 Gy. Survival, proliferation and cell cycle were assessed 7 days after irradiation. Cell survival, estimated by clonal assay, demonstrated considerably stronger inactivation effect of protons compared to gamma rays. Very high surviving fraction for gamma rays, that was 0.96 at 2 Gy (SF2), indicates that these cells are among the most radio-resistant. SF2 value at the full energy Bragg peak maximum was 0.93. Moving along SOBP, from proximal to distal irradiation position, SF2 decreased from 0.88 to 0.59. Increased radio-sensitivity of the cells was noticed for the doses at and below 4 Gy, resulting in two gradients of cell inactivation, stronger for lower and weaker for higher doses. At the full energy Bragg peak maximum the relative biological effectiveness (RBE) for cell survival was ~ 1.64. Along SOBP, RBE values increased gradually from 1.68 to 2.84 at the distal end of SOBP. Further rise of RBE reaching 7.14 was at its distal declining edge. Both gamma rays and protons induced significant dose dependent decrease of cell proliferation 7 days after irradiation. Due to the high radio-resistance of HTB140 cells, cell cycle phase redistribution exhibited only a modest cell accumulation in G2/M phase for all irradiation positions.

Higher RBE values indicate that protons, because of their greater LET, have better effects on cell inactivation compared to gamma rays. Strong killing ability at the distal declining edge of the proton SOBP is the consequence of the permanent rise of LET up to the end of particle range. The described findings are important for therapeutic protocols, particularly when a vital healthy tissue is close to the treated tumor. The results illustrate the behavior of the limit case of the cellular radio-resistance, thus predicting its therapeutic success.

EFFECTS OF IONIZING RADIATION ON BACTERIAL CELLS

N.S. Kudryasheva, M.A. Alexandrova, T.V. Rozhko

Institute of Biophysics, SB RAS, Krasnoyarsk, Russia
Siberian Federal University, Krasnoyarsk, Russia

Marine luminous bacteria serve as a convenient model for studing effects of ionizing radiation on living organisms. These bacteria are widely used as an ecological bioassay for more than forty years. The bioluminescent (BL) bioassays are traditionally applied for monitoring of chemical toxicity, and not long ago we used them for the first time to monitor radiation toxicity in solutions of alpha- and beta-radionuclides. Main testing physiological parameter of the bioassays is BL intensity.

The purpose of the work was to study chronic effects of radionuclides on glowing of luminous bacteria *Photobacterium Phosphoreum*. Effects of model solutions of alpha-emitting nuclide Am-241 and beta-emitting nuclide tritium were studied. The bacteria were grown in nutrient media with addition of Am-241 (up to 7 kBq/L), H-3-labled aminoacid valine, or tritiated water (up to 100 MBq/L). The Am-241 inhibited bacterial growth at all activities of the nutrient media. The tritium increased bacterial growth at activity <30 MBq/L, and inhibited it at >30 MBq/L. Bacteria were sampled at exponential and stationary stages of growth; BL time-course of the samples was studied and compared with that of a control (nonradioactive) sample. Three stages were found in BL kinetics of the radioactive samples of Am-241 and tritium: (1) absence of the effect, (2) BL activation, and (3) BL inhibition. The BL activation reached 1000-2000%; it was attributed to hormesis phenomenon. No linearity in radioactivity – BL intensity dependences were found. All three BL kinetics stages were found in solutions of both Am-241 and tritium, i.e. the response of the cells was unified. The stages of BL time-course correspond to general regularity in responses of organisms to stress-factors: (1) identification of a stress- factor, (2) adaptive response/syndrome, (3) suppression of a physiological function.

BL time-course in the presence of Am-241 and tritium was studied in BL system of coupled enzymatic reactions.

Accumulation of Am-241 and tritium in cells and DNA was determined.

The role of peroxides (as secondary products of ionizing radiation in water) in the effects radionuclides on luminous bacteria and their enzymatic reactions was studied. Peroxides were found in to be effective in Am-241 solutions and were not – in tritium solutions.

EXTRACELLULAR NUCLEOTIDE HYDROLYSIS IN ADULT FEMALE RAT BRAIN AFTER IONIZING IRRADIATION

Dunja Drakulić, Ivana Grković, Maja Milošević, Snježana Petrović, Miloš Stanojlović, Nataša Mitrović, Anica Horvat

Vinca Institute of Nuclear Sciences, Laboratory of Molecular Biology and Endocrinology, University of Belgrade, Serbia

Introduction: Although ionizing radiation (IR) is commonly used in diagnostic protocols and for therapeutic purposes, it causes current, irreversible and long-lasting damages in the brain by inducing the formation of reactive oxygen species (ROS). ROS disrupt structure of DNA molecule and, by modulating protein-protein and protein-lipid interactions, impair the structure, permeability and fluidity of plasma membrane. Ecto-nucleotidases, NTPDase1,2,3 and ecto-5'-nucleotidase, are surface-located enzymes in synaptic plasma membranes (SPMs) that hydrolyze adenine nucleotides ATP, ADP and AMP to adenosine. The aim of this study was to investigate whether acute exposure of female rats to therapeutic dose (2Gy) is sufficient to alter the enzyme activity in SPMs 1h, 24h and 72h after irradiation.

Materials and methods: Adult (60 days old) Wistar female rats were confined in plywood boxes and divided into two groups: sham-irradiated controls (C) and rats exposed to acute whole body irradiation with 2Gy (IR). Animals were sacrificed 1h, 24h and 72h after irradiation and SPMs were isolated from whole brains. ATP, ADP and AMP hydrolysis, as indicators of ecto-nucleotidase activities, were measured by colorimetric determination of liberated inorganic phosphate and expressed as a percentage of control.

Results and discussion: Whole body exposure to therapeutic dose of 2Gy caused modulation in both NTPDase and ecto-5'-nucleotidase activity in the nerve terminals of adult female rats. Although IR provoked significant decrease of ATP and ADP hydrolysis at all time points, the greatest impact appeared after 24h when ATP hydrolysis was reduced by 25%, while ADP hydrolysis was declined by 35%. Given its role as an excitatory neurotransmitter, ATP accumulated in synaptic cleft due to inhibition of ecto-nucleotidase activity by 2Gy radiation might be neurocytotoxic and initiate cell death. According to our results, 72h after IR ATP and ADP hydrolysis were just slightly decreased, probably due to activation of cells defense mechanisms in adult rat's neurons.

Furthermore, the significant decrease in AMP hydrolysis was observed 24h and 72h after irradiation while after 1h investigated hydrolysis was reduced but not considerably. Knowing that adenosine is an important neuroprotective agent, diminished ecto-5'-nucleotidase activity by radiation that we observed may contribute to lesser extracellular adenosine formation and be harmful for neurons.

Conclusion: Our findings indicate that acute whole body irradiation with therapeutic dose of 2Gy alters neuronal ecto-nucleotides activity in female rats and thus, reduce the formation of adenosine, impair function of neuronal cells and increase possibility of cell death occurrence.

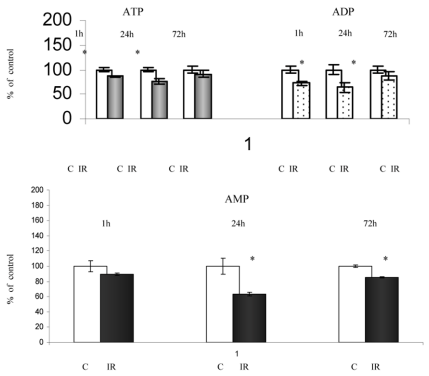

Figure. NTPDase1,2,3 and ecto-5'-nucleotidase activities presented as a percentage of control, mean ± SEM from 3 independent experiments done in triplicate (*p<0.05)

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^{210}Po ACTIVITY CONCENTRATION OF BLOOD SAMPLES AFTER THE RADON INHALATORIC THERAPY

Borbála Máté[1], Mária Horváth[2], János Somlai[1], László Kovács[3], Tibor Kovács[1]

[1] Institute of Radiochemistry and Radioecology, University of Pannonia, Hungary
[2] Social Organization for Radioecological Cleanliness, Veszprém, Hungary
[3] Department of Allergy, Hospital of Tapolca, Tapolca, Hungary

One of the most effective treatments of asthmatic and other respiratory tract illnesses is the cave therapy. The hospital cave in Tapolca (Hungary) has been used for treatments of patients suffering from asthma for decades. In summer ^{222}Rn concentration may even reach 20 kBq/m^3 (17 times higher than winter), the role of radon in the treatment of asthma is still not clarified. During the cave therapy the inbreathing air with high radon-content causes the significant radiation dose to the patients. Daughter elements of ^{222}Rn (^{210}Pb; ^{210}Po) with longer half-lives may accumulate in blood increasing the radiation dose of human body. The change of ^{210}Po concentration in blood samples taken from the patients were examined in winter and summer months. ^{210}Po concentration of blood samples was measured with the semi-conductor detector α-spectrometer. The samples were solved with HNO_3, HCl and sources were prepared by spontaneous deposition on stainless steel. To increase measurement accuracy ^{209}Po tracer was added to the samples. In 63 samples the measured ^{210}Po activity concentrations were between 0.035 – 0.800 mBq/g. Compare the concentrations of the blood samples taken before and after the treatment it was found that they increased in each cases. Based on this result, it was possible to calculate the absorbed dose of the patient during the treatment.

A SURVEY OF RADIATION DOSE TO PATIENTS AND MEDICAL STUFF DURING DIFFERENT DIAGNOSTIC PROCEDURES USING TLD DOSIMETRY

K. Theodorou, A. Sulieman, T. Topaltzikis, C. Kappas

Medical Physics Department, Medical School, University of Thessaly, Biopolis, Larissa, Greece

According to the Euratom directive 97/43, patient dose surveys in diagnostic radiology should be performed as well as the determination of dose reference levels (DRLs) is required. For image guided interventional procedures estimation of dose received by medical staff is also important as well as the dose to accompanying persons whenever is applicable. At the University Hospital of Larissa, Greece, we have developed a solid methodology for measuring entrance surface dose (ESD) using thermoluminescent dosimetry (TLD) and for calculating the absorbed and the effective dose to different organs at risk. We also measure the absorbed and the effective dose to the medical staff involved to the diagnostic procedures. In this study we are going to present cumulative results for different static, dynamic and interventional diagnostic techniques e.g. pediatric chest x-rays, endoscopic retrograde cholangiopancreatography, angiography of lower limbs, DSA of carotid and renal arteries, pediatric micturating cystourethography, enderoclysis and hysterosalpingography. We are also going to present cancer risk estimation for the above procedures as well as the determination of local DRLs.

RADIATION STANDARDS FOR RADIOTHERAPY, IMAGING AND RADIATION PROTECTION APPLICATIONS

Ahmed Meghzifene

Head Dosimetry & Medical Radiation Physics Section, International Atomic Energy Agency, IAEA

Ionizing radiation dosimetry quantities need to be traceable to the International System of Units (SI). Traceability is the only way to demonstrate that a gray measured in a dosimetry laboratory or a hospital for a given quantity, such as air kerma or absorbed dose to water, is equivalent to another measurement of the same quantity measured somewhere else. At the international level, a Mutual Recognition Arrangement (MRA) was setup in 1999 [1] to demonstrate international recognition and equivalence of measurement and calibration capabilities of relevant institutions through participation in comparisons [2].

Radiation standards are developed at primary standards dosimetry laboratories and transferred to secondary standards dosimetry laboratories which disseminate them to end users with an acceptable uncertainty [3]. In the medical field, the medical physicists will make use of these standards, together with an adequate dosimetry code of practice to determine the radiation dose to patients in radiotherapy and imaging. Similarly, radiation protection specialists also use the dosimetry standards to determine occupational or ambient dose.

The presentation will give an overview of the MRA as applicable to radiation dosimetry, the different types of dosimetry comparisons and the main results that have been published in the recent years. It will also review the status of dosimetry protocols and highlight the gaps in the medical field.

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EVALUATION OF THE HOLOGIC SELENIA FFDM SYSTEM WITH TUNGSTEN TUBE

Vesna Gershan, Mimoza Ristova

Institute of Physics, Faculty of Natural Sciences and Mathematics, Skopje, Macedonia

The Full Field Digital Mammography (FFDM) system HOLOGIC Selenia with W target and Rh and Ag filters was introduced to the market in 2008. Those target/filter combinations are different than common ones used in mammography systems.

Such FFDM system was recently installed in Macedonia and performance testing was done using the Barracuda cabinet and Multi Propose Detector (MPD) with the appropriate calibration. The radiation output and beam quality measurements were done for broad and fine focus, and for both target/filter combination.

To determine the relationship between the detector and radiation output variables Pixel Value (PV) and Air Kerma, measurements for detector response function for each target/filter combination were performed. In terms to assess that the detector flat fielding correction has been correctly applied by the manufacture or local service, detector uniformity was assessed. The degree of possible persistence of a signal from one image into subsequent, was evaluated.

In order to check the consistency of the Automatic Exposure Control (AEC) photo timer by means of PV and Signal Noise Ratio (SNR), it was performed PV and standard deviation evaluation for three AEC sensitivities. The AEC responds to changes with the phantom thickness in terms of PV and SNR variation were ascertained, as well as the Contrast-Noise Ratio (CNR) changes with thickness.

Mean Glandular Dose (MGD) was calculated using exposure parameters (kV, mAs, filter) for 4.5 cm phantom. Additionally, MGD was calculated for different phantom thicknesses exposed in fully automated mode (AUTOFILTER).

Image quality assessment was done using a Contrast Detail Mammography Phantom (CDMAM) and TOR MAX phantom. It was determined SNR and CNR for a thickness range 2 to 7 cm. A high contrast spatial resolution, Modulation Transfer Function (MTF) and threshold contrast were also evaluated.

The results were discussed in terms of comparison of the parameters declare by the manufacture and with others FFDM Systems.

PATIENT ORGANS DOSE CALCULATIONS IN NUCLEAR MEDICINE

Nadia Helal

Radiation Safety Dept. NCNSRC, Atomic Energy Authority, P. O. Box 7551 Nasr City, Cairo, Egypt

Radionuclides are used in nuclear medicine in a variety of diagnostic and therapeutic procedures. Two types of risk are identified following the administration of a radiopharmaceutical to a patient: the risk to the patient and the risk to critical groups exposed to the patient. 1) For the scope of risk assessment in protection against diagnostic ionizing radiation, it is necessary to determine the internal radiation dose to specific body organs and tissues of patients. For this purpose, absorbed dose from intravenously administered ^{99m}Tc-MDP, ^{99m}Tc-MIBI, and ^{111}In-Ibritumomab Tiuxetan were calculated using the MIRDose model version 3.0. 2) Patients who have administered radiopharmaceuticals could be a source of radiation to their relatives, medical nurses and people who have contact them. In this study, the dose rates at various distances of 5 cm, 10 cm, 50 cm, 1 m and 2 m from patient who administered diagnostic amounts of ^{131}I-NaI, ^{99m}Tc-MIBI and ^{201}Tl-Chloride radiopharmaceuticals at five different interval times were calculated using RADAR software. Finally, the dose rate have been calculated for nuclear medicine staff exposed to 2 patients performed 2 different scans with different radiopharmaceuticals.

RADIATION EXPOSURE IN FLUOROSCOPICALLY-GUIDED INTERVENTIONAL PROCEDURES

G.K. Korir[1], B.O. Ochieng[2], J. S. Wambani[3], I.K Korir[4], C. Yuko-Jowi[5]

[1] Department of Physics and Applied Physics, University of Massachusetts Lowell, U.S.A
[2] Heart & Cancer Centre, Aga Khan University Hospital, Nairobi, Kenya
[3] Radiology Department, Kenyatta National Hospital, Nairobi, Kenya
[4] National Nuclear Regulator, Centurion, South Africa
[5] Department of Pediatrics and Child Health, University of Nairobi, Kenya

Objective: To assess the workload statistics, the radiation dose to patients and staff involved in interventional procedures.

Methods: A survey in four Kenyan hospitals performing interventional radiology and cardiology procedures.

Results: The maximum and minimum KAP values were found to be 137.1 Gy.cm^2 and 4.2 Gy.cm^2 while measured PSD values were 740 mGy and 52 mGy respectively. Fluoroscopic time range was between 3.3 - 164.0 minutes. Staff doses per procedure ranged between 0.05 -1.41 mSv for doctors, 0.03 - 1.16 mSv for nurses, 0.04 - 0.78 mSv for radiographers and 0.04 - 0.88 mSv for auxiliary staff.

Conclusions: With the current number of IP specialists, an annual increase in workload as determined in the study will result in ICRP annual dose limit being exceeded by 10%. A concerted effort is necessary to contain these dose levels through optimization of practice and justification.

JUSTIFICATION OF COMPUTERIZED TOMOGRAPHY EXAMINATIONS AND RADIATION RISKS IN EVERYDAY RADIOLOGICAL PRACTICE

D.R. Hadnađev, O. Nikolić, S. Stojanović

Center for Radiology, Clinical Center of Vojvodina, Novi Sad

Objective. To discuss the justification of computerized tomography (CT) examinations, as well as the consequent risk of radiation in everyday radiological practice.

Method. A review of the most recent literature regarding uncritical CT overuse and insufficient use of alternative non-ionizing diagnostic modalities is presented.

Procedure analysis. The number of CT examinations has dramatically increased, mainly for the new clinical applications which technically improved CT scanners made it widely available. Abdominal and pelvic CT examinations are two major contributors for increase in population radiation exposure. These examinations are associated with the greatest radiation burden among all types of CT procedures. The study of radiation exposure of patients undergone standard CT examinations has been conducted in our institution. The purpose of the study is the introduction of patients radiation records in everyday practice. This is particularly important in patients suffering from malignant or hematologic diseases, for whom periodic follow-up CT scan is required. Radiation doses received by patients during examinations by multidetector CT scanners (for head CT 2mSv, thorax CT 8 mSv, abdomen and pelvic CT 10 mSv, and whole body CT 26 mSv) have a tendency to increase, hence it is necessary for radiological community to develop and adapt appropriate criteria for routine multidetector CT examinations. For the assessment of radiation risk and comparison of different procedures, it is necessary to determine the effective dose value. It is also essential to optimize CT protocols according to indications, as well as dosimetric parameters of exposure and the region of interest. Application of bismuth shields on radiosensitive body regions can significantly reduce the dose.

Conclusion. By informing and educating the clinicians and radiologists primarily on the risk of radiation and strategies to minimize it during a CT exam, we can justify the examination itself and the patient radiation risk.

Key words: computerized tomography, radiation, radiation risk

TLD POSTAL DOSE QUALITY AUDIT FOR 6 MV AND 15 MV PHOTON BEAMS IN RADIOTHERAPY CLINICAL PRACTICE

Sonja Petkovska[1], Margarita Ginovska[2], Hristina Spasevska[2], Nadica Dimitrovska[1]

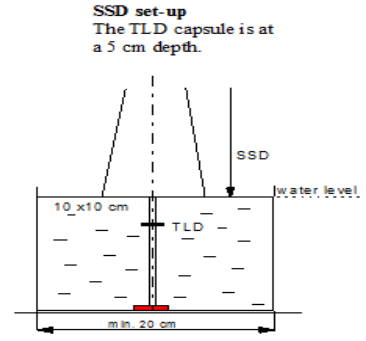
[1] University Clinic for Radiotherapy and Oncology, Dept. of External Radioth, Skopje, Republic of Macedonia
[2] Faculty of Electrical Engineering and Information Technologies, Ss Ciril and Metodious University, Skopje, Republic of Macedonia

The accuracy requirements and the medical consequences in radiotherapy need a dedicated QA programme. Except internal QA procedures, external comparison with an independent dosimetry laboratory is useful, in order to check physical parameters such as reference beam output, depth dose data, beam output variations, etc. The ESTRO QUALity Assurance network (EQUAL) is established with the purpose to perform the comparison in different beam parameters in clinical practice. The measurements of dose delivered on axis in reference and non-reference conditions for external radiotherapy presented below, are compared in the frame of the ESTRO-EQUAL project for high energy photon beam.

Thermoluminescent Dosimeters (TLDs) with lithium fluoride powder (LiF) are used. For high energy photon beams used in radiotherapy, LiF does not perturb significantly photon and electron fluencies. The Physics Department of the Institut Gustave-Roussy (IGR, Villejuif, France) has been elected as the measuring laboratory (ML) in the frame of the EQUAL programme.

TLDs are irradiated in a water phantom at a fixed source-skin-distance SSD. The irradiation should be performed at the usual reference SSD = 100 cm with a vertical beam of 10 x 10 cm. The number of monitor units required for 2 Gy at 5 cm depth, are calculated by the local treatment planning system in use in clinical practice. Two dosimeters (TLDs) are irradiated for each energy one by one at given depth (5 cm).

The purpose of this TLD audit is to check the dose delivered by radiotherapy unit. EQUAL-ESTRO laboratory provides an independent and trustworthy verification of dose delivery. The external audits also allow detecting dosimetric errors. The levels of deviation between measured and stated quantities (Q_m/Q_s) and the corresponding EQUAL actions are specified as follows: optimal level when the deviation Q_m/Q_s is less than 3 %; a level outside optimal and within tolerance level when the deviation is between 3 % and 5 %; a level outside tolerance level when the deviation is between 5 % and 10 %, and emergency level when the deviation is bigger than 10 %. The results from ML show that the relative deviation Q_m/Q_s for these analyzed 6 MV and 15 MV photon beams, do not exceed 3 %. As a conclusion, the presented results in the paper belong to the optimal level according to the acceptability criteria in the project.



geometry set-ups for the TLD irradiation.

FIELD NATURE OF LIFE

Valeriy Zaporozhan, Andriy Popnomarenko

Odessa National Medical University, Ukraine

For scientific progress, it is very important to realize the correct hierarchy of life-keeping and life-regulatory structures and forces. We tried to trace evolution of our conceptualization in the field, which was strictly followed by the progress in our general scientific knowledge and accessible methodology. Let us depict this evolution of our understanding of the main life-keeping entity as follows: Spiritual – Morphological – Biochemical – Genomic – Proteomic. We believe that the next stage in this sequence should be the "Life Field Matrix". The word "Field" by definition means 'predominantly the Electromagnetic field'. Possible substantiation of the statement includes the fact that 99 percent of all interactions in live matter are of electromagnetic nature, regardless of what life-related process we are considering: muscle contraction, hormonal regulation or cell division. The term "Matrix" is present in the definition because of the morphogenetic role of the EMF in living beings. Of course, there are chemical signals/clues regulating numerous bio-reactions, cell division and differentiation, etc. But, nonetheless, there should be a guided force ensuring the definite specific shape (sometimes very complicated and fascinating) of all biological objects from proteins to metazoan. The only known force that could guide such a precision movements of biomolecules and to secure their shapes is the EMF. What consequences/ conclusions are resulting from understanding and acceptance of the Electromagnetic Life Field Matrix stage in our Life cognition process? To outline some of them:

1) Methods of the EMF detection can provide indispensable information about vital processes, their dynamics and possible abnormalities. Existing methods and medical devices (like Electroencephalography, electrocardiography, MRT and emerging medical applications of the Raman spectroscopy) perfectly illustrate this thesis.

2) Dynamics of the biological processes could be evaluated and predicted by way of study of corresponding EM-interactions and their biological effects. Among currently investigated and theoretically elaborated examples of this statement can be mentioned: a) Epigenetic effects of the EMF; b) informational-regulatory mechanisms of the EMF in living objects (*McCaig et al.*); c) Mechanism of weak magnetic field influence on gene expression (*Zaporozhan et al.*); d) Role of the Electrostatic characteristics of viruses and antibodies in viral infection and epidemiology (*Ponomarenko et al.*).

3) Elaboration of new efficient treatment methods can be achieved by utilizing EMF. Examples: a) Stimulation of Cell differentiation and regeneration by Magnetic field; b) Transcranial Magnetic Stimulation (TMS) for treatment of various neurological and psychiatric disorders; c) New Cancer treatment methods based on cancer cell membrane permeabilization using High frequency EMF.

Possible perspectives: 1) Elaboration of biophysical approaches and corresponding instruments/ equipment to alleviate negative Health effects of Solar and Geomagnetic storms; 2) Electromagnetic approaches to infectious diseases prophylaxis and treatment. 3) Creation of the EM-Field Matrices for Tissue Engineering and electromagnetic targeting of drugs and progenitor cells to the diseased site (partially achieved).

Conclusion: Conceptual shift to the Field Matrix paradigm in Bio-medicine is timely and promising for directional elaboration of new treatments, prophylaxis, and as a new suitable model for the evaluation of the Health risks of the various variants of the human EMF exposure.

TWO FIELD BREAST PLAN VS. OPTIMIZED CONFORMAL BREAST PLAN: COMPARISON OF PLAN PARAMETERS

Borko Basarić, Ozren Čudić, Milan Teodorović, Borislava Petrović, Milutin Baucal, Laza Rutonjski, Ljubica Smiljanić

Radiotherapy Department, Institute of Oncology Vojvodina, Sremska Kamenica, Serbia

Introduction: Breast cancer external beam radiotherapy treatment involves different techniques, which depend on available technical resources in the medical institution and the stage of disease. This study compares the optimized conformal plan (with additional small fields) and the two field tangential breast plan. Dosimetric verification of a small number of MU (monitor units) per field is also presented.

Materials and methods: Computed tomography (CT) scans of 10 patients were obtained and imported into treatment planning system (TPS). Patients were delineated according to the institutional protocol, and the stage of the disease. Apart from target volumes, heart, spinal cord and both lungs (OAR - organs at risk) were separately delineated. Patients were treated according to the protocol, but an additional plan was created for the purpose of comparison. The basic plan assumes two tangential fields, but for the purpose of dose-volume coverage improvement, additional small fields were added (optimized conformal plan) with small doses applied. The small field sizes were adjusted to obtain the optimal breast dose-volume coverage and to optimize the sparing effect to the lung and heart. Dose volume histograms (DVHs) of the breast, and OARs for both plans were calculated and compared. The small fields and small doses on these fields (5-10% of prescribed dose) resulted in smaller number of MU overall. The stability and reproducibility of the accelerator output was verified for this purpose. The results of dosimetric verification are presented for the 10 x 10 cm² field and energy of 6MV. 100 MU in steps of (20 x 5 MU) and (10 x 10 MU) were compared to the calibrated output in same conditions (1 x 100 MU).

Results: Reduction in the total number of MU for the optimized plan was observed (20%) in comparison to the two field plan. The DVH showed that the optimized plan allowed much better dose-volume coverage than the two field plan (7-10%). Dosimetric verification has shown that there were no significant differences in the output for the small fields and the small number of MU, in comparison to the machine calibration output as shown in Table 1.

Conclusion: The study suggests that for the breast cancer external beam radiotherapy treatment, the optimized plan has the advantage over two field plan (dose reduction to organs at risk, increased target dose conformity and reduction of total number of MU and total body scatter radiation).

Measurement No. (N)	Q [*nC*] for (N x 5 MU)	Q [*nC*] for (N x 10 MU)	Q [*nC*] for (N x 100 MU)
1.	0.709	1.412	14.040
2.	1.419	2.821	
3.	2.132	4.230	
4.	2.844	5.639	
5.	3.556	7.049	
6.	4.268	8.458	
7.	4.979	9.866	
8.	5.690	11.271	
9.	6.401	12.680	
10.	7.113	14.090	
11.	7.823		
12.	8.535		
13.	9.245		
14.	9.956		
15.	10.670		
16.	11.381		
17.	12.090		
18.	12.800		
19.	13.511		
20.	14.220		
$\sum_{i=1}^{N} Q_i$	**14.220**	**14.090**	**14.040**

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FEASIBILITY STUDIES OF EU + LI CO-DOPED GD_2O_3 AS A THERMOLUMINESCENCE DETECTOR FOR UV EMISSION

Yanka I. Baneva[1], Hristo Y. Hristov[2], Nina N. Arhangelova[2], Ilia P. Penev[3], Paolo Rossi[4], Giuliano Moschini[4], Nikolay M. Uzunov[2, 4]

[1] Dept. of Physics and Biophysics, Medical University, 150 Tzar Liberator str., 9000 Varna, Bulgaria
[2] Faculty of Natural Sciences, Shumen University "K. Preslavski", 115 Universitetska str., 9712 Shumen, Bulgaria
[3] Institute for Nuclear Research and Nuclear Energy, BAS, 72 Tzarigradsko chaussee Blvd., 1784 Sofia, Bulgaria
[4] National Laboratories of Legnaro, INFN, Viale del'Universita 2, 35020 Lagnaro (PD), Italy

We have already studied the possibility to apply some sintered crystals such as ZrO_2 doped with Er and Li as appropriate detectors for ultra-violet (UV) light. The detection of the UV irradiation exploits the thermoluminescence (TL) emission of some crystals (phosphors) after being exposed to UV irradiation with wavelength in the interval of 280 nm – 360 nm. It turned out that such crystals are easy to create and their TL glow curves possess well-shaped peaks with sufficient statistical data.

In this article we present the results of our research toward the creation of new sintered crystals, sensible to the UV emission. Analysis of the thermoluminescence properties of Gd_2O_3, doped with Eu and Li has been conducted. Different quantities of lithium co-dopant have been added as Li_2CO_3 to a mixture of Gd_2O_3 with 10 wt% Eu_2O_3. Pellets sintered at a temperature of 1000°C have been prepared and the kinetic parameters of the phosphors have been studied after irradiation with UV light from a XBO lamp. It has been shown that the addition of 10 wt% of Li_2CO_3 to the mixture of Gd_2O_3 with 10 wt% Eu_2O_3 yields a maximum intensity of the peaks at 60 °C and at 169 °C. Spectral emission and spectral sensitivity of the phosphors have been studied. The analysis applied to TL glow curves, obtained from the UV irradiated phosphors and kept after the irradiation at different times in a dark storage, revealed that the peak at 169 °C has a relatively long fading.

Analysis of the thermoluminescence properties of the phosphors obtained from Gd_2O_3, doped with Eu and Li, shows that they possess a good sensitivity to the UV emission and could be used for quantitative measurements of UV light.

THE ISSUE OF DOSE OUTPUT INCONSTANCY IN COMMISSIONING OF THE X-RAY THERAPY UNIT

D. Dimitric, D. Otasevic

Radiotherapy Department, Military Medical Academy, Belgrade, Serbia

This work is concerned with measuring methods and configurations which were used for measuring dose output of the X-ray therapy unit XSTRAHL 3300, manufactured by Gulmay Medical Ltd., UK. This unit is in clinical use from April 2011 at The Radiotherapy department of The Military Medical Academy, Belgrade. According to the IAEA convention, its nine different energy qualities cover the low and the middle part of the whole energy range used in clinical radiotherapy today.

Reference and relative measurements were conducted. Two different types of ionization chamber were chosen. First one being the FARMER type, **NE 2571** is aimed at measuring local ionization (dose) in water for the middle energy beams while the second one, the Plan-parallel chamber type, **PTW 23343** for measuring the local ionization in a Plexiglas for the low energy beams.

The X-ray beams are known to show not so good repeatability. That is especially so when the non-standard (non-referent) applicator is engaged because in that case the additional output factor must be included in order to provide the reference to the calibration dose value obtained under referent measuring conditions. As consequence, there comes impossible or very difficult for someone to define the unique criterion of constancy for all energy-applicator combinations used clinically. In dealing with that, the proposition came from the authors in [1] saying that surface doses in PDIs (Percentual Depth Ionizations) should be rather obtained by extrapolation than using direct measurement with the chamber positioned at the water surface. The results of output repeatability for both of the methods are summarized in Table 1. Table columns marked ***Met1*** represent the results for conventional measuring method, while those marked ***Met2*** represent the method of applying the extrapolated instead of the measured values.

Table 1. Percent deviation of the dose value from repeated measurements of middle energy beams in water with FARMER type chamber

ENERGY	APPLICATOR(FSD=50 cm) 10x10		8X8		7X5		10X5	
	Met1	***[%] Met2***	***Met1***	***[%] Met2***	***Met1***	***[%] Met2***	***Met1***	***[%] Met2***
300 keV, 3 mmCu	0.47	-0.08	1.45	-3.18	-6.51	-3.37	-5.36	-1.58
250 keV,2 mmCu	1.37	0.90	3.36	-0.32	-2.95	-1.66	-3.91	-1.53
200 keV,1 mmCu	1.09	0.69	3.49	-9.36	-3.09	-4.72	-4.93	-2.41

The two methods comparison shows that the alternative method made no considerable advance in defining the unique constancy criterion for the middle range energy and rectangular applicators. It is interesting that similar comparison when done for combinations of the low range energy and circular applicators has given much better distinction between the two methods putting in favor ***Met2.*** In this work the results of these two comparisons are discussed and some guidance is provided in coping with the X-ray therapy beams inconsistency.

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CALIBRATION OF DOSIMETERS USED IN DIAGNOSTIC RADIOLOGY IN TERMS OF KERMA-AREA PRODUCT

Dragana Cekerevac, Olivera Ciraj-Bjelac, Milojko Kovacevic, Predrag Bozovic, Aleksandra Milenkovic

Vinca Institute of Nuclear Sciences, Belgrade, Serbia

The air-kerma area product (P_{KA}) is a dosimetric quantity used in diagnostic radiology, in particular in fluoroscopic examinations. P_{KA} is integral of air kerma over the x-ray beam area. It is a measure of the total energy imparted and thus related to effective dose and overall radiation risk to patients. P_{KA} is measured using transmission parallel plate ionizing chambers i.e. Air Kerma Area product meters (KAP meters) in any plane orthogonal to x-ray beam axis. The KAP meters are widely used in clinical diagnostic radiology dosimetry, especially in fluoroscopy, interventional radiology, general radiography and dental radiography. Installation of built in devices to measure P_{KA} in x-ray units used for interventional procedures is a regulatory requirement and consequently, most of the modern units have KAP meters.

To get a reliable measurement of patient dose, it is essential that P_{KA} measurement is calibrated in a proper manner. One of the methods for the filed calibration of built in P_{KA} measuring devices is based on use of reference P_{KA} meters should be, calibrated in the Secondary Standard Dosimetry Laboratory (SSLD). Both, the field calibration procedures and calibration procedures for reference KAP-meters at the SSDL are developed in the SSDL of Vinca Institute of Nuclear Sconces based on International Atomic Energy Agency (IAEA) document Dosimetry in diagnostic radiology: an international code of practice (TRS 457). This paper presents the calibration procedures and their application for measurements performed under international wide scale comparison of calibration procedures of KAP meters initiated by IAEA and the European Association of National Metrology Institutes (EURAMET).

Calibration procedures for two KAP meters (KermaX, IBA and PDC, Radcal) in various standard and non-standard bema qualities are presented. Used standard beam qualities were: RQR 3 (50 kV), RQR 5 (70 kV), RQR 6 (80 kV), RQR 8 (100 kV) and RQR 9 (120 kV), while non-standard beam qualities were generated using typical tube voltages and aluminum and copper filtration used in interventional procedures. A diagnostic radiology chamber, Magna A650 calibrated in terms of air kerma was used as a secondary standard. A set of calibration coefficients was obtained for different standard radiation qualities and non-standard beam qualities. The calibration coefficients ranged from 1.12 to 1.62 and from 1.0 to 1.32, for two chambers respectively. In this manner, traceability to the primary dosimetric standards is achieved, and important information on parameters influencing the calibration coefficients is given. Assessed combined and expanded uncertainty (k=2) of the calibration was 12%. Regular calibration of KAP meters is essential for reliable and accurate clinical dosimetry in diagnostic and interventional radiology.

COMPUTER AIDED DESIGN OF STRUCTURAL SHIELDING

Adnan Beganović[1], Amra Skopljak-Beganović[1], Advan Drljević[1], Senad Odžak[2], Vildana Karić, Davorin Samek[3], Elma Kučukalić-Selimović[4], Sandra Vegar-Zubović[5]

[1] Department of Medical Physics and Radiation Safety, Clinical Centre of Sarajevo University, Bosnia and Herzegovina
[2] Faculty of Science, University of Sarajevo, Bosnia and Herzegovina
[3] Veterinary Faculty, University of Sarajevo, Bosnia and Herzegovina
[4] Clinic of Nuclear Medicine, Clinical Centre of Sarajevo University, Bosnia and Herzegovina
[5] Clinic of Radiology, Clinical Centre of Sarajevo University, Bosnia and Herzegovina

Legislation in most countries requires design of structural shielding prior to installation and use of new sources of ionizing radiation. Facility well designed means that structural shielding is good enough to keep doses to the staff below the target value, but it also does not unnecessarily increase construction costs.

Structural shielding design is a challenging task, especially in nuclear medicine, where both radioactive and x-ray sources are used. Positrons emitted by fluorine-18 and other sources used for positron emission tomography (PET) are annihilated by surrounding electrons, thus creating two photons of 511 keV that are used for imaging. Structural shielding must satisfy regulatory recommendations.

In our study target dose to the staff was 0.3 mSv. Provisional architectural design was selected, and positions of sources (patients and devices), specific test points, walls, rooms and special areas were loaded into MS Access Database. Visual Basic subroutines were used to calculate minimum thickness of barriers (walls) needed. Another subroutine calculated integral doses in 100,000 random points. Calculated data was analyzed by a crosstab query and used to calculate average doses in specific working areas, such as control rooms, corridors, etc. Points were used to create isodose plot.

This approach is a good tool for optimization of structural shielding. Use of average dose in specific working areas and not worst case scenario point allows shielding thickness to be minimized, and therefore lower the costs of construction.

PATIENT DOSES IN UROGENITAL RADIOGRAPHY IN CLINICAL CENTRE OF SARAJEVO UNIVERSITY

Adnan Beganović[1], Irma Zoranić, Davorin Samek[2], Sabina Prevljak[3], Amela Kuskunović[3], Sandra Vegar-Zubović[3] Amra Džananović[3], Aladin Čarovac[3]

[1] Department of Medical Physics and Radiation Safety, Clinical Centre of Sarajevo University, Bosnia and Herzegovina
[2] Veterinary Faculty, University of Sarajevo, Bosnia and Herzegovina
[3] Clinic of Radiology, Clinical Centre of Sarajevo University, Bosnia and Herzegovina

The most common procedures in urogenital radiography include intravenous urography (IVU) and micturating cystouretography (MCUG). IVU is used to visualize abnormalities of the urinary system, including the kidneys, ureters, and bladder, while MCUG is a technique for watching a person's urethra and urinary bladder while the patient urinates (voids). Standard protocol for IVU and MCUG include imaging of lower abdomen and pelvic area before, during and after administration of contrast medium. Repeated exposures increase overall dose.

X-ray parameters used for visualisation of urogenital area in anterior-posterior (AP) projection are dependent on patient's body mass. Additional filtration selected is 2 mmAl, which adds up to 4.8 mmAl of total filtration. Newborns are exposed using 48 kV of anode potential and 25 mAs of tube current. Children aged 7 around 52 kV and 25 mAs, while adult's anode potential ranges from 66 to 81 kV, with tube current of 32 mAs. Both, MCUG and IVU need 5–8 exposures for complete examination. Effective dose to newborns exposed 7 times is 1.6 mSv, 7 year old children 2.0 mSv, while adults receive doses ranging from 3.8 to 6.7 mSv per examination. All entrance skin doses are below national diagnostic reference levels (DRL).

Doses in urogenital radiography are high in comparison to other radiographic examinations. It is primarily due to necessary repeated exposures. Doses for IVU examination could be even higher than those received during "equivalent" non-contrast CT examination.

If doses are higher than the appropriate DRL, optimization (lowering the dose while maintaining adequate image quality) needs to be performed. Knowing doses in urogenital radiography is the basis for optimization.

A SURVEY OF SOME PARAMETERS RELATED TO PATIENTS TREATED WITH ^{131}I IN NUCLEAR MEDICINE IRAN

N. Ahmadi Jeshvaghane[1], R. Paydar[1], B. Fasaei[1], A. Paknyat[1], A. Karamloo[1], M.R. Deevband[1], H.R. Khosravi[1,2]

[1] Iranian Nuclear Regulatory Authority, P.O. Box 14155-4494, Tehran, Iran
[2] Nuclear Sciences Research School, Nuclear Sciences and Technology Research Institute, P.O. Box 81745-313, Tehran, Iran

There are many important parameters of patients treated with ^{131}I sodium iodide regarding to radiation protection of patients and public. In this study, some of these parameters such as Administered activity, Exposure dose rate after Administration, Exposure dose rate after released, Estimated Effective half life (h) and Residual Activity (MBq) were investigated in 6 nuclear medicine centers out of total 7 centers in Iran and 330 patients in total were surveyed. ED of patients was measured by physicists of the centers during 6 months (May-Nov2009) at 1 meter distance from the thyroid of each patient on the 1st, 2nd and 3rd day after administration by a calibrated survey meter. The mean value of Administered activity was obtained 5.24 as well as the mean value of treatment day that was 2.17 day. Maximum and Minimum values of ED were 21 and 11 μSv/h respectively. Furthermore, the Maximum and Minimum values of RA during release of patient were 720 and 250 MBq, respectively. The estimated mean effective half life was calculated 12.6 hours.

***Keywords*:** nuclear medicine, radiation protection of patient, I-131.

PATIENT DOSE EVALUATION FOR CARDIAC INTERVENTIONAL EXAMINATIONS IN IRAN

B. Fasaei[1], R. Paydar[1], N. Ahmadi Jeshvaghane[1], H.R. Khosravi[1,2], M.R. Deevband[1], A. Karamloo[1], A. Paknyat[1]

1 National Radiation Protection Department, Iranian Nuclear Regulatory Authority, P.O. Box 14155-4494, Tehran, Iran
2 Nuclear Science Research School, Nuclear Science and Technology Research Institute, Tehran, Iran

The number of interventional cardiology (IC) procedures has increased rapidly in Iran. Vascular interventional procedures carried out under fluoroscopic guidance often involve high radiation doses. Patient radiation doses received during interventional cardiology procedures can be significant. The purpose of this study was evaluation of patient dose during different cardiovascular angiography procedures. The investigated procedures were CA, PCI, EPS, PDA, ASD, PS and PTMC. In this study, 5260 patients were monitored at two most important central cardiac intervention hospitals in Iran. DAP value of patients and FT and total number of cine frames were recorded by Physisits of center during 12 month. The DAP values were measured by calibrated DAP meter of angiography equipments.

The average of DAP value for CA, PCI, EPS, PDA, ASD, PS and PTMC procedures were measured 166.99, 669.5, 133.5, 273.7, 281.75, 191.2 and 2317.4 Gy.cm^2 respectively and FT for these procedures were measured 8.15, 17.25, 29.7, 33.4, 16.3, 7.6 and 14.8 min respectively. The corresponded total number of cine frames for above mentioned procedures was 841, 2137, 0, 329, 557, 940, 3248 respectively. The diagnostic reference level for these procedures were suggested equal to 36.5, 183, 24.6, 44.9, 53.8, 39.1 and 270.1 Gy.cm^2 respectively.

High-dose patients were often associated with long screening times, a high patient body mass index, low technology level of equipment and complexity of the procedure. With these commonly performed relatively high-dose procedures, it is important that some guideline values are available to encourage optimized strategies.

***Keywords*:** interventional cardiology, patient dose, reference level

DOSE CALIBRATION OF MEDICAL LINEAR ACCELERATORS: INSTITUTIONAL BEAM CALIBRATION PROTOCOL VS. IAEA/WHO TLD POSTAL DOSE AUDIT

Ozren Čudić, Borko Basarić, Milan Teodorović, Borislava Petrović, Milutin Baucal, Laza Rutonjski, Ljubica Smiljanić

Radiotherapy Department, Institute of Oncology Vojvodina, Sremska Kamenica, Serbia

Introduction. Absorbed dose to water is the quantity of main interest in radiation therapy, since this quantity relates closely to the biological effects of radiation. The advantages of calibrations in terms of absorbed dose to water and dosimetry procedures using these calibration factors have been described in literature. IAEA developed Code of Practice based on standards of absorbed dose to water [1], and it was adopted as calibration protocol at our Institution in 2004. Previous protocol was Code of Practice entitled Absorbed Dose Determination in Photon and Electron Beams [2]. On the other hand, IAEA has developed independent TLD postal dose quality audit, in order to validate the calibration of radiation beams in developing Member States.

Materials and methods. Institutional protocol is based on IAEA TRS 398 protocol that is applied to all photon and electron beam energies available on all medical linear accelerators. For beam calibration, calibrated farmer ionization chamber and electrometer were used. Machine outputs were checked for several different machines and beam energies. TLD postal dose audit is performed with the TLD dosimeters and holders, supplied by IAEA, and irradiated clinically. TLDs are read in the IAEA's Dosimetry Laboratory, and dose calculated and compared to the dose stated by the participant.

Results. TLD results are obtained after reading at IAEA and are represented in terms of:

$\frac{IAEA\_mean\_dose}{user\_stated\_dose}$ and deviation relative to IAEA mean dose .

Conclusion. Throughout the years, the agreement within ± 5% between the user stated dose and the IAEA measured dose has been consistent. Beam calibration has been done in accordance with the recommended protocol, and consistent.

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INDUCED RADIOACTIVITY DUE TO PHOTONUCLEAR PRODUCTION OF RADIOISOTOPES IN A HIGH-ENERGY LINEAR ACCELERATOR USED FOR RADIATION THERAPY

Bratislav Cvetkovic[1], Olivera Ciraj-Bjelac[2], Milojko Kovacevic[2], Djordje Lazarevic[2]

[1] Clinical Center Nis, Zorana Djindjica 48, Nis, Serbia
[2] Vinca Institute of Nuclear Sciences, Belgrade, Serbia

Induced activity due to photonuclear reactions in medical accelerators becomes important when they operate above certain proton energies and contributes to the exposure of the staff operating the accelerator. The photons emitted from the target of the accelerator interact with the electron shell of atoms and with the nuclei when the energy is high enough. In the energy range of medical linear accelerators two major processes are involved in the generation of activation products. Firs is nuclear photo effect, i.e. (γ,n) reaction, resulting in the neutron emission. The produced neutron is able to initiate nuclear reactions itself and facilitate another process - neutron capture, i.e. (n,γ) reaction which is essentially absorption of a neutron by a nucleus, followed by the emission of excess energy in the form of photons.

The aim of present work is to obtain activation behavior of radiotherapy linear accelerator, including in situ gamma spectrometry and dose measurements. A linear accelerator included in the study was Siemens Primus (Siemens Medical Solutions, Malvern, USA) operated at 18 MV. In situ gamma spectroscopy was performed using calibrated gamma spectrometer consisting of high purity germanium detector InSpector 2000 (Canberra, Meriden, USA). Dose measurements from induced activity in terms of photon equivalent dose rate were performed using a calibrated portable scintillation measuring unit 6150 ADB (Automess, Ladenburg, Germany).

Spectral analysis was performed in parallel with dose rate measurements in the isocenter of linear accelerators, immediately after termination of irradiation. The linear accelerator itself is subject to considerable activation, particularly the target, the flattening filter and the collimators. Major radioisotopes revealed form spectral analysis were the short-lived isotopes as ^{28}Al and ^{62}Cu important for clinical routine and medium-lived isotopes as ^{56}Mn, ^{57}Ni, ^{64}Cu and ^{187}W whose contribution to radiation dose increases during working day. Principal radionuclide are produced in process-neutron capture, i.e. (n,γ) reactions. The major dose contributors are ^{28}Al, ^{56}Mn and ^{24}Na. Measured dose rate at isocenter ranged from 2.2 μSv/h to 10 μSv/h in various measuring points of interest for radiotherapy staff members. Dose rate are significant in the first ten minutes after termination of irradiation, dominated by the 2.3 min half-life of ^{28}Al for the short treatment times.

Although the high-energy fields are not very often in clinical practice, the radiotherapy staff receive dose from activation quasi-continuously, following each treatment, as a result of the previous high-energy activation. As a basis for effective radiation protection programme, it is important to assess additional dose due to activation products at each particular radiotherapy installation taking into account the local practice.

REDUCTION OF PATIENT RADIATION DOSE IN THE CASE OF X-RAY MEDICAL IMAGING

B. Nikolić[1], M. Đekić[2], H. Šamić[1]

[1] Faculty of Electrical Engineering, Zmaja od Bosne bb, Sarajevo, Bosnia and Herzegovina
[2] Faculty of Science, Zmaja od Bosne 33-35, Sarajevo, Bosnia and Herzegovina

Compound semiconductors with wide gap and high atomic number Z proved to be suitable for high resolution detectors operating at room temperature. In this paper, we consider GaAs, InP, CdTe, HgI_2 and CsI and taking into account their physical properties we calculate patient radiation dose in range of 30- 120 keV. Finally, considering good image quality and lower radiation dose, we propose the best detector material for specific area of medical imaging from mammographyc to bone radiography.

Keywords: radiation detectors, GaAs, InP, CdTe, HgI_2, CsI, x-ray medical imaging

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DOSIMETRIC VERIFICATION OF INTENSITY MODULATED RADIOTHERAPY (IMRT) TREATMENT PLANNING IN CENTER FOR RADIOTHERAPY BANJA LUKA

Bojan Štrbac, Oliver Arsovski[1]

[1]International Medical Centers, Banja Luka, Bosnia and Herzegovina

Background and purpose. Intensity modulated radiation therapy (IMRT) refers to a radiation therapy technique in which nonuniform fluence is delivered from any given position of the treatment beam to optimize the composite dose distribution [HYPERLINK \l "Kha03" 1]. The purpose of this work is to investigate the accuracy of dose calculation of a commercial treatment planning system**.** The basic difference between conventional (3D CRT) and IMRT is that latter provides extra degree of freedom, that is, intensity modulation, in achieving dose conformity. Recently, Center for radiotherapy Banja Luka has introduced this technique in radiation treatment of patients. There are many reasons for comprehensive quality assurance (QA) system for IMRT delivery. Many narrow, overlapping and adjacent sub-fields complicate computation of output factors in a treatment planning system and dose gradients created by multi leaf collimators (MLC) may have a large influence on the dose distribution2]. The quality assurance (QA) procedure of checking the IMRT plans includes several aspects, such as multileaf collimator (MLC) QA, measurements of individual patient fluence maps, calibration of the tools used and procedures to ensure accurate patient positioning. In this report we are going to describe dosimetry verification of IMRT plans as part of QA IMRT. IMRT dose delivery is dynamic process where the incident fluence shape and intensity are varying function during the treatment. Therefore, for dose measurement of IMRT treatment plans we need to use integrating dosimetric technique [HYPERLINK \l "Low11" 3]. Most of the clinics, for dosimetry QA process, include verifying the absolute dose, and also relative planar isodose distribution 4].

Methods. The fluence map has been calculated by treatment planning system Eclipse (Varian). The agreement between the measured and calculated fluence maps was evaluated in terms of percent dose error (PDE) at a few points and percent of passing points (PPP) for the isodose distribution, in order to establish reasonably achievable and clinically acceptable limits for the dose deviations. The 3% criterion is used for the percent difference analysis, and the 3 mm criterion for distance to agreement (DTA) analysis, with the prevalent standard for acceptance testing being the combined [(3%)/(3 mm DTA)] [HYPERLINK \l "Ben07" 5]. All measurement was performing with 2d array Mapcheck 2 from Sun Nuclear. The MapCheck 2 can make both relative and absolute dose measurement simultaneously.

Results. The results were 100% PPP for ±3 %/3 mm diff/DTA for the relative distribution and 0.1%-0.5% PDE for the absolute dose.

Conclusions. IMRT is implemented in rapidly growing number of centers in Europe. QA system for IMRT has become standard tools in modern clinical medical physical department. In this report we describe how our institution performs dosimetry QA analysis for IMRT delivery technique. We introduced standardized acceptance testing which is applied in majority institution around world. The results show that whole QA chain was setup correctly.

Key words: IMRT QA, IMRT, dosimetry, quality system, quality assurance

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COMPARISON CALCULATOR OF C_{VOL} AND DLP WITH CT DOSIMETRY OBTAINED FROM DICOM IMAGES OF ABDOMEN

D.M. Orejuela[1,2,3], M. Arciniegas[1,2], S. Kodlulovich[3], M.C. Plazas[2], C.A. Poveda[1], J.A. Lozano[1]

[1] Instituto Nacional de Cancerología E.S.E., Imaging and Radiology Department, Bogotá D.C., Colombia
[2] Universidad Nacional de Colombia, Master in Medical Physics, Department of Physics, Bogotá D.C., Colombia
[3] Instituto de Radioproteção e Dosimetria, Department of Medical Physics, Rio de Janeiro, Brazil

Objective: Radiology departments in Colombia consider the CT reports as a reference of the patient doses received in the procedure. This information can be considered reliable if an appropriate CT dosimetry is carried out properly. These calculations are based on the Cw, CT dose index (Cvol) and dose length product (DLP). These magnitudes depend primarily on the characteristics of the CT scanner and then to the protocol applied in 100 CT exams. In many Latin America countries the dose estimate is based on the register of all scan parameters obtained during the exam, which consume time and interfere in the procedure. The data obtained from DICOM header retrospectively is easily but not always report all indispensable information or the information is totally guarantee.

Methods: The survey was carried out in the Instituto Nacional de Câncer (INCA/Brazil) and in the Instituto Nacional de Cancerología (INC/Colombia). The DICOM images of abdomen area were taken from a Philips Brillance 6 (INCA) and in the GE BrightSpeed Elite 16 and Siemens Somaton Sensation 16 (INC). In the DICOM header of this images can be extracted exposition factors per slides. Therefore, the Cvol and DLP values are calculated by Python software and compared with beam dosimetry, technical factors and console display.

Result: The estimated Cvol and DLP values were in accordance with the DICOM header and console display. The perceptual differences between these values were 8%.

Conclusion: This calculate of doses from DICOM header and by Python Software is a useful and easy tool allow determinate and report the patients radiation doses in each patient faster and immediately or retrospectively after of scan.

Keywords: C_{vol}, Dose Length Product, DICOM header, Python, Radiation Dose

INDIRECT METHOD OF ENTRANCE SURFACE DOSE ESTIMATION OF PATIENTS IN RADIOGRAPHIC EXAMINATIONS

L. Stadnyk, O. Nosyk, O. Shalepa

Grigorev Institute for Medical Radiology, Kharkov, Ukraine

Optimization of the population dose from medical exposure should be directed at reducing the radiation doses of patients in the X-ray diagnostics, while maintaining a high quality of diagnostic images. To solve this problem it is necessary the organization of patient dose monitoring.

At present in Ukraine the assessments of doses of patients during X-ray examinations have been based on tabular data, which are listed in the Order of the Ministry of Health N 295 of 18/07/2001. However, these estimations do not correspond to the actual doses to patients because it does not take into account the technique of diagnostic procedures at each X-ray machines.

One of the tools to control exposure to the population in the X-ray diagnostic in the country is to establish the diagnostic reference levels (DRLs), based on real patient dose measurements.

In 2009-2011 for 9 most widespread X-Ray examinations the investigations of entrance surface doses (ESDs) were conducted on studying by a method of thermoluminescent dosimetry (TLD). Measurements of ESDs have been carried out at 92 X-ray Units for diagnostic radiography. However, in Ukraine there are more than 7500 conventional X-ray Units for radiographic examinations, therefore the use of TLD method for ESD monitoring in all X-ray diagnostic rooms is not possible.

In our study, ESDs were evaluated indirectly - from measurements of the radiation output by the ionization method or according to the measurements of the dose area product by the transmission ionization chamber mounted on the X-ray tubes exit window. The measurements were carried out by dosimeter type TRIAD (KEITHLEY) using an ionization chamber model 10100A. For each patient, the value of ESD was calculated from the results of radiation output measurements of X-ray Units for conditions of the diagnostic investigation and individual anthropometric data of patient. These results were compared with the values of the ESDs from the measurements by the TL dosimetry.

Also experimental work on comparison between two methods has been performed. There are compared the direct method of evaluation of ESDs by TLD with indirect dosimetry method used the measurements at the heterogeneous phantom. The calculation of ESDs on a phantom surface was carried out with using the results of dose area product measurements by digital DAP-meter mounted on the X-ray tubes exit window.

By comparing the results of the ESDs, as measured by TLDs, with the calculated values, the correlation coefficient of the results amounted to R = 0,92 (TLD measurements on patients) and to R = 0,98 (phantom measurements). The difference between measured and calculated ESD values did not exceed ±25-30 % - for the measurements on the patients and ±15-20 % - for the measurements on the phantom. This is probably due to the inaccuracy in the assessment geometry sizes of irradiation conditions (field size and distance of focus-cassette with film).

Thus, the introduction of the indirect method of assessment of ESDs from the radiation output measurements will allow estimating with reasonable accuracy the values of the ESDs during the main X-ray investigations in nearly every X-ray diagnostic room and comparing them with the values national diagnostic reference levels established in Ukraine.

THE INVESTIGATION OF PATIENT DOSES IN DIAGNOSTIC RADIOLOGY

L. Stadnyk, O. Nosyk, O. Shalepa, K. Goptsii

Grigorev Institute for Medical Radiology, Kharkov, Ukraine

Currently in Ukraine there are over 10,300 X-ray Units, including some 2,000 fluorography, 7500 conventional radiology units, 150 CT, 350 mammography, etc. According to data of Ministry of Health in 2010 in Ukraine there was carried out about 40 million X-ray studies, including CT examinations, mammography, angiography, interventional procedures, which amounted to 0.8 procedures per inhabitant of the country.

It is known that methods of X-Ray diagnostic are the most informative methods for the delivery of diagnoses of diseases, but it is associated with high radiation doses of patients, and in the case of interventional procedures - and high doses of the medical staff. Therefore, the actual problem of radiation protection is the assessment of the collective effective doses of the population due to diagnostic radiology on the study of patient doses and frequency of different diagnostic procedures for finding of the way of optimization of medical exposure.

In 2009-2011 the national studies of structure of X-ray examinations was conducted in all regions of the country. As a result of questioning it was revealed that the most widespread types of x-ray studies include: screening fluorography of chest - 43.3 %, chest radiography - 16.4%, bone X-rays – 25 %. Among the tissues and organs of bone and joint system the highest effective doses are formed due to X-Ray diagnostic investigations of the cervical, thoracic, lumbar spine and pelvis.

For the above-mentioned types of radiographic examinations and screening chest fluorography the entrance surface doses (ESDs) of the patients were studied during X-ray investigations (in two basic projections). The measurements of ESDs were carried out by the method of thermoluminescence dosimetry for 3140 patients by 92 X-Ray machines in 9 Regions of Ukraine. There were also studied the conditions of X-Ray investigations on each X-Ray Units.

The distributions of ESDs and average values for the selected types of diagnostic procedures were estimated. The third quartile of ESD distributions for each type of X-Ray investigations could be accepted as the National diagnostic reference levels (DRLs). They are following: chest (PA – projection) – 0,9 mGy; the cervical spine – 2,0 mGy; thorax – 11,0 and 18,0 mGy, the lumbar – 15,0 and 40,0 mGy (PA and lateral projections accordingly); pelvis - 15,0 mGy (AP projection). It was established that for the majority types of X-ray examinations the values of the third quartiles distributions ESD were exceed in 2-2.5 times of Guidance Levels, recommended by IAEA BSS-115. The optimization of medical exposure in Diagnostic Radiology is possible only due to introduction to the quality assurance program in practice of each X-ray diagnostic department and the patient dose monitoring.

RTOG CRITERIA TO EVALUATE ACUTE SKIN REACTION AND ITS RISK FACTORS IN PATIENTS WITH HEAD AND NECK CANCER SUBMITTED TO IMRT RADIOTHERAPY

Khaldoon Mahmoud Radaideh[1], Laila Mahmoud Matalqah[2], Lee Fabian Wei Luen [3], Abd Aziz Tajuddin[1]

[1] Department of Medical Physics, School of Physics, Universiti Sains Malaysia, Minden 11800, Pulau Pinang, Malaysia
[2] Department of Clinical Pharmacy, School of Pharmaceutical Sciences, Universiti Sains Malaysia, Minden 11800, Pulau Pinang, Malaysia
[3] Department of Radiotherapy, Mount Miriam Cancer Hospital, Jalan Bulan, Pulau Pinang Malaysia

Purpose: Skin reaction is one of the frequent adverse reactions that occur in patients submitted to head and neck IMRT radiotherapy where a high skin dose is expected. In vivo dosimetry is a useful measurements tool for skin dose as the treatment planning system may not give accurate dose values at the surface. The purposes of this work were to measure skin dose, evaluate and classify skin reactions through the Radiation Therapy Oncology Group (RTOG) criteria and characterize factors that can intervene in these reactions such as using multiple tangential beams with IMRT plans, patients' age, concomitant or previous chemotherapy and the accumulative dose delivered to the skin.

Material and methods: A prospective study, included 21 Nasopharyngeal cancer patients submitted to IMRT with the gross target volume receiving 70 Gy and the clinical target volume 60 Gy in a 6 MeV Linear Accelerator. Personal data were collected and in vivo measurements were performed using Thermoluminescent dosimeters LiF:Mg;Ti TLDs that were placed at orbital, buccal and neck regions. A thermoplastic mask covering the head, neck, and shoulder was used for immobilization. All patients were monitored clinically for skin toxicity weekly.

Results: Grade 1 toxicity was observed in 8 patients, Grade 2 in 11 patients, and Grade 3 in 2 patients toward the end of treatment. The average skin dose was 89.5% at neck, 37.9% at buccal but only 10.8% at the orbital region. Higher accumulative skin doses ($p<0.05$) was identified as a risk factor for skin toxicity. However, previous or concomitant chemotherapy with radiotherapy and patients' age were not significant factors for the severity of skin reactions.

Conclusion: The neck skin should be identified as a sensitive structure for dose optimization.

LUNG DOSIMETRIC MODEL FOR RADON DOSE CALCULATION

D. Vučić[1], D. Nikezić[2]

[1] Institute on Occupational Health, Niš, Serbia
[2] Faculty of Sciences, University of Kragujevac, Kragujevac, Serbia

Absorbed dose that human lung receives from gas radon and its short lived progenies during air inhalation was calculated and presented in this paper. The dosimetric lung model, developed by authors according ICRP 66 (International Commission on Radiological Protection) compartment model, is used for radon progeny absorbed dose calculation. Authentic software was developed for determination dose absorbed per unit inhaled activity, DCF (Dose Conversion Factor), e.g. the dose per unit exposure to the radon progenies.

The calculations were provided for the real city population, including real gender, age and physical activity level differences among real human population.

The log-normal distribution for DCF was found, with the median value of 15 mSv/WLM.

Key words: dosimetry, lung model, radon, absorbed dose, real population

VALIDITY OF USING THE FIRST FRACTION DWELL TIMES FOR THE REMAINING FRACTIONS FOR BRACHYTHERAPY TREATMENT OF CARCINOMA OF THE UTERINE CERVIX

Zoran Stefanovski

University Clinic of Radiotherapy and Oncology, Vodnjanska 17, 1000 Skopje, Macedonia

Purpose: The aim of this study is to explore the possibility of delivering the same dwell time for all three fractions while conducting brachytherapy treatment of carcinoma of the uterine cervix.

Methods: Brachytherapy treatment of cervix uteri cancer is performed with Varian tandem and ring applicators. Points A (left and right) are chosen for delivering the prescribed dose, while constraints are nearest points of the rectum and the bladder. These points are obtained after the reconstruction from orthogonal simulation images. Using geometry of the reconstruction with the help of TPS the dwell times for the radioactive Ir-192 source is obtained. Orthogonal simulation images are obtained for the second and third fraction too, and these images are compared visually with the images of the first fraction. If the positions of the rectum and the bladder are similar to the positions in the first fraction a plan is made in which we apply the dwell times from the first fraction. These plans are used to compare the doses in recorded points with the doses in respective points in the first plan and to draw a conclusion whether such a mechanistic usage of dwell times is dosimetrically justified. For this study 34 patients consecutively treated were chosen. We recorded the doses in the bladder, the maximum dose in rectum, the doses in the left and right point A and the volume occupied by the 100 % isodose. The presumption is that the same dwell times will yield very similar isodose distributions and very close dose values in recorded points.

Results: The means of doses of considered points in second and third fraction were compared with the means of the same points in first fraction. The t test showed that only the point A did not belong to the same population, i.e. the means were significantly different from the means in the first fraction. All other doses to the other points (bladder, rectum and 100 % isodose curve volume) appear to be drawn from the same population within 95 % confidence interval. Standard deviations for all compared points, except the bladder point, in fractions 2 and 3 were significantly different (larger) than the standard deviations for the first fraction. For the bladder point the standard deviation in the first fraction was bigger than in the fractions 2 and 3.

Conclusions: Despite the fact that the mean values of doses to point A for fractions 2 and 3 were very close to the mean value for the first fraction, standard deviations were far greater for fractions 2 and 3 that the standard deviation for the first fraction. This implies that it is not safe to take the dwell time from the first fraction to the other fractions.

COMMISSIONING OF COMPUTERIZED TREATMENT PLANNING SYSTEMS FOR EXTERNAL HIGH-ENERGY PHOTON BEAM RADIOTHERAPY

A. Salčinović[1], D. Samek[2], A. Drljević[3]

[1] Faculty of Science, University of Sarajevo, Bosnia and Herzegovina
[2] Veterinary Faculty, University of Sarajevo, Bosnia and Herzegovina
[3] Clinical Center, University of Sarajevo, Bosnia and Herzegovina

Radiotherapy is used for cancer treatment. It uses ionising radiation to destroy DNA inside cancer cells. The aim of radiotherapy is to deliver an accurate dose to a target volume and irradiate as little normal tissue as possible. Quality Assurance (QA) in radiotherapy is crucial to reduce uncertainties and errors in dose delivery to the patient. Computerized treatment planning systems (RTPSs) are used to generate dose distributions and beam shapes. Commissioning is one of the important parts of the QA programme for RTPSs and it includes testing system functions and verifying the ability of the dose calculation algorithms to reproduce dose values determined by measurement. Commissioning of the RTPS "Precise Plan" has been done following IAEA Protocol TECDOC-1583 which consists of eight dosimetric tests. Each test covers the check of several different parameters. The measurements were performed on LINAC SL 20 ELECTA for two photon energies 6 and 18 MeV at the Clinical Center University of Sarajevo, using ionising chamber PTW 30013 0, 6 cm, electrometer PTW UNIDOSE T 10009-90344 and anthropomorphic phantom CIRS Thorax Model 002LFC. The differences between measured and calculated dose values were compared with agreement criteria for each test and the obtained results were discussed. The results of the clinical commissioning test can be used for the periodic QA programme of RTPS.

Keywords: Radiotherapy, Quality Assurance, Computerized Treatment Planning System, Commissioning

ESTIMATION OF THE BEAM QUALITY CONVERSION COEFFICIENT IN THE HIGH PHOTON BEAM CALIBRATION

Ivan Stojanović[1], Dragomir Paunović[2], Nebojša T. Milošević[3]

[1] High School "Sveti Sava" Kladovo, Serbia
[2] Department of Oncology, Health Center Kladovo, Serbia
[3] Department of Biophysics, Medical Faculty, University of Belgrade, Serbia

Introduction

Advances in radiation dosimetry continue to improve the accuracy of calibrating photon beams for radiation therapy. This study investigates the beam quality, following the guidance of two international protocols of the high energy photon beam calibration.

Materials and Methods

6 MV photon beam, obtained from Clinac 600C (Varian, USA), was calibrated in the water phantom by two farmer type ionization chambers (FC65-G(Wellhofer, Germany) and (NE2571(NE Technology Limited, England)) with corresponding electrometer (Wellhofer DOSE1(Wellhofer, Germany)). The correction factors and absorbed doze in the water were calculated by TG 51 (Task Group 51 recommended by AAPM) and TRS 398 (Technical Reports Series No 398 recommended by IAEA).

Results

Table 1 summarizes calculation of two parameters and two quantities for two ionization chambers, according to the guidelines of two calibration protocols.

Protocol	TG-51		TRS-398	
Chamber	FC65-G	NE2571	FC65-G	NE2571
PDD (z_{ref})	66.6	66.8	66.6	66.8
k_{QQo}	0.99280	0.995	0.9937	0.994
$D_w(z_{ref})$ (Gy)	1.308	0.634	1.305	0.631
$D_{w,max}$ (cGy)	196.337	94.936	195.947	94.420

Conclusion

The differences in the beam quality and absorbed dose between two calibration protocols, for both chambers, are smaller than 5%. This finding corresponds with recommendation, which defines maximal uncertainty in the calibration protocol. Our results suggest that the choice of the calibration protocol does not influence in the high photon beam calibration. This conclusion will be further investigated for 10 MV and 18 MV photon beams.

OPTIMIZING PEDIATRIC DOSES IN CT

Drilona Kishta[1], Antoneta Deda, Krenar Preza[1], Renato Osmenaj

[1] University Hospital Centre "Mother Teresa", Tirane, Albania

The ALARA principle and different dissymmetric methods were carried out and checked with the pediatric data. The CT protocols are studied and compared with standards IEAE. In this study, CT scan was performed on 100 cases, which include children and adults with different diagnoses, and that applies as much QC protocol and the ionizing radiation protection for patients, as lower doses of exposure are for staff working in labs CT.

Results show that small doses of 3-5 mGy have side effects, mostly in children. The maximum dose achieved in this study was 10 Gy dose which is not high but based on the evaluation of the justification should be considered for child patient (physique of the patient).

The study was made from CT data of different manufacturers. Dissymmetric comparison is made by DAP and the TLD device. This paper presents the parameters that should be used to take a dose as low qualities and must not be tolerated in the examination. These parameters are also closely related to the age and weight of the patient.

Also presented is the possible damage that can appear in children performing the CT examinations without using predetermined protocols and standards referred to references published by IEAE. In this work are also presented statistics from various countries of the world on how to optimize doses in pediatric CT but without forgetting the adults.

OPTIMIZATION OF IONIZING RADIATION IN MEDICINE

Drilona Kishta[1], Antoneta Deda, Krenar Preza[1]

[1] University Hospital Centre "Mother Teresa", Tirane, Albania

Ionizing radiation has nowadays become a powerful tool in diagnostic, radiotherapy and nuclear medicine, and, at the same time, it is significantly increasing the population's medical exposures. As a result, a large number of people always need training for the above purposes. Under these conditions, the significant task is the optimization of these exposures, in order to avoid the possible detrimental effects of different radiations, especially for those procedures that are related to high doses, which are part of procedures in intervention radiology.

Medical radiations have to fulfill the three principles of radiation protection requirements: justification, optimization and dose limits. Many institutions and companies aim to reduce the doses received by patients by giving them smaller/lower doses than the rates allow. On the other hand, this allows a significant reduction of doses received even by people exposed professionally.

In diagnostic radiology, there is a need for a periodical check of the physical and geometrical characteristics of the X-ray beam and screens that are used to divide areas which are not related to the examination. Generally, in all the cabinets related with the usage of ionizing radiation or radioactivity materials for medical purposes, a periodical quality control check of the equipment is needed. We have to always follow the recommendations of Basic Safety Standards related with classifications of areas, dose limits, etc. Finally, TLD dosimeters for personal doses monitoring are used by all the medical stuff who are working in different cabinets of “Mother Teresa” Hospital.

DOSIMETRY OF HIGH-DOSE-RATE INTRACAVITARY BRACHYTHERAPY WITH THE MAMMOSITE APPLICATOR USING MONT CARLO SIMULATION

M. Oshaghi[1], M. Sadeghi[2], S.R. Mahdavi[3], A. Shirazi[3]

[1] Department of Medical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2] Agricultural, Medical & Industrial Research School, Nuclear Science and Technology Research Institute, Karaj, Tehran, Iran
[3] Department of Medical physics, Faculty of Medicine, Tehran University of Medical Sciences, Tehran, Iran

In the treatment of early stage breast cancer, MammoSite brachytherapy has been use as one of the partial breast irradiation techniques after breast surgery. The MammoSite applicator is a single catheter with an inflatable balloon at its distal end that can be placed in the resected cavity (tumor bed). The treatment is performed by delivering the Ir-192 high-dose-rate source through the center lumen of the catheter by a remote after loader while the balloon is inflated in the tumor bed cavity. The Monte Carlo MCNP-5 code use to simulate dose rate in the planning target volume (PTV) of a 1cm radius MammoSite balloon dose delivery system. The simulation carried out using an average female chest phantom and Ir-192 source for brachytherapy application. The balloon doses were found to be underestimated by PTV. The underestimation error from the treatment planning system will be less than +/-2.0 % & +/-3.5 % at the balloon surface and balloon PTV respectively, when comparing Mont Carlo results.

Keyword: Brachytherapy, MammoSite, Ir-192, Mont Carlo simulation

NANO-DOSIMETRIC COMPARISON OF ^{90}Y, ^{67}CU, AND ^{32}P RADIOACTIVE NANOPARTICLES IN SOLID TUMORS

Hamidreza Jabal-Ameli [1], Mahdi Sadeghi [2], Seyed Javad Ahmadi [3], Claudio Tenreiro[4]

[1] Agricultural, Medical and Industrial Research School, Nuclear Science and Technology Research Institute, Karaj, Iran
[2] Department of Nuclear Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[3] Jaber Ibne Hayan Research Laboratories, Nuclear Science and Technology Research Institute, Tehran, Iran
[4] Department of Energy Science, SungKyunKwan University, 300 Cheoncheon–dong, Suwon, Korea

In radioimmunotherapy radioactive atoms are attached to monoclonal antibodies to be used in treating cancer while limiting radiation to healthy tissues. However, it has been shown that only one radioactive atom is linked to each antibody and the deposited dose is often insufficient to eradicate solid tumor. In recent years, there have been widely studies that radioactive nanoparticles have beneficial features. These nanoparticles have more surface area to accommodate a large number of different types of functional groups so that more than one antibody can be conjugated. The aim of this paper is to assess, by means of MCNPX simulations, the absorbed dose of radioactive nanoparticles around and throughout solid tumors. Spherical tumors evaluated with 1 and 0.1 cm diameters and we have also defined a model with non-uniform distribution of antibodies within solid tumors are taken into account. Nanodosimetry calculations have been performed for the beta-emitting radioactive nanoparticles, including 32P, 67Cu, 90Y. Simulations with MCNPX showed that enough energy deposition can be delivered inside tumors by radioactive nanoparticles containing hundreds of radioactive atoms. In addition, for the radioactive nanoparticles distributions investigated, high energy beta emitters, such as 90Y, are most effective in treating large tumors and for small tumors (d=0.1 cm) 67Cu are better suited.

Key words: nanodosimetry, radioactive nanoparticles, radioimmunotherapy, Monte Carlo

CAPILAROSCOPY – A USEFUL TOOL FOR AN EARLY DETECTION OF VASCULAR RADIOLESIONS

Vlatka Brumen

University of Applied Health Studies Zagreb, Croatia

An ever growing use of EM sources and their rising medical and social relevance calls for a constant monitoring of their health impact on the exposed population. Skin represents a part of the body most commonly exposed to radiation. Accidental skin irradiation may yield visible skin changes in form of acute dermatitis, but the latter can also present in its sub-acute and chronic form, making the affected skin portion prone to malignancies. In the era of high-tech diagnostics, medical professionals sometimes neglect to resort to simpler, easier-to-perform, but nevertheless informative tools and methods capable of giving at least a preliminary insight into the health status on the whole and/or the status of the area under consideration.

Capillary system offers the fastest visually accessible response to radiation. The skin reaction is essentially an inflammatory one, and is featured by five characteristics each MD had to know by heart during his/her medical studies: *rubor, calor, dolor, tumour and functio laesa*. The considerable portion of damage is caused not only by changes in haemostasis and neuro-humoral regulation, but also by direct impact of radiation on capillary vessel wall, in particular by an endothelial lesion.

Despite of all giant steps made by *ars medica* in the years we left behind, capillaroscopy is still the only technique capable of giving an *in vivo* insight into the status of the tiniest, but most represented vessels in the human body – capillaries, which get to be attacked and affected first. The method boils down to stereomicroscopic visualisation of suitable loci, the nail-fold being the most preferable one. The method is highly sensitive (95 %), less, but still acceptably specific (80 %) and of high positive prediction (86-90 %). As such, it represents an ideal, non-invasive screening test capable of sorting out the individuals that should be subjected to more sophisticated, but not rarely also more invasive diagnostic methods.

EXTRA ABSORBED DOSE ASSESSMENT OF CARDIAC AND OTHER TISSUES AROUND THE CARDIAC DURING THE TRANSMISSION ATTENUATION CORRECTION OF CARDIAC SPECT IMAGING

A. Karimian[1], M. Hedyehzadeh[1], A. Hajarizadeh[2]

[1] Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran
[2] Department of Physics, Faculty of Science, University of Isfahan, Isfahan, Iran

Cardiac disease is one of the most important causes of death in the world. Myocardial perfusion imaging using SPECT (Single Photon Emission Computed Tomography) is one of the best methods which have been used for diagnosis aims. Photon attenuation is the most important factor which degrades accuracy and quality of SPECT images. To overcome this shortcoming, a method based on producing the attenuation map using transmission source is usually used for attenuation correction. Using transmission source in this correction method increases the received dose by cardiac and other tissues around it. The purpose of this research is to assess the extra absorbed dose of cardiac and other tissues around it during the transmission attenuation correction of cardiac SPECT imaging. So in this research a Monte Carlo simulation was done to calculate the absorbed dose. The cardiac and torso were simulated in cylindrical coordinate. The torso was considered as a cylinder with the dimensions of 20cm in diameter and 70 cm in length. Also cardiac was simulated by two nested cylinders with the dimensions of 3.5 cm & 5.5 cm in radius and 10 cm in length. The transmission attenuation correction (TAC) was done by using a line source of Gd153 with the activity of about 30 mCi and the length of 10 cm. Then the extra absorbed dose of cardiac and its surrounding tissues during TAC were calculated by Monte Carlo method. The results showed, cardiac, its surrounding tissues and also skin have received considerable extra absorbed dose which are much higher than the reported limits by ICRP60. Therefore in order to have the advantages of using TAC during cardiac SPECT and reduce the extra absorbed doses as much as possible, the SPECT system should be calibrated well. Furthermore the optimum activity of Gd-153 in TAC system should be used. To achieve this purpose the suitable lead filters should replace and remove in the suitable time, depend on the activity of TAC source.

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RISK ASSESSMENT OF BONE METASTASIS TREATMENT BY MONTE CARLO METHOD

Alireza Karimian[1], Ziba Eghbali[2], Iraj Jabbarib[3]

[1] Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran
[2] Department of Physics, Faculty of Science, University of Isfahan, Isfahan, Iran
[3] Department of Nuclear Engineering, Faculty of New Sciences and Technologies, University of Isfahan, Isfahan, Iran

In order to evaluate the risk assessment of bone metastasis treatment by using radiation therapy, the Monte Carlo simulation method is used. In this research work to evaluate and assess the radiation absorbed dose in the metastasis bone and its normal surrounding tissues for treating bone metastasis by using 153Sm-EDTMP the EGSnrc which is one of the Monte Carlo based codes has been used. This simulation code has some special advantages such as: possibility to use a CT scan image to define the material geometry and source distribution which cause to achieve more precise and actual assessment.

In this research, the CT-create subroutine was designed and written to create geometry of the tissues as a three dimensional phantom. Then a desirable volumetric distribution of 153Sm-EDTMP was considered inside the bone metastasis. Then the designed simulation program in this research was executed for 200 million particles of β-, in 3 different and dominant energies of Sm-153 means: 640, 710, 810 keV and gamma photons (103 keV) by considering all possible interactions. Finally the 3D absorbed dose in different parts of under treatment tissue and its surrounding tissues were calculated by DOSXYZnrc Code.

In our study, the amount of absorbed dose in the minimum and maximum range were calculated for a metastasis bone (3.6 - 7.8 Gy), for the bone without metastasis (0.35 - 1.6 Gy) and for the muscle and lungs (between the amounts 0.025 - 0.035 and 0.0005 - 0.004 Gy) respectively.

Our results showed in treatment the bone metastasis by using 153Sm-EDTMP the absorbed dose inside the metastasis bone is about 4 - 20 times more than the normal bone which justify that, this treatment method is very effective. Furthermore, always we should consider that for treating cancer the amount of effective equivalent dose must be satisfy the conditions of international standards such as ICRP.

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SUPERVISION OF THE RADIOACTIVE INVENTORY IN WASTE WATER SYSTEMS

W. Westmeier

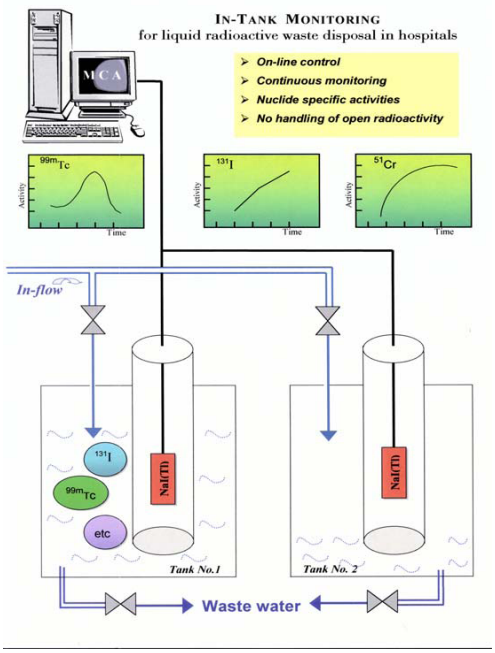
Gesellschaft für Kernspektrometrie mbH, 35085 Ebsdorfergrund, Germany

Facilities using radioactive substances, like for example in therapeutic or diagnostic applications in nuclear medicine departments, normally need facilities for storage and supervision of waste water before it can be released to the public sewage system. In most applications one can use scintillation detectors operated at room temperature in a well shielded environment. There are variants of such supervision systems which involve various levels of exposure to radiation for the personnel:

- Open sampling of waste water, typically into a Marinelli beaker and measurement with a 3"x3" NaI(Tl) detector is the simplest though most exposing method. Exposure can happen with respect to biological/viral and radiological contamination.

  A formerly frequently used variant of sample measurement in a Marinelli beaker was the determination of activity shortly after collection (when activity was high) and calculation of necessary decay time. This procedure is no longer permissible in modern legislation, but quantitative measurement shortly before release is demanded, instead.
- The water is pumped in a closed circle from the storage tank through a well-shielded measuring container, in which a submerged detector measures the content of radioactivity, and then back onto the storage tank.
- A watertight tube is submerged into every storage tank, which contains a detector for measurement of activity in the tank (see figure). Measurements are performed fully automatic in all tanks in a cyclic sequence thus yielding several data points every day.

Advantages and problems of the various measuring strategies as well as physical or technological limitations and possibilities are discussed.



FUKUSHIMA FALLOUT AT THESSALONIKI, GREECE (40°N) AND MILANO, ITALY (45°N)

A. Ioannidou[1,4], M. Manolopoulou[1], S. Stoulos1, E. Vagena[1], C. Papastefanou[1], E. Giannakaki[2,3], L. Gini[4], S. Manenti[4], F. Groppi[4]

[1] Aristotle University of Thessaloniki, Physics Department, Nuclear Physics & Elementary Particle Physics Division, 54124, Thessaloniki, Greece
[2] Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Thessaloniki, 54124, Greece
[3] Finnish Meteorological Institute, Kuopio Unit, Kuopio, FI-70211, Finland
[4] Università degli Studi di Milano and Istituto Nazionale di Fisica Nucleare, LASA Laboratory, Segrate (MI), Italy

An earthquake of magnitude 9.0 occurred on March 11, 2011 on the Pacific Ocean side of northern Honshu, Japan, followed by a tsunami that struck the east coast of the Tohoku region and caused a serious nuclear accident at the Fukushima Daiichi Nuclear Power Plant. The contaminated air masses were transported across the Pacific towards the North American continent, Europe and Central Asia, despite dispersion and washout along the trip. Radionuclides such as ^{131}I, ^{134}Cs, and ^{137}Cs were detected in different locations throughout Europe (Bolsunovsky and Dementyev, 2011; Ioannidou et al., 2012; Lujaniene et al., 2011; Manolopoulou et al., 2011; Masson et al. 2011).

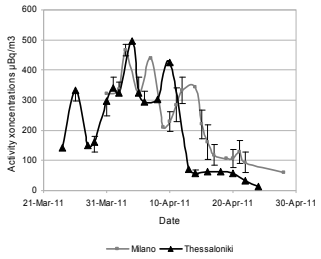


Fig. 1a. Atmospheric concentration of ^{131}I, ^{137,134}Cs in the region of Thessaloniki, Greece (40°N)

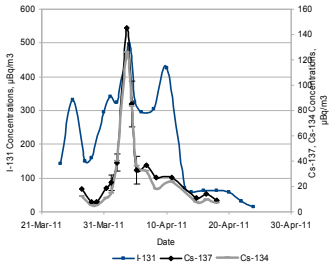


Fig. 2a. Atmospheric concentrations of ^{131}I in the regions of Milano (45°N) and Thessaloniki (40°N)

The ^{134}Cs/^{137}Cs activity ratio values in air were around 1 in both, Thessaloniki, Greece (40°N) and Milano, Italy (45°N) regions. The presence of more than one peak of ^{131}I and ^{137,} ^{134}Cs indicates that the radionuclides were continuously transferred from Fukushima, Japan to Europe till the end of April, 2011. The NOAA HYSPLIT model was used to assess the transport pattern and to explain the deviation in radionuclide activity concentrations found in Milan and Thessaloniki. The large ^{131}I/^{137}Cs ratio, observed during the first days after the accident, as high as 18, followed by lower values during the next days, as low as 3, reflects not only the initial release ratio but also the different volatility, attachment and removal of the two isotopes during transportation due to their different physicochemical properties. The maximum activity for ^{131}I was recorded between 4 and 5 of April, 2011 at both regions of study, while slightly higher ^{131}I activity concentrations were recorded in the region of Milano after 15th of April.

Analysis of air filter, rainwater and snow samples, as well as grass, soil and milk samples are reported in this work. The observed ^{131}I values in rainwater samples were below 1Bq L^{-1}. The dry deposition was more effective in the case of ^{137}Cs than it was for ^{131}I probably because iodine was mainly in gaseous form whereas caesium was rapidly bound to aerosols and thus highly subject to dry deposition. Finally, a dose assessment for the regions of investigation showed clearly that the detected activities in all environmental samples were very far below levels of concern.

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RADIATION EXPOSURE OF MEDICAL STAFF: APPLICATION OF HAND PHANTOMS IN EXPERIMENTS AND SIMULATIONS

Frank Becker, Christoph Blunck

[1] Institute for Radioactive Waste Disposal, Radiation Protection Research, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

With the growing use of nuclear medicine therapies and interventional procedures using real-time image control by means of fluoroscopy combined with a computed tomograph (CT), detailed research concerning the radiation protection for the persons working with these emitters becomes more and more important.

Medical workers are the largest proportion of exposed workers worldwide. The handling of high-energy beta-radiators and the CT-fluoroscopy are supposed to be among the highest exposure scenarios for medical staff.

The task is to develop a method, to model handling scenarios on the information of images taken and to simulate them with a Monte-Carlo-Code like MCNPX. Simulations using voxel hand phantoms or flexible geometrical hand phantoms are useful tools to investigate the hand exposure. In particular for the case of inhomogeneous radiation fields, where measurements could be difficult, time consuming or not feasible at all, simulations are advantageous. Different scenarios can be simulated and situations with highest exposures can be revealed.

However, measurements performed with phantoms and detector equipments are still necessary in order to validate the simulations. Figure 1 shows an example of a hand phantom used for measurements.

So far representative measurements and simulations for nuclear medicine therapies employing the beta emitting nuclide ^{90}Y are almost finished. For the measurement of the extremity dose $H_P(0.07)$ thin-layer thermo luminescence detectors were used. A flexible hand phantom model was developed for simulations (see figure 1).

The hand model can be moved via an interactive controlling interface. If 3-D coordinates of marked points on the hand, which can be obtained with a multi-camera system, are available, modelling can further be facilitated with an inverse kinematics procedure.

The latest results from the above mentioned scenarios in nuclear medicine and the just started CT-fluoroscopy investigations will be presented.

Figure 1: Wax hand phantom equipped with active (black) and passive (blue) sensors to determine the radiation exposure.

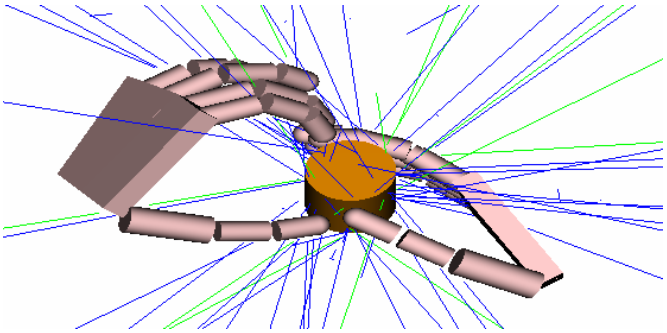

Figure 2: Radiation scenario modelled with the self-developed software using an articulated hand phantom. The blue and green lines illustrate the photon (green) and beta (blue) rays emitted from the fictive cylinder source.

ENVIRONMENTAL AND RADIATION PROTECTION AT THE KFKI CAMPUS

Károly Bodor

Hungarian Academy of Sciences, Centre for Energy Research, 1121, Budapest, Hungary, Konkoly Thegy M. st. 29-33.

At the KFKI campus there are two main facilities: the Budapest Research Reactor (BKR) and the Institute of Isotopes Co., Ltd. It is necessary to monitor the radioactive releases at the campus. The Environmental Protection Service (EPS) of the Centre for Energy Research, Hungarian Academy of Sciences do this task. The EPS equipped with on and off-line monitoring systems and staffs. In the presentation the monitoring systems and other devices of the EPS will be summarized.

^{14}C ACTIVITY MONITORING IN THE VICINITY OF THE NUCLEAR POWER PLANT KRŠKO 2006 - 2011

Ines Krajcar Bronić[1], Bogomil Obelić[1], Nada Horvatinčić[1], Andreja Sironić[1], Jadranka Barešić[1], Anita Rajtarić[1], Borut Breznik[2], Aleš Volčanšek[2]

[1] Ruđer Bošković Institute, Zagreb, Croatia
[2] Krško Nuclear Power Plant, Krško, Slovenia

Monitoring of ^{14}C activity in the atmospheric CO_2 and in biological samples (apples, corn, wheat and grass) in the close vicinity of the Krško Nuclear Power Plant (NPP) has been regularly performed since 2006 to estimate the possible influence of the plant on environmental ^{14}C levels and eventually its possible contribution to the effective dose of local population through food chain. Atmospheric CO_2 was collected regularly every two months, while the biological samples were collected twice a year (in June/July and September/October) on several locations within a radius of about 1 km from the Krško NPP, as well as on the control point at Dobova, 12 km from the plant.

Increase of ^{14}C activity in atmospheric CO_2 is observed during and immediately after the refueling of the power plant, which has been performed every 18 months. ^{14}C activities in plants from the vicinity of NPP are always higher than those at the control point, and depend both on the distance from the exhaust of the plant ventilation system and on the prevailing wind direction. Higher ^{14}C activities are measured in plants if the refueling has been performed in spring, while autumn effluents do not significantly influence the ^{14}C activity in plants.

DEPTH PROFILES OF ^{137}CS AND ^{14}C IN LAKE SEDIMENTS FROM THE PLITVICE LAKES

Andreja Sironić[1], Nada Horvatinčić[1], Istvan Bikit[2], Nataša Todorović[2], Jovana Nikolov[2], Dusan Mrdja[2], Sofija Forkapic[2]

[1] Laboratory for Low-level Radioactivity, Ruđer Bošković Institute, Zagreb, Croatia
[2] University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia

Radioactive isotopes ^{137}Cs (half-life 30.2 yr) and ^{14}C (half-life 5730 yr) are used as a suitable tool in a lake sediment study. ^{137}Cs is an anthropogenic isotope introduced into the atmosphere by nuclear weapon tests in fifties and sixties in the last century and additionally in 1986 as Chernobyl fallout. ^{14}C is basically of the natural origin, but significant ^{14}C contamination of the atmospheric CO_2 by nuclear weapon test also occurred with maximum in 1963. The anthropogenic contamination of the atmosphere by ^{137}Cs and ^{14}C was reflected in the lake sediments but with a different intensity response and with a certain time delay. The record of the ^{137}Cs and ^{14}C in recent carbonate sediments can be used to determine sedimentation rate as well as to follow environmental processes of carbon geochemistry.

The distribution of ^{137}Cs and ^{14}C in the profile of the recent carbonate sediments (top 40 cm) was determined in lakes Kozjak and Prošće in the Plitvice Lakes National Park, Croatia. Frozen sediment cores, 40 cm long, were cut into 1- to 2-cm-thick layers and dried prior to analyses. Sediments consisted mainly of carbonate/calcite (80-90%) precipitated from the water. ^{14}C activity was measured in carbonate and organic fraction using liquid scintillation counter technique with benzene synthesis method for carbonate fraction, and accelerator mass spectrometry technique with graphite synthesis for organic fraction. ^{137}Cs activity was measured by gamma spectrometry method.

The results of ^{137}Cs and ^{14}C activity distribution in sediment profile of lakes Kozjak and Prošće will be compared. Sedimentation rate in both lakes based on ^{137}Cs will be determined and the response of the ^{14}C activity in the lake sediments in carbonate and organic fraction caused by atmospheric CO_2 contamination will be discussed.

The work was performed within the project with the Plitvice National Park, Bilateral scientific project between Croatia and Serbia, and EU FP7 SOWAEUMED project.

AN ESTIMATION OF ^{238}PU ACTIVITY IN MONTENEGRO SOIL USING THE ^{238}PU/$^{239+240}$PU ACTIVITY RATIO

Nevenka M. Antovic[1], Perko Vukotic[2], Nikola Svrkota[3], Sergey K. Andrukhovich[4]

[1]Faculty of Natural Sciences and Mathematics, University of Montenegro, Podgorica, Montenegro
[2]Montenegrin Academy of Sciences and Arts, Podgorica, Montenegro
[3]Center for Ecotoxicological Research, Podgorica, Montenegro
[4]B. I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus

Activity concentrations of ^{238}Pu in surface (0-5 cm) soil layer at 24 localities in Montenegro have been estimated using a level of the $^{239+240}$Pu activity at the same localities and known ^{238}Pu/$^{239+240}$Pu activity ratio for Montenegro soil – obtained from direct plutonium measurements with an average of 0.03 and standard deviation of 0.007. Pu-238 activities showed a level from 0.0011 to 0.2479 Bq kg^{-1}, with a mean, standard deviation and median of 0.0491, 0.0578 and 0.0299 Bq kg^{-1}, respectively. On the basis of the ^{238}Pu/$^{239+240}$Pu activity ratio and a survey of relevant literature, it can be concluded that the source of plutonium in Montenegro is deposition from the global fallout.

ANNUAL AND SEASONAL VARIATIONS OF INDOOR RADON CONCENTRATION IN SKOPJE (REPUBLIC OF MACEDONIA)

Zdenka Stojanovska[1], Blazo Boev[2], Mimoza Ristova[3], Jovan Januseski[4]

[1] Faculty of Medical Sciences, Goce Delcev University, Stip, Republic of Macedonia
[2] Faculty of Mining, Geology and Polytechnic, Goce Delcev University, Stip, Republic of Macedonia
[3] Institute of Physics, Faculty of Natural Sciences and Mathematics, University in Skopje, Republic of Macedonia
[4] Institute for Public Health of RM, Laboratory for Radioecology Skopje, Republic of Macedonia

This paper presents the results of a survey of indoor radon concentrations in the dwellings of municipalities in Skopje: the capital and the largest city of the Republic of Macedonia. The indoor radon concentrations were measured during the four successive seasons from December 2008 to December 2009 using integrating passive alpha track-etch detectors with an exposure period of three months. The annual mean indoor radon concentration in each measuring site was estimated as an arithmetic mean from the four individual measurements.

The measurements were completed for 124 dwellings, of which 112 dwellings revealed indoor radon concentrations lower than 200 Bq m^{-3}, and 3 showed radon concentrations in excess of 400 Bq m^{-3}. The annual mean indoor radon concentrations were found to be log-normally distributed, ranging from 18 to 502 Bq m^{-3}. The geometric mean value of the indoor radon concentration in Skopje region was estimated to be 83*/1.94 Bq m^{-3}. The results of analysis of variance showed statistically significant differences annual mean values of the indoor radon concentrations among the municipalities ($p=0.021$).

The influence of the factors linked to building characteristics in relation to the annual mean of indoor radon concentration was also a subject to examination. The factors which allow differentiation into subgroups (significance level $p<0.05$) were: the floor level ($p<0.0001$), presence of basement ($p<0.0001$), and type of heating ($p=0.004$). Seasonal dependence of indoor radon concentration was observed. The minimum indoor radon concentrations were found in the summer season whereas maximum levels were observed in the winter season ($p< 0.0001$).

RADIOLOGICAL ASPECTS OF THE USABILITY OF RED MUD AS BUILDING MATERIAL ADDITIVE

A. Milenković, M.M. Janković, D. Todorović, I. Smičiklas

Radiation and Environmental Protection Department, Vinča Institute of Nuclear Sciences, University of Belgrade, Belgrade, Serbia

Red mud is a waste and tail material from primary aluminum production, and is named for its color, coming from its iron oxide content. The quantity of red mud is almost equal to the primary aluminum production and leads to a considerable environmental issue. In order to minimize the negative effect of red mud, there have been or are presently many investigations carried out on usage of red mud in building materials. When industrial by-products are incorporated in building materials and there is reason to suspect that these contain enhanced levels of natural radionuclides, the activity concentrations of these nuclides in the final product should be measured or assessed reliably from the activities of all the component materials. Typical and maximum concentrations in common building materials and industrial by-products used for building material in the EU are presented in issue 112 of the Radiation Protection of the EU [1]. Naturally occurring radionuclides are found to be present in significant amounts in soil, building materials and recycled industrial waste products. The possible exposure to γ -radiation emitted from these radionuclides is not only confined to the outdoor environment but can also occur in houses, offices and other working places. External exposure is caused by direct gamma radiation. The internal exposure is caused by the inhalation of the radioactive inert gas radon, ^{222}Rn, and its short-lived decay product. The aim of this study was to measure the natural radioactivity in red mud supplied from the "Birač" Alumina Factory (Zvornik, eastern Bosnia) using gamma spectrometry. The sample was counted using a high purity germanium detector (HPGe) with relative efficiency of 23% and energy resolution of 1.8 keV for the 1332 keV ^{60}Co peak. Specific activities of radionuclides in red mud are given in Table 1.

Table 1. Specific activities of radionuclides in red mud

Activity concentrations of radionuclides (Bq Kg^{-1})						
^{226}Ra	^{232}Th	^{40}K	^{137}Cs	^{238}U	^{235}U	^{210}Pb
127 ± 13	273 ± 27	66 ± 11	< MDC	177 ± 36	7,88 ± 1,90	94 ± 55

The gamma index, *I*, the radium equivalent activity, Ra_{eq}, the external hazard index, *Hex* and the internal hazard index *Hin* were evaluated, as well. Results of specific activities and given indexes of the red mud which was measured immediately, were compared to the results of the sample which was left to stand for four weeks to establish radioactive equilibrium. The data were also compared to the samples of bauxite ores which are tested for years in Institute Vinča, Radiation and Environmental Protection Department in Belgrade, Serbia, as part of regular inspection of imported goods from the border crossing.

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INDOOR RADON MEASUREMENT IN FORMER URANIUM MINING REGIONS IN BULGARIA

Kremena Ivanova, Victor Badulin

National Center of Radiobiology and Radiation Protection, 3 Sv. Georgi Sofiiski, Str., Sofia, Bulgaria

Aim: Radon exposure situations have the characteristics of existing exposure situations since the source is unmodified concentrations of ubiquitous natural activity in the earth's crust. Human activities may create or modify pathways increasing indoor radon concentration compared to outdoor background. The mining and processing of uranium bearing minerals generate a variety of waste materials containing a number of radioactive and non-radioactive hazardous constituents. Conventional underground and open pit mining activities produce overburden, mineralized waste and barren waste rock, which are generally low in their uranium and thorium contents and are left at the mine site.

The study focuses on regions of former uranium mining industries, where the radiological risk is higher.

Methods: The cumulative (passive) method was used for the study. The measurements are carried out by E-PERM® system. Detectors are placed for approximately 6 months in randomly selected houses in former uranium mining site - Sliven-villages area, Eleshnica and Bachkovo. These sites are situated in mountains in different part of Bulgaria.

Results: The results of indoor radon concentration for investigation villages range from 125 Bq/m^3 to 4000 Bq/m^3. The maximum concentration was measured in Bachkovo village in Rodopi Mountain. This village is the least affected by the former uranium mining industry.

Conclusion: The results prove assumption that former uranium mining sites are radon prone areas and radiological risk is higher. The level of indoor radon of residential buildings in areas with higher uranium availability is around or above the recommended reference radon levels. The maximum value of the concentration of radon measured in areas less affected by uranium mining, proving the necessity to undertake a radon national survey to determine exact radon prone areas.

Key words: Radon concentration, long-term measurement, radon prone areas

RADIATION DOSE ORIGINATING FROM RADON AND RADON PROGENY EFFECTING WORKERS IN THE SHOW CAVE OF TAPOLCA (HUNGARY)

János Somlai[1], Annamária Kopek[2], Gábor Szeiler[1], Pomázi Gergely[1], Tibor Kovács[1,3]

[1]Institute of Radiochemistry and Radioecology, University of Pannonia, Veszprém
[2]Balaton Uplands National Park, Csopak
[3]Social Organization for Radioecological Cleanliness, Veszprém

More attention has been given to improve workplace conditions in the last few decades, primarily to reduce the many different health risks. In the air that accumulates in underground workplaces radon may constitute such a health risk.

The changes in the radon concentration monthly average in the show cave in Tapolca have been examined using SSNTD detectors for several years. Since the annual average radon concentration greatly exceeds the 1000 Bq/m^3 activity level in Hungary the authorities required personal radon dosimetry for those working there. Besides, gamma dose rate was also measured, and for a more accurate dose estimation even the equilibrium factor was identified using weekly measuring periods.

The radon concentration in the show cave is especially high in summer months, with the annual average (7342 – 10 370 Bq/m^3) much more, than the recommended action level (1000 Bq/m^3).

As the hours spent in the cave by the workers depend on the number of visitors, the radiation dose were estimated on the basis of personal SSNTD dosimeters. The personal radiation dose is significant, especially for those employed during the whole year. Taking into consideration the actual working hours, and the equilibrium factor F=0.4 given in the literature, it approaches and even exceeds the dose limit of 20 mSv/year. With a well-organized work schedule, as well as the employment of outside workers during the summer period, the dose limit of 20 mSv/year can probably be maintained. On the basis of EEC measurements by Pylon WLx, the actual equilibrium factor was determined to be F = 0.5, which in turn means a further 25% increase in the personal dose. The gamma dose rate values were between 100-200 nGy/hour, however, its dose contribution did not significantly effect the radiation dose.

During the survey the monthly radon concentration of the cave and the cave lounge were monitored. The received results were compared with the average annual temperature and pressure, the results appears to indicate correlation between the investigated parameters.

MEASURING LOW CONCENTRATIONS OF NATURALLY OCCURRING URANIUM BY ANALYSING THE 352 KEV GAMMA RAY PEAK OF ^{214}BI

J. Bezuidenhout

Faculty of Military Science, Stellenboch University, South Africa

Concentrations of natural occurring radionuclides are traditionally determined by utilising gamma ray spectra analyses. A count rate is typically extracted for a gamma ray energy window of one of the daughter of the parent isotope. The 1764 keV decay of ^{214}Bi is predominantly preferred for the determination of uranium concentrations. This article investigates the prospect of utilising the 352 keV decay of ^{214}Bi when determining the concentration of uranium. Samples were collected from various locations around South Africa and laboratory gamma ray spectra for each were obtained and analysed. The uranium concentrations where extracted and comparisons between the values of different peaks of ^{214}Bi were made based on accuracies and detection limits.

A STUDY OF THE RELATIONSHIP BETWEEN THE CONCENTRATIONS OF NATURALLY OCCURRING URANIUM AND THORIUM IN VARIOUS LOCATIONS IN THE REPUBLIC OF SOUTH AFRICA

J. Bezuidenhout

Faculty of Military Science, Stellenboch University, South Africa

Potassium, thorium and uranium are naturally occurring radionuclides of primordial origin. The characteristic concentrations of these radionuclides can be utilized as indicators in geological exploration. Potassium is by far the most abundant and consequently exhibit high levels of fluctuations, while thorium and uranium illustrated smaller concentrations and fluctuations. This article investigates the relationship between the concentrations of the thorium and uranium nuclides in various natural settings. Samples were collected from diverse locations around South Africa and laboratory gamma ray spectra for each were obtained and analysed. The uranium and thorium concentrations were extracted and compared. A distinctive relationship between the concentrations of these nuclides are demonstrated and discussed.

APPLICATION OF *IN-SITU* GAMMA-RAY SPECTROMETRY TO ASSESS THE CONCENTRATIONS OF ^{40}K, ^{238}U AND ^{232}TH AND MEAN ANNUAL EFFECTIVE DOSE RATE LEVELS IN THE SEVERAL UNITED ARAB EMIRATES CITIES

Hussein M. Elmehd, Attaelmanan Gaffar, Hussain M. Alawadhi

Applied Physics Department, University of Sharjah, PO Box: 27272 Sharjah, United Arab Emirates

A rapid *in-situ* gamma-ray spectroscopy method was employed for assessing radiation activity and detecting changes in environmental radioactivity in 35 locations in various United Arab Emirates (UAE) cities. These values were then used to calculate the natural gamma radiation dose levels in these cities. A 76 mm x76 mm NaI(Tl) detector, with a resolution of 8% at the 0662 MeV line of Cs 137, was placed 1 m above the ground and the tested locations were selected so that they cover the different geology of the UAE terrain.

The collected spectra then analyzed and the results show a noticeable variations in the total counts per second for the selected sites, with sites near the coastal cities showed lower cps rates. The total air absorbed dose rate was then calculated using standard models, which take into account the contribution due to activity concentrations of ^{40}K, ^{2}38U and ^{232}Th in Bq kg^{-1}. The results indicate that the values of terrestrial gamma radiation dose rate measured ranged between 11 and 325 nGy h^{-1}. The corresponding dose equivalent was also calculated. These results, which are the first in the UAE, are comparable to values reported in the literature for Saudi cities.

RECENT OBSERVATIONS OF SPACE RADIATION ENVIRONMENT IN A TISSUE-EQUIVALENT PHANTOM ON BOARD INTERNATIONAL SPACE STATION BY LIULIN-5 DOSEMETRIC TELESCOPE

J. Semkova[1], R. Koleva[1], St. Maltchev[1], N. Bankov[1], V. Benghin[2], I. Chernykh[2], V. Shurshakov[2], V. Petrov[2], S. Drobyshev[2]

[1] Space and Solar-Terrestrial Research Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2] State Scientific Center of Russian Federation, Institute of Biomedical Problems, Russian Academy of Sciences, Moscow, Russia

The radiation field in the International Space Station (ISS) is complex, composed by galactic cosmic rays, trapped radiation of the Earth radiation belts, solar energetic particles, albedo particles from Earth's atmosphere and the secondary radiation produced in the shielding materials of the spacecraft and in human body.

An essential parameter for assessment of radiation hazards to human in space is the organ dose determination. Human phantoms equipped with active and passive radiation detectors are used to obtain a better knowledge of the dose distribution inside the human body.

The Liulin-5 dosemetric telescope observes the radiation environment in the spherical tissue -equivalent phantom of MATROSHKA-R international project on ISS. The Liulin-5 experiment has started on ISS in June 2007. The objectives of Liulin-5 experiment are studying the dynamics of depth-dose distribution of the different components of the orbital radiation field in the phantom and mapping the radiation environment and its variations with time and orbital parameters (such as solar cycle, solar flare events, inclination and altitude). The dosemetric telescope Liulin-5 measures time resolved linear energy transfer spectrum, flux and absorbed dose rates for electrons, protons and the biologically relevant heavy ion components of the cosmic radiation.

In this report we present new results of Liulin-5 experiment for radiation quantities obtained from different components of the complex radiation field in low-Earth orbit and comparison with data from other radiation detectors on ISS.

USAGE OF MODERN DESIGNING METHODS FOR CALCULATION OF LOCAL RADIATION PARAMETERS ONBOARD SPACECRAFTS

N.M. Khamidullina, I.V. Zefirov.

Lavochkin Association, Roscosmos, Moscow, Russia

In the course of orbital and interplanetary missions spacecraft (SC) are exposed to high-energy cosmic radiation. To provide reliable operation of onboard equipment and the safety of manned SC crew it is very important to calculate correctly the absorbed (and equivalent) doses and parameters of single-events effects during the whole mission and at its different phases at different places of SC.

The task is solved by using the created program complex "LocalDose&SEE" based on the sectoring method and 3-dimensional SC model in CAD technology ("3Dstudio Max").

Logically the task interface is divided into two basically different parts:

1. Computation procedure and representation of mass distribution, local doses and single-events effects frequency values in digital forms.
2. Autonomous 3d-observation in "3Dstudio Max" format of mass distribution for each chosen local place at any mission phase. The distribution is represented in the form of colored 3d-sphere (the color intensity is a characteristic of protection width in the given direction).

The report presents the results of the local doses and single-events effects frequency values computation for different SC.

BALLOON-BORNE DOSIMETRY MEASUREMENTS IN THE FRAME OF THE BEXUS STUDENT PROGRAMME – THE COCORAD EXPERIMENT

Balázs Zábori[1], Attila Hirn[2], Tamás Pázmándi[3], Péter Szántó[3]

[1] Budapest University of Technology and Economics, Budapest, Hungary
[2] Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary
[3] Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary

Due to significant spatial and temporal changes in the cosmic radiation field, radiation measurements with advanced dosimetric instruments on board spacecrafts, aircrafts and balloons are very important. The Hungarian CoCoRAD Team was selected to take part in the BEXUS (Balloon Experiment for University Students) project. In the frame of the BEXUS programme Hungarian students from the Budapest University of Technology and Economics carried out scientific experiments on a research balloon, which was launched from Northern Sweden in September 2011.

The objective of the Combined TriTel/Pille Cosmic Radiation and Dosimetric Measurements (CoCoRAD) are to measure the effects of the cosmic radiation at lower altitudes where measurements with orbiting spacecrafts are not possible due to the strong atmospheric drag. This way it is also possible to make intercomparison of the measured doses and the first time to use the Linear Energy Transfer (LET) spectra measured by the TriTel 3D silicon detector telescope for corrections during data evaluation of the Pille thermoluminescent dosimeters.

By evaluating the deposited energy spectra recorded by TriTel and the glow curve obtained after the on-ground read-out of the retrieved Pille dosimeters, the LET spectra, the average quality factor of the cosmic radiation as well as the absorbed dose and the dose equivalent could be determined. The results of the two measurements will be intercompared and will be used to make an estimation of the doses that might be expected during launch of manned space flights or even commercial air flights.

This paper will present the main objectives of the CoCoRAD experiment, the radiation environment in the altitude range of the BEXUS balloon, the overview of the experiment and the preliminary results.

THE SERBIAN RADON MAPPING PROJECT: OVERVIEW, STATUS, FURTHER PLANS

Z.S. Zunic[1], P. Bossew[2], C. Carpentieri[3], N. Veselinovic[1], S. Radanovic[4], O. Cuknic[5], V. Udovicic[6], J. Filipovic[1], R. Banjanac[6], F. Bochicchio[3]

[1] Institute of Nuclear Sciences "Vinca", Electro Chemical Etching Laboratory – ECE LAB, Laboratory for Radiobiology and Molecular Genetics, P.O Box 522, 11000,University of Belgrade, Serbia
[2] Bundesamt für Strahlenschutz (German Federal Office for Radiation Protection), Köpenicker Allee 120-130, 10318 Berlin, Germany
[3] Istituto Superiore di Sanità (Italian National Institute of Health), Viale Regina Elena 99, 00161 Rome, Italy
[4]Economic Association for Coal and Energy Production, Mining Basin "Kolubara", Serbia,
[5] Public Company "Nuclear Facilities of Serbia", Vinca, Mike Petrovica Alasa 12-14, Belgrade, Serbia
[6]Institute of Physics, Pregrevica 118, University of Belgrade, Serbia

Although Serbia is not a large country, for historical reasons several institutions deal with Radon in a so far little coordinate manner. One survey which is currently under way and whose preliminary results will be the main subject of this presentation is based on measurements in primary schools. The approach has been chosen for logistical reasons: practically every village has an primary school and access is easy through administrative contacts. This is different from survey designs based on dwellings, which afford large logistical efforts. On the other hand, however, it is not straightforward to infer from school results to the radon exposure of the general population. Among disturbing factors are different usage and occupancy patterns of schools and residential houses, different building styles and air exchange modes, and possibly non-representative locations of schools within a town, with respect to the spatially mean geogenic Rn potential. To tentatively correct for these factors and to evaluate the representativeness of radon measurements in schools as regards the population exposure in dwellings, two separate auxiliary projects have been thought aimed to try to identify and to quantify them, the first one aimed to measure the radon concentration in dwellings located close to previously measured schools and a second one aimed to measure radon concentration in certain number of dwellings randomly picked in one or more municipalities involved in the survey.

In this presentation we show, in particular, the results of the schools survey (98% of all primary schools in the selected 13 municipalities in South Serbia, Balkan region) and first results about the relationship between schools and dwellings (the first of the two auxiliary projects), in terms of Rn concentrations.

Apart from discussing this project, its methods and preliminary results, we give an overview on past and on going surveys, and present plans for further development of the Serbian radon mapping so to be able fully to integrate into ongoing European Atlas on Natural Radiation, i.e. section Indoor Radon Mapping.

PET/CT PATIENT DOSE AND IMAGE QUALITY

Olivera Šveljo[1], Silvija Lučić[2], Andrea Peter[2], Dejan Kozarski[1], Miloš Lučić[1]

[1] Diagnostic Imaging Centre, Oncology Institute of Vojvodina, Sremska Kamenica
[2] Department of Nuclear Medicine, Oncology Institute of Vojvodina, Sremska Kamenica

In the least decade, multi-modality imaging options increased the number of nuclear medicine exams significantly. Hybrid PET/CT imaging is highly valuated in clinical practice due to the possibility to simultaneously obtain anatomical and functional data. On the other hand, increased use of this imaging technique raised general concerns about effective patient doses which cold be up to 32 mSv (1).

In this study we examine patient doses and image quality for PET/CT imaging with automatic exposure control CT scanning protocols. Patient doses and CT image quality are evaluated for the patients examined in a period of one month in Diagnostic Imaging Centre, Sremska Kamenica on Biograph 64 PET/CT scanner (Siemens, Erlangen, Germany). There are five brain (1 male, mean age 44.8±8.2) and 20 whole body (15 male, mean age 52.45±9.76) PET/CT exams. PET and CT patient doses are estimated according ICRP recommendations (2) and methodology proposed in (3). Image quality was assessed according to five point scale (1 – unacceptable, 2 – substandard, 3 – acceptable, 4 – above average, and 5 superior). For brain PET/CT exams average patient dose was 5.5 ± 2.04 mSv (max. 7.92 mSv; min 3.8mSv) and all CT images were rated with maximal score (5). For whole body PET/CT average patient dose was 10.48±1.92mSv (max 15.66 mSv; min 6.85mSv). CT image quality for whole body PET/CT exams was rated as acceptable (mean rate 3.8±0.8) in all except one patient.

According to our results, CT scanning protocols with automatic exposure control provide a good basis for optimization of patient doses and image quality in hybrid PET/CT imaging.

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RADAR AND TLD EFFECTIVE DOSES TO FAMILY MEMBERS OF HYPERTHYROID PATIENTS TREATED WITH IODINE 131

M. Zdraveska-Kocovska[1], O. Vaskova[1], V. Majstorov[1], S. Kuzmanovska, B. Crcareva

[1] Institute of Pathophysiology and Nuclear Medicine "Akademik Isak S. Tadzer"-Faculty of Medicine, University "Ss. Kiril and Metodij", Skopje, Republic of Macedonia

Introduction Patients who receive therapeutic amount of radioactive iodine 131 are a potentially significant source of radiation to their family members, members of the public and others. The situation can be overcome by imposing restrictions on the behavior of the patient to minimize the effective dose to close relatives and not to exceed the proposed dose limits by the International Commission of Radiation Protection and Basic Safety Standards from the International Atomic Energy Agency.

Aim The aim of this study was to evaluate effective dose to family members of hyperthyroid patients treated with radioiodine 131 and to compare with dose constraints proposed by International Commission on Radiological Protection and IAEA (BSS).

Material and methods We used thermoluminiscent dosimeters (TLD 100) and RADAR (Radiation Dose Assessment Resource) software for estimation of effective doses at thirty family members of the same number of hyperthyroid patients treated with radioiodine 131.

Results The mean value of effective dose to relatives of hyperthyroid patients was 0.87 mSv. The estimated value of RADAR calculated effective doses for the distance of 0.25, 0.5 m, 1.0 m, 2.0 m were 23 mSv, 5.90 mSv, 1.48 mSv and 0.37 mSv respectively for mean administered activity of 683 MBq.

Conclusion Estimated effective doses were well below recommended dose limits except in some cases. RADAR calculated doses were higher than estimated doses with TLD. Hyperthyroid patients should continue to be treated on out – patient basis but they should be well informed for their further behavior to be sure that they will represent minimal radiation hazard for the people in their environment.

Key words: hyperthyroid, relatives, radioiodine, TLD, RADAR software.

HUMAN BLOOD CELLS ZETA POTENTIAL RESPONSE UNDER IMPOSED β-RADIATION FIELD OF LOW RATE

Victor V. Zhirnov, Igor N. Iakovenko

Department of Cell Signal Systems, Institute of Bioorganic Chemistry and Petrochemistry of National Academy of Sciences of Ukraine. Murmanska Street, 1, 02660, Kiev, Ukraine

Purpose: To investigate the effect of imposed low rate radiation field on zeta potential of human blood erythrocytes, and neutrophils.

Materials and methods: The electrophoretic mobility of the cells as indicator of their zeta potential was determined using a cylindrical microelectrophoresis. Zeta potential response to β-irradiation was registered after addition in the cellular suspensions of $^{90}Sr/^{90}Y$ in the range from 4.44 to 44400 $Bq \cdot l^{-1}$.

Results: The dose rates in the range of 1.5 - 150 $nGy \cdot h^{-1}$ did not change zeta potential of human erythrocytes and neutrophils at 1-hour exposure. The further rise of the dose rate up to 15 $\mu Gy \cdot h^{-1}$ induced increasing the cellular zeta potentials about 20%. Washing of the erythrocytes from $^{90}Sr/^{90}Y$ abolished the radiation effect. There are recurrent jumps in the erythrocyte zeta potential registered for equal absorbed doses derived at dose rates differing by an order of magnitude in the range of 0.015 - 15 $\mu Gy \cdot hr^{-1}$.

YTTRIUM - 90 IN THE RADIONUCLIDE THERAPY - DOSIMETRIC ASPECTS

Monika Kempińska

Medical University of Gdańsk, Poland

Yttrium - 90 is widely applied in the field of radiation therapy mostly in oncology and orthopedics. The advantage of this isotope is a short distance of beta- radiation which concentrated in the target area, what greatly contributes to the therapy success. The best known therapy applications of ^{90}Y labeled radiopharmaceuticals are: somatostatin-receptor bearing tumors therapy e. g. neuroendocrine tumors (NETs), radioimmunotherapy, locoregional therapy e. g. radiosynovectomy.

An important element of therapy is the absorbed radiation dose in the other organs. There are contradictory reports on the absorbed dose of radiation in the target organ and other organs or systems in patient's body. Generally the radiation exposure of other organs is less than 5%, so higher injected activities of radioisotope can be used, which makes therapy even more effective.

^{90}Y – radiopharmaceuticals usually do not remain stable in target place. Dosimetric procedures prove that its local concentration is changing in time, so the compartmental analysis can be implemented to check the influence of illness pathophysiology on its transport. It gives very useful information for a physician. Using this information he can foresee the results of the undertaken therapy. The biodistribution of radiopharmaceuticals in patient's body requires more dosimetric experiments.

Dosimetry deals with calculation of radioisotope activity applied as well as defining radiation parameters which have an effect on human tissue. According to ICRP classification, there are three types of radiation exposure risks, i.e. medical exposure, occupational exposure of medical personnel and finally general public exposure. In case of radiation exposure it is necessary to define emission properties of the isotope used. ^{90}Y is a β-emitter, so it induces secondary radiation called Bremsstrahlung either during radiopharmaceutical's preparation, when beta radiation meets hard material, e. g. glass or in patient's body, e. g. when it meets high density tissue, for example bone. Bremsstrahlung properties depend on a kind of β-radiation, a shape of a surrounding material or tissue, the volume in a syringe, the material and density of the container or ionization chamber geometry.

Analyses of the radiation absorbed dose by the patient and medical personnel can be calculated using various methods. The most frequently used method of measurement is the thermoluminescence dosimetery. This method may give contradictory results due to the high level of uncertainty (read error). In some cases (Bremsstrahlung or β/ɣ - emitters) gammacamera measurements seem to be useful and precise tool in evaluating dosimetry. Measurements and calculations of absorbed dose provide information for radiation protection of patients and medical personnel.

THE RELATION OF RADON CONCENTRATION WITH TECTONICS THAT CAUSED THE EARTHQUAKE OF SEPTEMBER 2009, IN GJORICA, WITH MAGNITUDE 5.5

Hamza Reçi, Safet Dogjani, Edmond Dushi

Institute of Geosciences, Energy, Water and Environment Polytechnic University of Tirana, Tirana, Albania

As it is known form many studies, the level of Radon concentration in regions where are present new or old tectonic faults or cracks, is above the background.

The studies of the level concentration of Radon in the soils, in such geological conditions, serves to help the geological interpretation and in the determination of the area where the tectonic feature is present, especially in cases where it is covered by sediments. Physically, this phenomenon is well known, as for other gases as well, these tectonic features serves as a way for their movement from the depths toward the surface. In these situations, the level of Radon concentration changes in big ranges for the following reasons: Theoretically, the concentration of gas that moves toward the surface is conditioned from the level of uranium concentration in the bedrock from which it is released (starting from rocks situated in the hypocenter of the earthquake and till the superficial geological formations); the porosity of the geological formations from which it is released; during its movement toward the surface the gas is distributed in several tectonics and cracks which are activated during an earthquake.

In September 2009, an earthquake with magnitude 5.5 of Richter scale happened in the region of Peshkopia, Gjorica village, Albania. The earthquake with epicenter around 60 km from the capital city of Albania, Tirana, was felt in a region with distance up to 70 km from the epicenter. This earthquake caused economical loss around the epicenter. The main shock was associated with several aftershocks. The focal mechanism of the source was a normal fault. After the main shock during the time where the region was still seismically active, we carried out in soil radon measurements in several points, close to the tectonic fault, tracks of which were present in the surface. From the measurements we concluded that during the seismic activity of the region, Radon concentration increases several times comparing of a quite situation.

EXPOSURE ANALYSIS FOR THE MULLET SPECIES *LIZA RAMADA* (RISSO, 1826) FROM THE SOUTH ADRIATIC SEA

Ivanka Antovic[1], Nevenka M. Antovic[2]

[1] Department for Biomedical Sciences, State University of Novi Pazar, Vuka Karadzica bb, 36 300 Novi Pazar, Serbia
[2] Faculty of Natural Sciences and Mathematics, University of Montenegro, Dzordza Vasingtona bb, 20 000 Podgorica, Montenegro

Four whole individuals of *L. ramada* from the South Adriatic Sea – Boka Kotorska Bay, were analyzed for radioactivity due to ^{137}Cs, ^{40}K, ^{226}Ra and ^{232}Th. Their activity concentrations were determined to be from 0.45 to 1.04, 55.9 to 92.5, 0.59 to 1.18 and 0.7 to 0.93 Bq/kg, respectively. Because this pelagic fish is irradiated by the activity in water, and internally by incorporated radionuclides, the total dose rates were also calculated and found to be from 0.136 to 0.209 μGy/h, which is significanlty lower than the permissible limit of 10 mGy/d; and the effects caused by radioactivity could not be expected.

DETERMINATION OF ACTINIDES IN LOW LEVEL RADIOACTIVE WASTE FROM NPP "KOZLODUY"

A. Nikiforova[1], B. Slavchev[1], B. Veleva[2], D. Dimitrova[1]

[1] Institute for Nuclear Research and Nuclear Energy - BAS, Tzaridgradsko chausse 72, 1784, Sofia, Bulgaria
[2] National Institute of Meteorology and Hydrology - BAS, Tzaridgradsko chausse 66, 1784 Sofia, Bulgaria

The inventory analysis of the alkaline low level liquid and solid radioactive waste collected during more than 30 years of NPP "Kozloduy" operation requires determination of several α - (U, Pu, Am and Cm), β - (Sr, Ni, Fe, Tc, and C) and γ - emitters (Cs, Co, Nb and I). Alpha isotopes of interest are ^{233}U, ^{234}U, ^{235}U, ^{238}U; ^{238}Pu, $^{239/240}Pu$, ^{242}Pu; ^{241}Am and ^{242}Cm and ^{244}Cm.

The characterization is needed to confirm that the waste is in compliance with the operating license of the treatment and conditioning facilities, to facilitate the routing of the waste to the appropriate treatment and conditioning process and environmental protection and long term safety.

Different measurements and separation techniques such as gamma and alpha spectrometry, ICP OES, ionic exchange chromatography with AG and TEVA, UTEVA and TRU Eichrom Resins were applied. Essential challenges for determination of actinides are due to its low concentration in the complex matrix and need of more accurate alpha spectra. The application of tracer ^{236}Pu and ^{242}Pu as standard addition; ^{232}U and ^{233}U, ^{243}Am as well ^{244}Cm allows control of the isotope exchange and validation of chemical recovery.

The sources were prepared by micro co - precipitation with NdF_3 and electrodeposition and counted by alpha spectrometry with ORTEC Octete Alpha Spectrometric system equipped with 8 Ortec ULTRA-SA™ ion implanted detectors. In order to calibrate the spectrometer four laboratory calibration sources were prepared for the respective type of samples in addition to the standard reference sources used.

In the paper results from the analyses are presented as well as a discussion of the problems aroused during analysis.

It has been proved that the procedure applied for analysis of wastes is a balanced one where the NPP demands for very limited period of time were abided from one side and from the other it leads to results with good precision and accuracy.

ASSESSMENT OF RADIONUCLIDES AND RADON CONCENTRATION IN PRISKE - MOLLAS COAL AREA

Safet Dogjani, Fatbardha Vinçani

Institute of Geosciences, Energy, Water and Environment Polytechnic University of Tirana, Tirana, Albania

In the region where coal dumps are present at surface, radionuclides and radon concentration measurements were carried out. The area includes three sectors: Lalaj, Surrel Village and Shermine-Shpoze. The three sectors are located at Tirana-Dajti highway, along a 5 km line. They are at Dajti steep slope, respectively 560 m, 420 m and 400 m above sea level. The gradient of slope is 35º to 45º, with SW dip, towards Tirana capital and surrounding villages.

The Quaternary overburden it is not developed, it ranges from 0.2 to 0.4m and it is not uniform. It is mainly composed of silt where is grown grass, and scarce woods.

The area consists by Torthonian sandstone, argilitic slates, silts and lithotamnic limestone.

At Priska area the coal and coal slates of dumps and stockpiles are a point of pollution. The remained coal and radioactive coal slates, reworked and flow down as mass flows, contaminate the deeper parts of stockpiles and dumps, surrounding area and are disseminated also from wind in a larger distance.

For the evaluation of contamination are carried out:

- The measurements of natural radionuclides U-238, Th-232 and K-40
- The measurements of Radon concentration in soil
- The measurements of Radon indoors

Results of the study:

- At the stockpile is high Uranium content up to 608Bq/kg. The Uranium content in the stockpile ranges from 161-322Bq/kg
- K content is almost the same for stockpile, coal outcrop and dump: ranging respectively 250 - 420Bq/kg; 160-450 and 190 - 380Bq/kg.
- Thorium content is respectively 23-25Bq/kg, 14-32Bq/kg and 19-45 Bq/kg.

The radon measurements in soil have been conducted in the Linze – Priske area. The measurements have been made along the pathways from dump to environment. The level of Radon concentration range from 20000Bq/m^3 to 80000Bq/m^3

In the houses close to the dump are carried out eight indoor measurements, along 24 hours with monitors Filtra-2. In 7 measurements the mean Radon-222 is at the limit of 400Bq/m^3

Outdoor measurements are also carried out at point nr.3 of stockpile n-1 of the area. In total are carried out 57 radon measurements, every 10 minutes with Alfa GUARD monitor. Values range from 40 to 90Bq/m^3.

"IONIZING RADIATION" IN PRINTED MEDIA IN SERBIA

Gorana Đorić, Gordana Stojić

Faculty of Philosophy, University of Niš, Niš, Serbia

The paper presents the findings of an exploratory study into the incidence of topics related to ionizing radiation in printed media in Serbia during 2011. The assumption underlying the study is that to a considerable extent media define the way ionizing radiation is perceived by the public (according to Thomas' theorem *what has been defined as real is real in its consequences*). The following questions have been addressed in the study: What could have been learnt from the media about the risks and the protection from ionizing radiation? What does the public want to know about the issue (based on the comments on published texts)? What are the readers' major fears? Who provides the information published and in which way is the information presented? What triggers the interest of media and the public in ionizing radiation related phenomena?

The research aims at providing the policy makers in the field of ionizing radiation regulation and protection with an insight into the public perception of the ionizing radiation phenomenon. To the extent to which decision making about the issues of public interest is democraticized, this would facilitate mobilisation of public support for the decisions related to ionizing radiation which might have effect on population.

We have analysed the number of mostly read daily newspapers in Serbia, using the content analysis method. The unit of analysis is a text and commentaries on the text. The sample consists of the texts published in the analysed papers in 2011, selected on the basis of the key words referring to the ionizing radiation in different contexts (such as radiation, nuclear accident, Fukushima, depleted uranium, mammography and so). Some of the analytical dimensions used to classify the data include *the source of ionizing radiation being discussed*, *source of information*, *type of information*, *value orientation of the text*, *visual presentation*, *the occasion motivating the text*, *the context within which the information is interpreted*.

Key words: media representation, ionizing radiation, content analysis

THE RELIABILITY OF EARTHQUAKE PREDICTIONS WITH RADON IN SOIL GAS ANOMALIES AS PRECURSORS

Vanja Radolić[1], Igor Miklavčić[1], Marina Poje[1], Denis Stanić[1], Goran Šmit[2], Branko Vuković[1]

[1] Department of Physics, University in Osijek, Trg Lj. Gaja 6, 31 000 Osijek, Croatia
[2] Department of Chemistry, University in Osijek, Kuhačeva 20, 31 000 Osijek, Croatia

The mechanical processes of earthquake preparation are always accompanied by deformations of the elastic medium, and the complex short- or long-term precursory phenomena can appear. In the scientific literature, there are many dozens precursors but none of them is reliable for earthquake prediction (in the sense of forecasting of time, place and magnitude of a forthcoming earthquake). The observed anomalies of radon concentrations in soil gas as well as in ground water before some earthquakes in Asia in the late 60's have triggered extensive and systematic investigations on the possibility to use radon as a reliable earthquake precursor. Radon concentrations in soil gas in Croatia were continuously measured since 1998 by the LR-115 nuclear track detectors [1] as well as by the Barasol semiconductor detector since 2005. The influence of the meteorological parameters on the temporal radon variations is investigated and the reduction (deconvolution) of the radon variation caused by the barometric pressure, rainfall and temperature is described [2]. The obtained "clear" radon time series signal is correlated to selected seismic events occurred in the vicinity of a radon monitoring station. The calculated values of the parameters in empirical equations between the earthquake magnitude, epicentral distance and the precursor time enable the determination of the probability for a forthcoming earthquake that will occur at the epicentral distance R from the monitoring site in some expecting precursor time T [3, 4]. The reliability of these "earthquake predictions" (a posteriori) is discussed.

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CHALLENGES FOR IMPLEMENTATION OF FOOD IRRADIATION IN REPUBLIC OF MACEDONIA

Svetlana Petreska, Hristina Spasevska, Margarita Ginovska, Vladimir Dimcev

[1] Radiation Safety Directorate, Skopje, Republic of Macedonia
[2] Faculty of Electrical Engineering and Information Technologies, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia

In comparison with the other food preservation techniques, such as: heat, canning, freezing or chemical treatment, irradiation is considered as much more effective and appropriate technology to destroy food borne pathogens. The advantages of food irradiation (process safety, reduction of chemical use, and improved quality and safety of foods) over other food preservation techniques far outweigh the drawbacks - a slight reduction in nutrients.

This paper will present an overview of the techniques for irradiation of food and possibilities for their implementation in the Republic of Macedonia. The agriculture sector plays an important role in the country's economy: about 39% of the total area of the Republic of Macedonia, or 1.01 million hectares, is agricultural land, split almost evenly between cultivated land (arable land orchards, vineyards and meadows). In accordance with this, it is necessary to find appropriate techniques to be implemented, which are going to achieve the required quality of the products, to be competitive on the world market. Also, there is another field whereas the irradiation techniques could be apply despite of the agricultural industry, such as pharmaceuticali industry, going to encompass dried aromatic herbs, spices, seasoning, etc.

Food could be irradiated in "irradiators" that use electron beams, gamma rays or X-rays, as the source of ionizing energy (radiation). All commercial irradiators have four primary components, a source of radiation, a method of product conveyance, "shields" to prevent exposure of personnel and the environment to radiation and safety systems. Ionizing radiation is penetrating energy and thus, products are usually irradiated after they are fully packaged. The choice of which irradiator is most cost effective for a particular product depends on the type of product, how it is packaged, the product dose, dose uniformity requirements and, the most important, logistics.

THE ANALYSIS OF METEOROLOGICAL AND GEOLOGICAL INFLUENCE ON RADON CONCENTRATION IN THE SCHOOLS OF BANJALUKA CITY

Zoran Ćurguz[1], Zora S. Žunić[2], Branko Predojević[3], Predrag Kolarž[4]

[1] Faculty of Transport Doboj, University in East Sarajevo, Republic of Srpska,
[2] ECE Lab, Institute of Nuclear Sciences „Vinča“, University of Belgrade
[3] Faculty of Science, University of Banja Luka, Republic of Srpska
[4] Institute of Physics, University of Belgrade

Continual radon concentration measurements in 20 primary schools in Banja Luka city was performed during the year 2011/12. Continual radon measuring instrument RAD-7 was used for that purpose. Measurements lasted 7 days in every school while data sampling was set to be every 2 hours. In order to measure and explain changes in dynamics and amplitude of diurnal and weekly fluctuations of radon concentration, data from local meteorological station and small wireless weather station (placed nearby Rad-7 instrument) were used. Geographical data for every school was obtained using Google earth.

INDOOR RADON MEASUREMENTS IN THE ABANT IZZET BAYSAL UNIVERSITY CAMPUS, BOLU, TURKEY

Hakan Yetiş, Haluk Denizli, Seyma Atik

Abant Izzet Baysal University, Department of Physics, 14280 Bolu, Turkey

Indoor radon measurements were performed in the Abant Izzet Baysal University, located at the North-west part of Turkey, by AlphaGUARD P30 Radon Monitor. University campus site is near the North Anatolian Fault which is a major active right lateral-moving strike-slip fault in northern Anatolia which runs along the transform boundary between the Eurasian Plate and the Anatolian Plate. We preferred the long-term non-ventilated and enclosed spaces in determining areas of public life. During these studies, some measurements were carried out every other day, even sometimes for several days. This allows the observation of night and day difference between the radon concentrations. A total of 50 measurements were performed in the academic offices and the commissaries in our university in the period October 2011–January 2012. Radon concentrations in commissaries, located in the basements of a total of 6 faculties, were measured 3 times and the data was taken for 5 hours in a 10-minute periods by regarding the starting and ending times of the day. In Table 1, we have reported the average measurements obtained for one period in six different faculties.

Table 1. The average measurements obtained for one period in six different faculties.

Parameters						
	Science	Economics and Administrative Sciences	Education	Art	Foreign Language	Physical Education
^{222}Rn(Bq/m^3)	26.3 ± 9.8	19.1 ± 7.7	17.6 ± 7.2	11.6 ± 5.5	8.8 ± 4.7	22.7 ± 9.8
Temperature (^oC)	27.3	23.5	20.4	25.8	21.8	23.2
Pressure(mbar)	924.6	925.9	925.8	923.3	924.2	914.4
Humidity(%rH)	28.1	26.7	30.7	8.0	16.2	27.0

EVALUATION OF RADIATION LOAD OF MOSS AND LICHEN IN THE ĐERDAP NATIONAL PARK

Ana Čučulović[1], Rodoljub Čučulović[2], Dragan Veselinović[3]

[1] Institute for the Application of Nuclear Energy - INEP, Banatska 31b, 11080 Zemun, Serbia
[2] University Singidunum, Faculty for Applied Ecology Futura, Lazarevački drum 13-15, 11000 Belgrade, Serbia
[3] University of Belgrade, Faculty for Physical Chemistry, P.O. Box 137, 11001 Belgrade, Serbia

The ^{137}Cs ion is a chemical homologue of potassium and follows its metabolism in organisms. It has a half-life time of 30.2 years and is completely dissolvable in body fluids and is uniformly distributed in organisms. Absorbed doses of ^{137}Cs in moss (72 samples) and lichen (12 samples) from the NP Đerdap territory collected between 2003 and 2010 were determined. The measured specific activity of ^{137}Cs in samples was converted into doses with the assumption that all emitted particles (gamma and beta) were absorbed in tissue that accumulated ^{137}Cs. The strength of the absorbed dose in the observed period in investigated moss samples was between 0.00082 mGy/year (locality River on the right, 2010) and 14.1 mGy/year (locality Ploče, 2003) and in lichen samples it was between 0.02 mGY/year (locality River on the right, 2010) to 4.63 (Oman, 2003). Higher values of the absorbed ^{137}Cs dose strength in moss were noted on localities Veliki kazan, Šomrda, Alibeg's steam and Crni vrh, and in lichen on localities Oman and Ploče, The average value of the absorbed dose in moss in 2003 was 4.33 mGy/year, in 2006 2.08 mGy/year, 2008 0.29 mGy/year; 2009 0.10 mGy/year and in 2010 0.71 mGy/year. This increase in the average value of the absorbed dose in moss in 2010 was the consequence of including samples from Crni vrh, where moss in 2003 had higher values of the absorbed ^{137}Cs dose strength. Absorbed dose strengths on the territory of NP Đerdap in moss and lichen are lower than doses causing changes in reproductive cycles of flora and fauna (0.4 to 1 Gy a year) and lethal doses (4 Gy and 0.4 gY a year). This indicates that the obtained data was reliable.

THE CONTENT OF NATURAL RADIONUCLIDES IN LIGNITE SAMPLES FROM OPEN PIT MINES "KOLUBARA", SERBIA

M. Đurašević[1], A. Kandić[1], P. Stefanović[2], I. Vukanac[1], B. Šešlak[1]

[1] Institute of Nuclear Sciences "Vinča", Laboratory for Nuclear and Plasma Physics, University of Belgrade, Belgrade, Serbia
[2] Institute of Nuclear Sciences "Vinča", Laboratory of Thermal Engineering and Energy, University of Belgrade, Belgrade, Serbia

Coal as the most widely used fossil fuel contains traces of naturally occurring radioactivity from uranium and thorium series and ^{40}K. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated that average concentrations in coal worldwide are 50 Bq/kg for ^{40}K and 20 Bq/kg for both ^{238}U and ^{232}Th (range 5 Bq/kg – 300 Bq/kg). [1]

Activity concentrations of naturally occurring radionuclide ^{40}K, ^{238}U and ^{232}Th for tree groups of samples of coal and mineral matter mixed with coal (I (2008 year – 30 samples), II (2009 year – 26 samples) and III (2010 year – 26 samples)) are presented in this paper. Representative samples of different coal quality were especially collected at different locations at open pit mines in RB "Kolubara" which has annual production of 29 millions tones of lignite for the power generation at TPP "Nicola Tesla", Obrenovac.

The samples were pulverized, dried and sealed in Marinelli plastic boxes 0.5 l, and stored for forty days until radioactive equilibrium between ^{226}Ra and its decay products were achieved.

All samples were measured by means of coaxial germanium HPGe detector (ORTEC GEM-30, 30 % relative efficiency and 1.8 keV resolution for ^{60}Co at 1332 keV line). The detector was calibrated using standard solutions with radionuclide activities certified by CMI [2]. The experimentally obtained spectra were processed using Canberra's Genie2000 software.

The activity concentrations of ^{238}U and ^{232}Th were determined indirectly from the gamma-rays emitted by their progenies while ^{40}K was determined directly by its gamma-line of 1460.8 keV.

Table: Activity concentrations of natural radionuclide in coal samples from open pit mines "Kolubara"

Coal samples		**^{238}U [Bq/kg]**	**^{232}Th [Bq/kg]**	**^{40}K [Bq/kg]**
I(2008)	range	16.86 -86.38	11.82 - 44.30	25.86 – 312.53
	average ± σ	39.19 ± 2.31	24.84 ± 1.57	134.57 ± 7.55
II(2009)	range	0.77 – 52.68	5.10 – 48.30	17.30 – 495.87
	average ±σ	24.99 ± 3.14	20.13 ± 0.47	139.67 ± 11.67
III(2010)	range	2.26 - 84.79	10.55 – 58.52	19.13 – 290.9
	average ± σ	30.71 ± 4.92	21.59 ± 0.71	95.25 ± 3.44

It can be seen from this table that the measured coal samples have low activity concentrations and the artificial radionuclides were not detected. The obtained activity concentrations of naturally occurring radionuclides in analyzed coal samples are comparable with those in coals from other countries [3, 4].

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RADIATION PROTECTION MONITORING IN THE VICINITY OF THE COAL-FIRED POWER PLANTS "NIKOLA TESLA A" AND "NIKOLA TESLA B"

M. Eremić-Savković, S. Bogojević, I.Tanasković, Lj. Javorina, V. Arsić, J. Ilić

Serbian Institute of Occupational Health "Dr Dragomir Karajović", Deligradska 29, Belgrade, Serbia

Fossil fuels used for power plants contain incombustible minerals with traces of natural radionuclides. The combustion of coal, in the process of electrical power production in coal-fired power plants, results in the enrichment of natural radionuclides in ashes and slag, which poses a threat to the environment. The results of systematic, several year, radioactivity monitoring of the working and the general environment in and around coal-fired power plants "Nikola Tesla A" and "Nikola Tesla B", in the vicinity of Obrenovac are presented in this paper. Soil, plant and water samples as well as ashes and slag from the waste storage areas were examined. Concentrations of natural radionuclides ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U, ^{235}U and ^{137}Cs - radionuclide produced, were determined by gamma-spectrometry in all the samples, and for water samples additional gross alpha and beta measurements were made. Results indicated that the concentrations of radionuclides in ashes and slag are higher than corresponding concentrations in the earth crust, but not so elevated to raise significantly internal and external exposure.

EFFECTIVE DOSE TO STAFF IN INTERVENTIONAL CARDIOLOGY: ESTIMATION FROM FILM BAGE AND THERMOLUMINESCENT DOSIMETERS

M. Ghazanfari, M. Vahabi-Moghaddam, B. Ghanbar Moghaddam

Department of Physics, Faculty of Sciences, University of Guilan, Rasht, Iran

Radiation exposure is a significant concern for interventional cardiology workers because workloads and the complexity of procedures have increased over the past few years without a corresponding increase in the number of specialists. Although reduced scatter radiation in catheterization laboratories compared with that in old X-ray system laboratories, improved radiological protection facilities, and better, more inclusive radiation protection training for ICs have substantially reduced the risk of radiation exposure, the complexity and number of procedures have increased. Therefore, interventional cardiology is recognized as a high-radiation-risk practice, and evaluation and follow-up of occupational doses should be considered an important part of quality assurance (QA) programmes. In this study the exposure of 13 workers performing interventional procedures was measured in Arya Hospital in Iran in Rasht by means of two kind of dosimeters: Film badge that worn under the lead apron and two badges of thermoluminescent (TLD) dosimeters that one worn on the trunk of the body inside the apron and the other worn outside the apron at the level of the collar or the left shoulder. The effective doses calculated with film badge dosimeters ranged from 50 to 200 μSv. With the TLD dosimeter badges, the effective doses were calculated using NCRP algorithm, ranged from 0.04 to 82.62 μSv. It was concluded that the effective dose can be estimated more accurately when TLD dosimeters are used.

Keyword: interventional cardiology, radiation, effective dose, thermoluminescent dosimeter (TLD), film badge

POPULATION DOSES FROM TERRESTRIAL GAMMA EXPOSURE IN BELGRADE (SERBIA) AND THEIR RELATION TO GEOLOGICAL SETTING

Lj. Janković-Mandić[1], R. Dragović[2], M. Mirković[1], S. Dragović[3]

[1] University of Belgrade, Vinča Institute of Nuclear Sciences, P.O. Box 522, Belgrade
[2] University of Niš, Faculty of Science and Mathematics, Višegradska 33, Niš
[3] University of Belgrade, Institute for the Application of Nuclear Energy, Banatska 31b, Belgrade

Terrestrial radiation exposure emitted from naturally occurring radionuclides, such as ^{40}K and radionuclides from the ^{238}U and ^{232}Th series and their decay products represent the main external source of irradiation to human body. The purpose of this study was to provide the assessment of the doses from terrestrial exposure of population in Belgrade.

The gamma dose rate, annual effective doses and external hazard indexes due to terrestrial natural occurring radionuclides (^{40}K, ^{238}U, ^{232}Th) were calculated based on their activities in soil samples in Belgrade determined by gamma-ray spectrometry.

The mean value of the total absorbed gamma dose rate outdoors due to terrestrial radionuclides for Belgrade was 59 nGy/h which is close to the worldwide average value (54 nGy/h). The values of the gamma dose rate varied among sampling locations as a consequence of different geological formations in the investigated area. The mean value of annual effective dose of 73 μSv was significantly lower than the maximum allowed dose of 1 mSv for the population and was consistent with the worldwide average value. The mean value of external hazard index was found to be 0.28. The results of this assessment study pointed out that there is no significant radiation risk to the population of Belgrade due to terrestrial exposure to radiation from natural sources outdoors.

OBSERVATION OF RADON-222 PROGENY DECAY PROCESSES BY THE TIME DEPENDENT GAMMA-RAY SPECTROSCOPY

A. Jantsikene, V. Kabin, R. Koch, I. Rebane

University of Tartu, Institute of Physics

Radon is a naturally occurring radioactive inert gas found in drinking water or indoor air and may cause cancer. People exposed to radon in drinking water enter the risk group of getting cancer over the course of their lifetime, especially lung or stomach cancer. Highest radon concentrations are usually estimated in toilet, shower and kitchen. High levels of gas in these areas are caused by the fact that radon and all other uranium-238 decay chain radionuclides are taken up by the water that travels over rocks and through soil.

The main objective of this work was to improve gamma-ray spectroscopy method for estimating radon concentration in tap water. Gamma-ray spectroscopy is a well-known method for estimating concentrations of gamma emitting radionuclides in different types of samples. Yet, it seems that radon measurements are done with the gross alpha/beta scintillation counters that show the total concentration, but indicate neither the dynamics of ingrowth nor decay of daughter nuclides. Gamma-ray spectroscopy enables to estimate the concentration of radon instantly after the sample was taken. Given that radon emits only alpha radiation, the focus of these measurements is on two of its short-term gamma-ray emitting daughter nuclides that come right after Po-218, namely Pb-214 and Bi-214, with the half-lives of 26,8 minutes and 19,7 minutes respectively. A series of short-term measurements repeated with equal intervals (10 min) with various numbers of samples has been conducted.

A model was designed to estimate radon concentrations from the collected data in various conditions. The results demonstrated certain time dynamics of Pb-214 and Bi-214 behaviour that were not available in ordinary long-term gamma-ray spectroscopy measurements. This method was also applied in the analysis of the same daughter nuclides decay processes, which were adsorbed by the well-known filter material activated charcoal that being used in water and air. These findings are believed to improve the gamma-ray spectroscopy method for estimating parent nuclide content through its decay products in water and other materials and to give information about radon and its daughter behaviour and also to study time dependent behaviour of daughter nuclides in other decay chains.

DETECTION LIMIT AND SAMPLING PERIOD IN ENVIRONMENTAL ANALYSIS

András Kocsonya

Environmental Protection Services, Centre for Energy Research, Hungarian Academy of Sciences,
Konkoly-Thege Miklós út 29-33., 1121 Budapest, Hungary

Several methods applied in the field of environmental analysis are based on sampling and consecutive sample analysis. Analytic methods based on sampling can produce results by a given time delay. This delay depends on the sampling period and the time of the measurement and evaluation.

The environmental monitoring activity has at least two aims:

- continuous data collection of environmental parameters and their changes
- provide quick alert, if any environmental parameter reaches critical or hazardous level

In normal conditions the activity levels to be measured are rather low, therefore the detection limits should be as low as reasonably possible. Besides the sampling method and the properties of the applied spectrometer the available measurement time is the limiting factor of detection limit.

In emergency situations the quick alert is most important factor. The monitoring system should give alarm signals when the value of one or more parameters exceeds the critical level. Since quickness is the primary aspect, sampling period can be reduced to provide quicker response. Due to the finite capacity of spectrometers the analysis times must be often reduced, which increases the detection limit.

Regulations about environmental radioactivity define critical levels: recording, investigation and action levels. Upon the request of environmental monitoring the detection limits of the applied method should fulfil the conditions of these critical levels the within reasonable time. The adjustment of sampling frequency and analytic conditions to the critical levels will be discussed in the paper.

The sampling and analytic procedures applied at the Environmental Protection Service (EPS) of Centre for Energy Research of Hungarian Academy of Sciences are described. The changes of normal procedures in the case of emergency situations are shown. The application of these measures and the obtained results after the accident of Fukushima nuclear power plant will be discussed.

THE COMPARATIVE ANALYSIS OF INCIDENCE ILLNESSES OF SYSTEM OF BLOOD CIRCULATION AMONG VARIOUS CATEGORIES OF THE POPULATION, UNDERGONE TO INFLUENCE IONIZING RADIATIONS OWING TO ACCIDENT ON THE CHERNOBYL ATOMIC POWER STATION

A. Kotava[1], A. Sosnovskaya[2]

[1] The Yanka Kupala State University of Grodno, Grodno, Belarus
[2] The Gomel regional clinical hospital, Gomel, Belarus

Objectives: to present results of the comparative analysis of incidence illnesses of system of blood circulation (ISBC) among adult population of Belarus undergone to influence of radiation owing to accident on the Chernobyl atomic power station.

Methods: in research have been included: liquidators (1 GPA), the persons who evacuated or have independently left zones of evacuation in 1986 (2 GPA) and persons living in territories with density of pollution radioactive 137Cs more than 555 кBq/m2, and also removed or independently gone away from these zones after accident (3 GPA).

The analysis of incidence ISBC is lead for the period of 1993-2009. The investigated period has been divided into three intervals - 1993-1997, 1998-2002 and 2002-2009. In research are included following nosological forms: ISBC as a whole, the hypertensive diseases (HD), an ischemic illness of heart (IIH), including an acute and subsequent myocardial infarction (AMI), cerebrovascular illnesses (CVI), including a subarachnoid haemorrhage (SH), an an intrabrain haemorrhage (IH) and a cerebral infarction (CI).

Standardized parameters paid off. Standardization of parameters has been lead by an indirect method. For the standard average has been accepted for the period of 1993-2009 age incidence ISBC (with the account nosological forms) the persons registered in the Belarusian State register of the persons who have undergone to influence of radiation owing to accident on Chernobyl atomic power station. For investigated intervals average indices of incidence and a mistake of average paid off.

The statistical significance of differences in incidence rates was assessed by Student's criterion. Differences were considered statistically significant at probability of a mistake less than 5% ($p<0,05$). Growth rate of incidence paid off the standard method.

Results: the analysis of standardized parameters of incidence has shown, that in 2003-2009 in comparison with 1993-1997 decrease in incidence of ISBC in 1 and 3 GPA was observed, and in the 2 GPA incidence of ISBC has grown on 10,8 % and has made 9304,4±611,3.

Parameters of incidence HD have grown in 2003-2009 in comparison with 1993-1997 on 105,1% in 2 GPA and 24,4% in 3 GPA.

On a background of decrease in incidence of IIH in all GPA growth of incidence by a AMI was marked, the parameter has grown on 13,1% and has made in 2003-2009 241,8±13,1 in 1 GPA, on 115,4% and has made 144,6±20,2 in 2 GPA, on 55,8% and has made 142,5±10,6 in 3 GPA. Most unfortunate trends were marked in dynamics of incidence by separate nosologic units of CVI. So, in 2003-2009 in comparison with 1993-1997 the parameter of incidence an IH among persons 2 GPA has grown on 19,3%, and among persons 3 GPA - on 48,2%. The parameter of incidence SH has grown on 1,8% among liquidators, and on - 64,6% among persons 2 GPA. Also essential growth of incidence by a CI in 2003-2009 was marked in comparison with 1993-1997, among persons 1 GPA this parameter has grown on 475,8%, among persons 2 GPA - on 509,1%, among persons 3 GPA - on 1098,1%.

INTERCOMPARISON OF LOW-LEVEL TRITIUM AND RADIOCARBON MEASUREMENTS IN ENVIRONMENTAL SAMPLES

Ines Krajcar Bronić[1], Nataša Todorović[2], Jovana Nikolov[2], Jadranka Barešić[1]

[1] Laboratory for Measurements of Low-level Radioactivity, Ruđer Bošković Institute, Zagreb, Croatia
[2] University of Novi Sad, Faculty of Sciences, Department of Physics, Novi Sad, Serbia

Laboratory for Measurements of Low-level Radioactivities, Ruđer Bošković Institute (RBI) from Zagreb, Croatia, and Laboratory for Nuclear Physics, Department of Physics of the University of Novi Sad (UNS), Serbia, have started recently inter-laboratory comparisons of tritium (^{3}H) and radiocarbon (^{14}C) activities in various environmental samples. Both laboratories have the same type of detector, ultra low-level liquid scintillation counter (LSC) Quantulus 1220 (PerkinElmer Life Sciences).

In the RBI laboratory water samples for ^{3}H measurements are enriched by electrolysis, mixed with a scintillation cocktail and then measured by LSC. The lowest detection limit (LDL) of this method is 0.5 TU (TU = Tritium Unit, 1 TU = 0.118 Bq/L). At UNS, tritium concentration is measured either directly after mixing with the scintillation cocktail or by using an automatic Sample Oxidizer method. Also, several water samples enriched for tritium at RBI have been measured for comparison purposes at UNS.

For radiocarbon measurement, the automatic Sample Oxidizer method has been used for sample preparation at UNS. In the RBI laboratory, samples are first pre-treated chemically by a standard acid-alkali-acid method, combusted to CO_2 in a stream of pure oxygen and then the benzene is synthesized.

This paper presents results of intercomparison of different methods for tritium (^{3}H) measurements in water and for radiocarbon (^{14}C) measurements in environmental samples between the two laboratories.

The work was performed within the Bilateral scientific project between Croatia and Serbia.

STUDY OF SELF-ABSORPTION CORRECTION FOR ENVIRONMENTAL GAMMA-SPECTROSCOPY OF SOIL SAMPLES USING MARINELLI BEAKER

M. Lotfi[1], S.M. Mostajabodaavati[2], B.T. Sichani[3]

[1] Department of Nuclear Engineering, Faculty of Advanced Sciences & Technologies, University of Isfahan, Isfahan, Iran
[2] Department of Physics, University of Isfahan, Isfahan, Iran
[3] Nuclear Science & Technology Research Institute, Reactor & Accelerator Research & Development School, Isfahan, Iran

Self-absorption correction (*Cs*) measurement in precise gamma-ray spectrometry of environmental samples is an essential issue. For a given geometric setup, the correction factor is expressed as the ratio of efficiency of standard to that of the sample. The procedure is to be applied to obtain *Cs* for various densities (ρ) and photon energies *E*. The obtained self-absorption corrections for each photon energy are fitted to an appropriate function *Cs*(ρ). This *Cs*(ρ) was determined experimentally, using five radioactive standard reference materials with different matrix densities (1-1.5 g/cm^3) in Marinelli beakers. Similarly, using the method and conditions described previously, *Cs*(ρ) was obtain by Mont Carlo simulation for each of the samples (the composition of each matrix, which is necessary for the simulations, was obtained by XRF). Obviously, Self-absorption correction factors (*Cs*) depend on both sample density and chemical composition, but normally chemical composition dependence is ignored in studies. In this work, a new parameter (f_a), has been introduced to represent both sample density and chemical composition. By this method, *Cs*(f_a) was obtained. The calculated correction factors were evaluated by experimental data. The obtained activates using *Cs*(f_a), Experimentally obtained Cs(ρ) & Mont Carlo obtained Cs(ρ) show less relative error, Respectively. We conclude that *Cs*(f_a) is more useful than Cs(ρ) to measure the activities of soil samples using Marinelli beaker.

Table1: Functions of Cs(ρ) & Cs(f_a) and associated correlation coefficients (R^2) over range energy under 1500 keV.

Energy (keV)	Cs(ρ) MCNP-	R^2	*Cs*(f_a) MCNP-	R^2	Cs(ρ) Experiment-	R^2
0<E<250	*Cs*=0.311ln(ρ)+0.974	0.917	$+1.242\ f_a$ *Cs*=-0.291	0.638	*Cs*=0.465ln(ρ)+0.89	0.97
250<E<500	*Cs*=0.118ln(ρ)+0.974	0.984	$+1.242\ f_a$ *Cs*=-0.291	0.638	*Cs*=0.029ln(ρ)+0.939	0.94
500<E<1000	*Cs*=0.109ln(ρ)+0.976	0.985	$+1.242\ f_a$ *Cs*=-0.291	0.638	*Cs*=0.134ln(ρ)+0.976	0.92
1000<E<1500	*Cs*=0.090ln(ρ)+0.978	0.941	*Cs*=-0.291 f_a +1.242	0.638	*Cs*=0.02ln(ρ)+1.08	0.95

FOLLOW-UP OF CS-137 ACTIVITY IN THE FIRST 100 AIR SAMPLES IN THE AREA OF KUMODRAZ, BELGRADE IN THE 2008 TO 2011 PERIOD

Tatjana Marković, Aleksandra Samolov, Nataša Pajić

Military Technical Institute, Ratka Resanovića 1, Belgrade, Serbia

This paper presents results of gamma spectrometric analyses of air samples, collected in the period from 2008 to 2011, at Kumodraz location. Cs-137 specific activity has been monitored for 4 years. Exposure rate of gamma background radiation has been showed, as well. Obtained results show that average annual effective doses are in the range from 1.01 to 1.19 mSv/y and lower than the worldwide average.

Keywords: gamma spectrometry, Cs-137, background radiation, monitoring, dose

RADIOLOGICAL CHARACTERIZATION OF FLY AND BOTTOM ASH LANDFILL OF THE FORMER SULFATE PULP FACTORY PLAŠKI

Visnja Orescanin[1], Robert Kollar[1], Kresimir Buben[2], Ivanka Lovrencic Mikelic[3], Karlo Kollar[1], Melkior Kollar[1], Gordana Medunic[4]

[1] Advanced Energy Ltd., V. Prekrata 43, Zagreb, Croatia, Phone/Fax: +385-1-6535532; E-
[2] International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, A-1400 Vienna, Austria
[3] Laboratory for Radioecology, Institute R. Boskovic, Bijenicka 54, POB 180, HR-10000 Zagreb, Croatia
[4] Institute of Mineralogy and Petrography, Faculty of Science, University of Zagreb, Horvatovac bb, Zagreb, Croatia

The purpose of this research was determination of the radiological profile of the fly and bottom ash, by-product of coal burning in the thermoelectric unit of the former "Simo Dimic" sulfate pulp factory. The characterization was done in order to clasify the waste material, assess its impact to the environment and exposed population and recommend appropriate management solution. The factory was situated in a small Croatian town of Plaski, in Karlovac county. The landfill contains about 70 000 m^3 of the waste ash accumulated during the production period. The height of the landfill varies from 3.5 to about 13 m. During the whole production period fly and bottom ash were deposited directly on the land without any kind of the protection cover and left to the weathering processes. Until present study there were no available data on the chemical and radiological characteristics of the disposed material or the informations about the origin and radiological data of the coal used.

The research involves determination of the activities of the radionuclides using a HPGe GR1520 semiconductor detector coupled with a multichannel analyzer LYNX and *in situ* measurement of an effective dose rate above the landfill using RadEye PRD-ER device. The mean value of the total effective dose rate measured in the air at the height of 1 m for all samples of ash and soil under the influence of the landfill was 1.60 mSv/yr. Compared to Croatian average (0.7015 mSv/yr), the determined mean value for the Plaski landfill is two times higher. However, compared to the local background (0.14 mSv/yr), mean value of the total effective dose rate measured above the Plaski landfill is 11.4 times higher. In the samples of ash regardless of the sampling position the activity concentrations of the radionuclides in Bq/kg vary in the following ranges: ^{226}Ra from 82.10 to 314.90 (mean value 144.3), ^{232}Th from 32.50 to 223.60 (mean value 72.7) and ^{238}U from 69.10 to 243.20 (mean value 129.6). Compared to the mean values found in the background soil ^{226}Ra and ^{238}U mean activity concentrations increased from 1.6 to 6.4 times and ^{232}Th from 1.4 to 4.3 times. In order to reduce total effective dose rate to the local "background" values and to prevent redistribution of the radionuclides and heavy metals from the deposited material into the environment fly and bottom ash landfill must be sealed with 10 cm thick layer of the material with low permeability.

Keywords: fly and bottom ash landfill, Plaski, total effective dose rate, radionuclides.

NEUTRON DETECTION AROUND HIGH ENERGY LINEAR ACCELERATORS IN CLINICAL HOSPITAL CENTER OF OSIJEK

Marina Poje[1], Branko Vuković[1], Vanja Radolić[1], Igor Miklavčić[1], Dario Faj[2]

[1] Department of Physics, University Josip Juraj Strossmayer, Osijek, Croatia
[2] Faculty of Medicine, University Josip Juraj Strossmayer, Osijek, Croatia

High energy electron linear accelerators (15 – 25 MeV) are in wide use in radiotherapy. When photon beams with photon energies more than 10 MeV are used, unwanted neutrons can be produced in giant dipole resonance (GDR) reaction between photon beam and accelerator head material (led, tungsten). In this reaction an isotropic flux Φ of neutrons is produced (neutrons / cm^2 s), dominated by neutrons with energies between 700 keV and 1 MeV. Characterisation of full radiation field is important to correctly evaluate patients and medical personnel exposure.

Neutron detection was done around 15 MeV photon beam of Siemens Mevatron MD2 and 18 MeV photon beam of Siemens Oncor Impression linear accelerators in Clinical Hospital Center of Osijek. It was performed by nuclear track etched detectors CR-39 associated with converter (radiator) that consist of ^{10}B. In nuclear reaction ^{10}B (n, α) ^{7}Li , α particle and Li ion are emitted, producing a latent tracks in the detector body itself. As a result of chemical etching these track become larger and visible under the optical microscope. After detector processing and determination of track density, with detector response known from the calibration exposure, we can evaluate neutron ambient dose equivalent *H*(10)*. Previously described nuclear reaction is identical to one in BNCT (boron neutron capture therapy) in which ^{10}B is injected in the cancer cells and the tissue is exposed to the thermal neutrons. As a consequence a short range (~ 5μm) α particle and Li ion are emitted, and because of their short range they deposit majority of their energy inside the cancer cells and spare surrounding healthy tissue [1].

Detectors were set at several important locations with the goal to evaluate neutron ambient dose equivalent and/or neutron dose rate to which are exposed both, medical personnel and patients. Given values out of the bunker are in range from 2 to 5 μSv/h in dependence of measuring location what is consistent with already published values [2] [3]. Measurements made in the photon beam were considerably higher with significantly increased values in 18 MeV photon beam over measurements in 15 MeV photon beam.

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NATURAL RADIONUCLIDES IN SOILS IN SERBIA: DOSE CALCULATIONS AND ENVIRONMENTAL RISK ASSESSMENT

Dragana Popović[1], Dragana Todorović[2], Jelena Nikolić[2], Jelena Ajtić[1]

[1] University of Belgrade, Faculty of Veterinary Medicine, Department of Biophysics, Belgrade, Serbia
[2] University of Belgrade, Institute of Nuclear Sciences Vinca, Belgrade, Serbia

The paper presents the results of a study on the content of natural radionuclides (^{40}K, ^{226}Ra, ^{232}Th, $^{235/238}$U) in cultivated and uncultivated soils in Serbia during 1980–2009. Soils were sampled in urban areas, mountain regions, around coal power plants and in the region exposed to the NATO intervention in 1999. Activity of the radionuclides was determined on HPGe detectors by standard gamma spectrometry. External dose rates, radium equivalent activities, external hazard indices and annual effective doses were calculated according to UNCEAR (2000) and the environmental risk from natural radionuclides in soils estimated.

The activities of natural radionuclides in soils in Serbia are within the range of values obtained for the region and elsewhere, but the variations are in a large range of (30–50) %.

The highest content of natural radionuclides in the mountainous soils was found in Besna Kobila and the lowest content in the soils of Rudnik, Goc and Crni Vrh. The external absorbed gamma dose rate in air and annual effective dose in Besna Kobila are 98 nGy/h and 0.120 mSv, respectively, which is about five times higher than the values calculated for Mt. Goc: 20 nGy/h and 0.025 mSv, respectively. The contents of natural radionuclides in soils in urban areas were somewhat lower that in soils around coal power plants and the Vranje region, but the differences are not significant. This also accounts for the values of external absorbed gamma dose rate in air and annual effective dose. Among the cities, the highest values for the external dose rate and annual effective dose were found for the town of Arandjelovac (90 nGy/h and 0.110 mSv, respectively), and the lowest for the city of Beograd (50 nGy/h and 0.061 mSv, respectively). High values in Arandjelovac were most likely due to fertilisation.

Radiological risk is maximal in areas around the coal power plants and in the region of Vranje. The risk of radionuclides in soils around the coal power plants is comparable to the risk reported for the experimental farm of Radmilovac, where soils were chemically treated. In the region of Vranje, which was exposed to DU ammunition in 1999, there were significant differences in radiological risk assessment between the sampling locations. For example, the values of external dose rate and annual effective dose at Bratoselce (110 nGy/h and 0.135 mSv, respectively) were five times higher than at Borovac (22 nGy/h and 0.027 mSv, respectively). The annual external dose at Bratoselce was the highest for the country on the whole, and it exceeded the world average value by a factor of two (UNSCEAR, 2000).

Key words: *natural radionuclides, soils, dose, risk assessment*

Reference:

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COMPARISON OF CONTENT OF NATURALLY OCCURRING RADIONUCLIDES IN IMPORTED AND PHARMACEUTICAL ZEOLITE

Milica Rajačić, Jelena Nikolic, Marija Jankovic, Dragana Todorovic

Institute for Nuclear Sciences Vinca, Radiation and Environmental Protection Department, Belgrade, Serbia

As a part of regular continuous control of imported goods, in the Radiation and Environmental Protection Department of Institute for Nuclear Sciences Vinca, the content of naturally occurring radionuclides was investigated in samples of zeolite, imported mainly from the Czech Republic, intended for use in production of artificial fertilizers and cattle feed. The samples were collected over the time period of 6 years. The measurement was performed using gamma spectrometry, on high purity germanium (HPGe) detector, relative efficiency 23%. External hazard index (H_{ex}), external dose rate ($\dot{D}$), radium equivalent (Ra_{eq}) and annual effective dose were calculated. Also, the same analysis of commercial pharmaceutical zeolite in capsules, intended for human use, was performed and based on these results, an intake of naturally occurring radionuclides by ingestion was estimated. These results were then compared to the annual intake of naturally occurring radionuclides via ingestion of food. The aim was to establish the increase of individual effective dose due to ingestion of pharmaceutical zeolite. Also, the content of naturally occurring radionuclides in imported and pharmaceutical zeolite was compared in order to estimate which part of zeolite as a raw material can be found in zeolite intended for human use.

Key words: *zeolite, gamma spectrometry, naturally occurring radionuclides*

DETERMINATION OF U AND TH IN CONTAMINATED SOIL AND PLANT SAMPLES BY INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY (ICP-MS)

R.S. Radicheva, V.V. Mihaylova, R.G. Djingova

Department of Analytical Chemistry, Faculty of Chemistry, University of Sofia, 1, J. Bourchier blvd., 1164 Sofia, Bulgaria

Uranium mining and processing involve the removal of large amounts of accompanying materials and decay products, which might increase exposure to natural radiation through different pathways. Uranium is characterized by both radiotoxicity and chemical toxicity, whereas thorium is to be considered as only radiotoxic. In order to assess possible contamination by U and Th, soil samples were collected from the Buhovo abandoned mining area, located in Western Bulgaria. Extensive mining was conducted in this region between 1938 and 1992. The mine was closed in 1992 and recultivation of the abandoned mining area started ten years later.

In this study, uranium and thorium concentrations were determined by inductively coupled plasma mass spectrometry (ICP-MS). The reference materials analyses demonstrated the high accuracy and precision of the determination.

Fresh solutions of ^{238}U and ^{232}Th in 2% HNO_3 with concentrations 0.5 ng/ml, 1 ng/ml, 10 ng/ml were analyzed immediately and re-analyzed two weeks later. Significant deviations in the measured concentrations were established. The results show that uranium and thorium easily adhere to the sample vessel's walls, as well as to the internal components of the ICP system. This can lead to an apparent loss of Th and U, especially at low concentration. HNO_3 was used because it contributes least to matrix and interference effects. A constant thorium and uranium signal was not reached below acid strength of 4%. Below this level, the U and Th concentrations were unpredictable. We also determined the transfer coefficient (TF) for grass, wheat and dandelion, differences in the uptake of these radionuclides by different plants, and temporal variations of U and Th in different plant species as well.

The concentrations of uranium in the investigated soil samples from Buhovo mining area ranged from 45 to 60 μg/g with a mean value of 55 μg/g and plants average value of 0,103 μg/g. The range and mean concentration of Th were 65-87 μg/g and 73 μg/g, respectively, with plants average value of 0,054 μg/g. The normal radioactive background in Buhovo is 0,15-0,23 μSv/h. The dose rate from the soil there is 0,6 – 1,03 μSv/h, or higher by about a factor of 5, which obviously means that the area is contaminated.

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THE REQUIREMENTS OF REGULATIONS FOR APPROVAL OF PERSONAL DOSIMETRY SERVICES IN ROMANIA

Silvia Serban

National Commission for Nuclear Activities Control Bucharest
Department of Surveillance and Inspection of Ionizing Radiation Activities

The national authority for regulation, authorization and control of nuclear activities in Romania - the National Commission for Nuclear Activities Control (CNCAN Romanian abbreviation) is a legal institution subordinated to the Chancellery of the Prime Minister. CNCAN's activity as a national regulatory body is based on the provisions of the Law no. 111/1996 on the safe deployment, regulation, authorization and control of nuclear activities, republished in the Official Gazette.

CNCAN has an important role in providing strict compliance with the requirements for nuclear safety and for protection of people's health against the dangers from ionizing radiation.

The Division of Ionizing Radiation regulates and keeps under control all the activities outside the nuclear fuel cycle.

The main fields of activities are:

- Medical
- Industrial
- Research and education

The routine monitoring of the individual exposure of workers constitutes an integral part of any radiation protection programme.

Both the BBS (EU 1996 a) and ICRP (ICRP 103) recommendation approaches to minimizing the risk of radiation work by setting out a system of dose limitation, dose constraints and reference levels. The main principles are:

- the principle of justification ;
- the principle of optimization of protection and ALARA principle
- the principle of application of dose limits

Romania as EU member implements EU policy in this field, in according the relevant Directives:

- Council Directive 96/29/EURATOM (Basic Safety Standards)
- Council Directive 90/641/ EURATOM and another.

CNCAN has issued the regulations in field of radiation protection and for the individual dosimetry are used:

- Fundamentals Norms for Radiological Safety;
- Individual Dosimetry Norms.
- In according with the provisions of these norms, CNCAN, as national authority verifies and recognizes that an approved dosimetry service:
- is technically competent;
- able to generate technically valid results;
- has adequate administration;
- has technical and quality systems;
- produces a reasonable degree of accuracy in the assessments of dose;
- is highly reliable;
- communicates the results of routine dose assessments to the employer and/or the NDR in a reasonable time;
- rapidly communicates to the employer, and subsequently to the authorities, the results of dose assessments made in the event of an accident, occurrence, or incident.

OPTIMIZATION OF RADIATION PROTECTION OF STAFF IN CARDIOLOGY

Ljubica Smiljanić[1], Nataša Todorović[2]

[1] Institute of oncology Vojvodina, Sremska Kamenica Serbia
[2] Faculty of Science, Department of physics, University of Novi Sad, Novi Sad, Serbia

Introduction:

Radiation protection of staff in interventional cardiology is of major importance since the doses received by the staff are close to the limit for professional exposure. Optimisation of procedure can reduce the doses to staff and improve efficiency (exposure time, number of images, change type of acquisition, etc.).

Materials and methods:

Measurements were performed with calibrated dosimeter UMO LB 123 (Berthold). Annual dose received by exposed professional medical staff was calculated, based on the results of mandatory annual absorbed dose rate measurements around X-ray apparatus in the angio room (with respect to duration of procedure and number of procedures per employee).

Results:

Results shown in the table emphasize the importance of radiation protection accessories. Effective dose is measured in following conditions: U=77kV, I= 800mA, during fluoroscopy. Staff is standing behind the protective screen.

	Measured effective dose	Time of one procedure	Number of procedures per employee	Annual received dose	Maximum duration of stay during exposure per week
Interventional cardiologist	38 μSv/h	45 min	2	11.4 mSv	13 h
Technician	12 μSv/h	45 min	2	3.6 mSv	42 h
Sterile instrumental nurse	22 μSv/h	5 min	2	0.733 mSv	23 h

Conclusion:

Since the recommended annual absorbed dose for the medical staff must not exceed 20mSv/year, the time of exposure of each team member should not be larger than emphasized in table 1, per work week. Minimization of dose to patient and staff is not the main issue in radiation protection, but optimization of dose to patient (adequate image quality) and minimization of dose to staff.

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DIFFERENCES IN ACTIVITY LEVELS OF ^{137}CS IN MUSHROOMS IN EASTERN AND WESTERN MACEDONIA

Aleksandra Todorovic[1], Pavle Sekulovski[1], Zehra Hajrulai-Musliu[1], Elizabeta Dimitrievska Stojkovic[1], Biljana Stojanovska Dimzoska[1]

[1] Food Institute, Faculty of Veterinary Medicine, Skopje

Wild mushrooms have become popular delicacy in many countries, including in Republic of Macedonia. Some of these species of mushrooms are capable of accumulating large quantities of certain heavy metals and radio nuclides. In Republic of Macedonia there is lack of research regarding the radioactive contamination of mushrooms. Therefore, the goal of this research was to state the differences in the regional mushroom sampling i.e., to see what are the differences between Eastern and Western Macedonia.

120 samples of mushrooms collected from various areas in R. Macedonia, have been analyzed. Based on the obtained results, separate evaluation of the condition in Eastern and Western Macedonia has been concluded. After comparing it with the Book of Rules for maximum permitted quantity of radio nuclides in food, it has been stated that all the samples are within the allowed criteria.

Keywords: radioactivity, radio nuclides, mushrooms, analysis, gamma spectrometry, results.

RISK OF DEVELOPMENT OF MALIGNANT TUMORS AT BELARUSIAN LIQUIDATORS OF CONSEQUENCES OF ACCIDENT ON THE CHERNOBYL ATOMIC POWER STATION

A. Sosnovskaya[1], A. Kotava[2]

[1] The Gomel regional clinical hospital, Gomel, Belarus
[2] The Yanka Kupala State University of Grodno, Grodno, Belarus

Objectives: To estimate risk of development malignant tumors (MT) various localizations at Belarusian liquidators (BL) of consequences of accident on the Chernobyl atomic power station.

Methods: The analysis of incidence is lead for the period of 1993-2008 years which is broken into two time intervals: 1993-1996 and 1997-2008. In research are included: all localizations of a cancer, MT a stomach, a colon, a lung, a skin, kidneys, a bladder and a thyroid gland.

As control group inhabitants of Vitebsk area are chosen. Standardization of parameters of incidence was carried out by a method of the truncated standard in the age of than 20 years are more senior. Parameters were standardized by a direct method with use of the world standard (World). The relative risk (RR) paid off as the attitude of parameters of incidence standardized on age among liquidators to incidence of the population of control group. Accuracy RR was defined by size of 95% of a confidential interval (CI).

Results: Comparison of average standardized parameters of incidence MT for the period of 1993-1996 all localizations of a cancer between liquidators and the population of control group has not revealed statistically significant distinctions, except for incidence of a thyroid cancer. The parameter of incidence of a thyroid cancer during this period among liquidators has made 19,1±2,9, among the population of control group - 6,4±0,4 ($p<0,01$). In 1997-2008 in comparison with 1993-1996 incidence of a cancer of all localizations among liquidators has grown on 40,7% (in control group - on 14,6%), including a cancer of a stomach - on 54,2% (in control group has decreased on 16,2%), colon - on 38,8% (in control group - on 16,2%), lung - on 84,1% (in control group has decreased on 6,1%), skin - on 68,7% (in control group - on 46,4%), kidneys - on 90,4% (in control group - on 55,0%), a bladder - on 57,9% (in control group - on 19,4%).

In 1993-1996 RR was statistically doubtful for all investigated localizations of a cancer (except for thyroid cancer RR of 3,5 CI 2,75-4,68).

In 1997-2008 RR statistically significantly has exceeded 1 for all investigated localizations of a cancer, except for a cancer of a skin. RR incidence a cancer of all localizations has made 1,18 (CI 1,14-1,21), a cancer of a stomach - 1,24 (CI 1,13-1,36), colon - 1,3 (CI 1,13-1,48), lung - 1,3 (CI 1,21-1,4), kidneys - 1,43 (CI 1,26-1,62), a bladder - 1,76 (CI 1,52-2,03), a thyroid gland - 2,11 (CI 1,86-2,38).

STATE OF HEALTH OF THE POPULATION OF BELARUS INJURED IN THE CHERNOBYL ACCIDENT: RESULTS OF LONG-TERM MONITORING

A. Sosnovskaya[1], A. Kotava[2]

[1] The Gomel regional clinical hospital, Gomel, Belarus
[2] The Yanka Kupala State University of Grodno, Grodno, Belarus

Objectives: to estimate a state of health of the population of Belarus injured of accident on the Chernobyl atomic power station.

Methods: levels and dynamics of incidence by the basic classes of illnesses, the general disease and death rate among the injured population were estimated. Rough intensive and standardized parameters of incidence and general disease on 100000 population paid off. Parameters of death rate paid off on 1000 population. The period of research was from 1995-2009.

Results: in 2009 in comparison with 1995 among the population of Belarus injured of Chernobyl accident (ChA), decrease in incidence on 41,8% (with 112424,3 in 1995 to 65456,7 in 2009) was marked. On a background of decrease in incidence tumors on 28,1%, including malignant tumors in 2,0 times (with 256,6 in 1995 to 515,6 in 2009) and benign tumors - on 3,1%. Mid-annual growth rate of incidence malignant tumors among the injured population has made 4,6% that is essentially higher than a similar parameter among the population of Belarus as a whole (2,8%). For the investigated period among injured population incidence of malignant tumors of digestive organs has grown in 2,2 times (with 58,0 in 1995 to 127,6 in 2009), organs of breath and a thorax - in 1,8 times (with 41,5 in 1995 to 76,6 in 2009), uric ways to 2,2 times (with 18,8 in 1995 to 41,9 in 2009), lymphatic and hemopoietic tissue - in 3,0 times (with 16,5 in 1995 to 49,7 in 2009), including leukemia. Till 2001 the expressed growth of incidence by a thyroid cancer was marked. In 2001 the level of incidence by a thyroid cancer has made 38,0 on 100000 injured population (in 1995 - 17,1) and has reached the maximal value for all period of supervision. The expressed growth of incidence hypothyrosis, autoimmune thyroiditis, nontoxic diffuse and nodular goiter, a diabetes mellitus, a cataract, the illnesses described by boosted bloody pressure, a acute myocardial infarction and a cerebral infarction.

During 1995-2009 dynamics of death rate from all reasons among the injured population had the expressed tendency to growth. Annually the parameter of death rate increased on the average for 4,4% and by 2009 has made 15,3 (in 1995-9,3).

MEASUREMENT UNCERTAINTY ESTIMATION RELATED TO CANCER MORTALITY RISK DUE TO LOW DOSE, LOW-LET EXTERNAL IRRADIATION

Vesna Spasić Jokić, Ljubica Župunski, Vojin Gordanić

[1] Faculty of Technical Sciences, University of Novi Sad, Serbia
[2] Geoscience, Belgrade, Serbia

Purpose. Monte Carlo simulations are very important for the environmental health risk assessments [1]. They are used to propagate uncertainty in the values of input variables to the output quantity. As a result, probability distribution is assigned to assessed risk as an output quantity. This probability distribution gives information about uncertainty of assessed risk opposed to deterministic point risk estimates. Uncertainty could be assigned to point risk estimate using "Guide to the expression of uncertainty in measurement (GUM)" framework for estimation of measurement uncertainty, but it is expected that probability distribution should be Gaussian. If it is suspected that probability distribution of output quantity deviates from Gaussian, it is recommended to use Monte Carlo techniques for propagation of uncertainty [2], [3]. Purpose of this study was to estimate measurement uncertainty of the cancer mortality risk due to external irradiation from the ^{40}K in soil using Monte Carlo techniques.

Methods. Methodology for cancer risk uncertainty estimation is presented for one year external exposure to ^{40}K in soil. Risk was calculated by multiplication of the measured ^{40}K activity concentration in soil sample (Bq/kg) [4], conversion factor obtained by Fotelp code (nGy/h)/(Bq/kg) [5] and mortality risk/Gy taken from Environmental Protection Agency Report for low-LET whole body irradiation [6]. Mathematical expectation and probability density distribution were assigned to every input quantity and Monte Carlo method was used to propagate uncertainty of input quantities.

Results and discussion. Uncertainty budget is presented in Table 1. Budget contains defined sources of uncertainty, their expectations and assigned probability density functions.

Table 1. Uncertainty budget

Sources of uncertainty	**Expectation and Probability density distribution**
Nominal whole body risk estimate*	5.75×10^{-2}/Gy
Sampling variation*	Normal (1.0, 0.15)
Diagnostic misclassification*	Normal (1.2, 0.06)
Temporal dependence*	Trapezoidal (0.5, 0.6, 1.0, 1.1)
Transport across populations*	Normal (1.1, 0.12)
Errors in dosimetry*	Normal (0.84, 0.095)
DDREF (dose and dose rate effectiveness factor)*	Uniform (1, 2): 50% ; Exponential (>2): 50%
Activity concentration (Bq/kg)	Uniform (358, 442)
Dose conversion factor ((nGy/h)/(Bq/kg))	Normal (0.039, 0.025)

*Distributions taken from EPA [6]

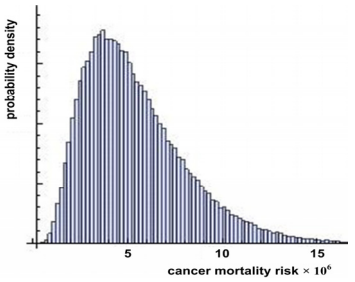

Figure 1. Probability density function estimation of output quantity obtained by Monte Carlo simulation

The mean of the obtained distribution that represents mortality cancer risk estimation of low level, low LET, whole body irradiation is 7.3×10^{-6} for one year exposure. The estimated 90 % confidential interval is 2.6×10^{-6} – 14.3×10^{-6} (Figure 1). According to GUM Framework, assessed risk is 6.3×10^{-6} with assigned Gaussian distribution. The estimated 90 % ($k \approx 1.65$) confidential interval is 0.5×10^{-6} – 11.7×10^{-6}.

Conclusion. Actual distribution obtained using Monte Carlo method is non-Gaussian, which was one of the conditions that justifies usage of Monte Carlo simulations, instead of GUM Framework.

Key words: uncertainty, external irradiation, cancer risk assessment, Monte Carlo simulation

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TOBACCO PLANT'S CAPACITY FOR URANIUM ADOPTION

Mirjana D. Stojanović, Marija L. Mihajlović, Jelena V. Milojković, Zorica R. Lopičić, Milan Adamović, Marija S. Petrović

Institute for Technology of Nuclear and Other Mineral Raw Materials, Belgrade, Serbia

This paper presents the uranium adoption aptitude by the shoots Virginia and Burley, two varieties of a tobacco plant (*Nicotiana tabacum* L.). Plants were grown on uranium tailings of the closed mine Kalna-Gabrovnica in southeast Serbia, with an average uranium content of 15.33 mgU kg^{-1}. Examined shoot samples were divided into five groups of leaves and stem sections. Uranium concentration was generally lower, about twenty times in leaves and about five times in stems, in younger sections, relative to the corresponding older ones. Statistical analysis of the results point to a very similar trend of uranium uptake within two types of tobacco plant, as well as within the same sections across the types. In contrast to this, variant parts and sections showed variance in uranium adoption regarding the section elderliness and origin of the parts. Based on the literature data, the results presented in this study demonstrate uranium hyperaccumulatory properties of tobacco plant and its utilization in phytoremediation of U contaminated mediums.

Keywords: uranium, uptake, tobacco plant, varieties, hyperaccumulators, phytoremediation.

A POSSIBILITY FOR MEASURING ^{235}U BY THE MULTIDETECTOR 4π GAMMA-SPECTROMETER PRIPYAT-2M

Nikola Svrkota[1], Nevenka M. Antovic[2]

[1] Center for Ecotoxicological Research, Podgorica, Montenegro
[2] Faculty of Natural Sciences and Mathematics, University of Montenegro, Podgorica, Montenegro

Measuring ^{235}U by the PRIPYAT-2M gamma-ray coincidence spectrometer, with six NaI(Tl) detectors and registration geometry close to 4π, has been analyzed. The radioactive series of ^{235}U which ends with a stable isotope of lead ^{207}Pb, contains 15 daughter radionuclides, undergoes a decay chain of 12 α- and 9 β-decays accompanied by emission of γ-rays, among which only several have energies and intensities appropriate for detection by the spectrometer PRIPYAT-2M and sodium iodide detectors. The present study considers γ-rays at the energies 235.971 keV (I = 12.3 %), 269.459 keV (I = 13.7 %) and 351.059 keV (I = 12.9 %) – from α-decays of ^{227}Th (to ^{223}Ra), ^{223}Ra (to ^{219}Rn) and ^{211}Bi (to ^{207}Tl), respectively; as well as possibility of their detection using the PRIPYAT-2M spectrometer in the energy range from 200 to 2000 keV.

ENTRANCE SURFACE DOSE MEASUREMENT IN PEDIATRIC PATIENTS UNDERGOING COMMON DIAGNOSTIC X-RAY EXAMINATIONS IN BLACK LION AND YEKATIT 12 HOSPITAL ADDIS ABABA, ETHIOPIA

Seife Teferi, Daniel Admassie, Tekle Abate, A. Durga Prasada Rao

Ab1 Department of Nuclear Physics, Andhra University, Visakhapatnam, India

Background: Early childhood exposure carries an enhanced radiation risk and estimated that the probability of induction of cancer especially leukemia is about two to three times as high as in adults. Hence, dose measurement is mandatory for optimization in radiation protection to comply with international reference levels.

Objectives: To estimate pediatric patient's radiation dose arising from common diagnostic x-ray examinations by measuring Entrance Surface Dose, thereby, to compare the results from established reference values and other published studies.

Material and Methods: A cross-sectional study was conducted on pediatric patients under 15 years of age in Black Lion and Yekatite 12 Hospitals in May and August, 2009 respectively. Exposure factors used for commonly performed x-ray examinations like; chest, skull, abdomen, pelvis and spine were obtained from each Hospital. For each examination, four age groups 0–1, 1–5, 5–10 and 10–15 years were studied. Entrance Surface Dose in air was measured using dositime dx X-ray Digital Dosimeter and Exposure Time Meter. The obtained data were analyzed using statistical software.

Result: In Black lion hospital, the lowest and the highest calculated mean Entrance Surface Doses in μGY were 104 and 2482 for chest Anteroposterior (0-1) years and lumbo-sacral lateral (10-15) years, respectively. In Yekatit 12 hospital, the lowest and the highest calculated mean Entrance Surface Doses in μGY were 200 and 3570 for chest antrioposterior (0-1) years and lumbo-sacral lateral (10-15) years, respectively. Wide variations of doses for the same type of examination and projection have been detected in each hospital.

Conclusion: The wider dose variation suggests that there is a pressing need to seek dose optimization to children in order to reduce the detriment caused by the unnecessary high doses imparted to them.

OCCUPATIONAL EXPOSURE AT HIGH ENERGY MEDICAL LINEAR ACCELERATOR

Milan Teodorović[1] , Nataša Todorović[2], Ljubica Smiljanić[1], Edit Karvak[2], Ozren Čudić, Borko Basarić

[1] Institute of Oncology Vojvodina, Sremska Kamenica, Serbia
[2] Faculty of Science, Department of Physics, University of Novi Sad, Novi Sad, Serbia

Introduction: Yearly monitoring of occupational radiation exposure is obligatory by law, to demonstrate compliance with dose limits and safety of workplaces where increased risk of exposure is an issue. The increased number of treatment procedures per day, especially for the technologists, could lead to an increase in the dose received by radiation medical staff. For this reason it is very important to measure absorbed doses around all X-ray aparatures, especially in position of workers.

Materials and methods: Measurements were performed with calibrated dosimeter UMO LB 123 (Berthold) and with Radiation Alert Inspector, Internal G-M LND7317 metod of HASL 300:1997. Measurements were done during regular work hours, and treatment of patients in the control room and bunker of the high energy medical linear accelerator Varian 2100C. Duration of treatment, number of patients, and the position of gantry and field size are important factors for calculation of absorbed doses.

Results: The results of measurements around the treatment head, at the place of an RTT, around the bunker door, are within the limits set by the law. Although increased dose (within the limits) is registered by the bunker door, (leakage) and it is known problem in construction of all types of bunker doors.

Table 1. Energy 15 MV, Gantry 270 (toward the RTT work place)

	RTT workplace control room (μSv/h)	bunker door, control room (μSv/h)	bunker wall (μSv/h)
2009	1.4	7.5	1.5
2010	0.4	6.4	0.12
2011	0.2	1.5	0.2

Conclusion: High energy medical linear accelerator, Varian 2100C in several years (2009, 2010, 2011) has been a powerful source of radiation, but with implemented radiation protection is also safe for work. It is not recommended to spend time close to bunker door during the linac operation as principle of lowering the dose to staff should be always kept in mind.

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THE INFLUENCE OF THE RADON VARIABILITY ON DOSE ASSESSMENT

Vladimir Udovičić[1], Aleksandar Dragić[1], Radomir Banjanac[1], Dejan Joković[1], Bojana Grabež[1], Zora S. Žunić[2], Jelena Filipović[2]

[1] Institute of Physics, Belgrade, Serbia, udovicic@ipb.ac.rs
[2] Institute of Nuclear Sciences "Vinča", ECE LAB, Belgrade, Serbia, ecelab@vinca.rs

The radon dose assessment is based on the recommended formula proposed by UNSCEAR and ICRP. There is still some misunderstanding in the two different approaches on radon dose assessments regarding how to transform radon concentration to the radon dose. One model is based on epidemiological assessments (ICRP) and the other one is evaluated from physical dosimetry (UNSCEAR). Also, it is very important to evaluate accurate annual radon concentration due to very complex indoor radon behavior. This task is not trivial and mostly come up from the radon variability. The aim of this work is to investigate the influence of the radon variability on dose assessment. For this purpose, we used the data sets from the different indoor radon measurements performed in Serbia.

URANIUM ELECTRODEPOSITION FOR ALPHA SPECTROMETRY SOURCES PREPARATION

O.A. Dumitru (Rusu)[1], D.C. Nita[1], R.Cs. Begy[1], L.D. Bobos[2], C. Cosma[1]

[1] Babeş-Bolyai University, Faculty of Environmental Sciences and Engineering; No. 30, Fantanele Street, Cluj-Napoca, Romania,
[2] Babeş-Bolyai University, Faculty of Chemistry and Chemical Engineering, No. 11 Arany-Janos, Cluj-Napoca, Romania

The measurements of uranium isotopes at low-level activity concentration are of a great interest in many fields such as nuclear industry, health physics, waste management, radiological protection and environmental science. Therefore, there is an increasing demand for accurate measurements of this radionuclide in various samples. Alpha spectrometry is commonly used to obtain the isotopic composition of this element in different matrixes at low specific activity. Electrodeposition procedure can produce excellent sources for alpha spectrometry. A good electrodeposition approach will result in a thin, uniform source which will produce a good resolution of the spectrum. In the present work measurements of uranium electrodeposition were performed and a simple method was used to design and set up an electrodeposition device for the alpha-emitting nuclides. Deposition was carried out onto polished stainless steel disks acting as cathode, while the anode was a platinum wire folded in the base into spiral shape. The parameters, such as, current density, type of electrolyte and the deposition time conditions were optimised such that preliminary results show a very good energy resolution of the spectrum. The measurements were performed by using an ORTEC SOLOIST alpha spectrometer with two PIPS detectors and the data acquisition was made by ASPEC-927 Dual Multichannel.

Keywords: uranium, electrodeposition, alpha-spectrometry, energy resolution

RADIONUCLIDE CONTENT IN LAUNDRY DETERGENTS AVAILABLE IN SERBIAN MARKET

I. Vukanac, A. Kandić, M. Đurašević, B. Šešlak, I. Čeliković, Z. Milošević

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

Three main ingredients of modern laundry detergent or washing powder are builders (50 % by weight, approximately), the alkylbenzenesulfonate surfactant (15 %), and bleaches (7 %). One of the most common builders (water softeners) is sodium triphosphate. Mainly, detergent ingredients have low biodegradation rate in environment resulting in a number of negative effects. Additionally, heavy use of soluble sodium triphosphate eventually discharged into natural waters lead to problem with eutrophication of lakes and streams. Also, phosphate deposits can contain significant amounts of naturally occurring heavy metals (cadmium, lead, nickel, copper, chromium, and uranium). For these reasons wastewater containing phosphate detergents should be directed to the sewerage system.

In order to provide a high level of protection of the environment, the European Union introduced regulations to require biodegradability in all detergents in 2004 [1], and intends to ban phosphates in domestic products from 2013 [2].

Presence of the phosphates in sample, in most cases indicates the presence of uranium and its daughter products. In order to perceive the radiological aspect of environmental pollution by wastewater, the analysis of laundry detergent available on Serbian market was undertaken. Measurements were performed by means of HPGe gamma spectrometer (35 % relative efficiency) in accordance with international recommendation [3]. Ten samples were placed in Marinelly bakers, sealed for six weeks and after reaching radioactive equilibrium measured. Total count rates in recorded spectra ranged from 2.32 $s^{-1}kg^{-1}$ to 3.69 $s^{-1}kg^{-1}$. Specific activities of ^{210}Pb ranged from 3 to 11.1 $Bqkg^{-1}$, ^{40}K from 1.25 to 22.2 $Bqkg^{-1}$, ^{226}Ra from 0.1 to 8.6 $Bqkg^{-1}$; concentrations of ^{238}U and ^{232}Th were up to 6.6 $Bqkg^{-1}$ and 1.1 $Bqkg^{-1}$, respectively, while artificial radionuclides were below MDA ($^{137}Cs<0.04$ $Bqkg^{-1}$).

Analysis of the obtained results showed that laundry detergents mostly used in Serbia have low content of radionuclides, but still considering the quantities used annually (~10^7 kg), this aspect of environmental pollution through wastewaters can not be neglected. Also, it should be mentioned that in facilities for wastewater treatment during the technological processes involved in water purification, precipitation and accumulation of radioactivity can occur, although the content of radionuclides is not expected to be high.

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SCINTIGRAPHIC EVALUATION OF CONSTIPATION IN CHILDREN WITH DYSFUNCTIONAL ELIMINATION SYNDROME – PRELIMINARY RESULTS

Vesna D. Zivkovic[1], Milica Lazovic[1], Ivona Stankovic[1], Marina Vlajkovic[2], Milos Stevic[2], Andjelka Slavkovic[3], Ivona Djordjevic[3], Zorica Jovanovic[3]

[1] Clinic of Physical Medicine, Rehabilitation and Prosthetics
[2] Department of Nuclear Medicine
[3] Clinic of Paediatric Surgery, Clinical Centre Nis, Serbia

Aim: To evaluate the type of constipation according to the colonic transit time, in children with dysfunctional elimination syndrome (DES) and to compare the results with transit type from children with chronic functional constipation without voiding dysfunction (control group).

Patients and methods: Seventy-three children 5-16 years old were included in the study. Medical history, physical examination including digital rectal examination, measurement of rectal diameter by transabdominal ultrasound and radionuclear transit scintigraphy were performed in all children. Thirty-three children with functional voiding disorders additionally kept voiding diary, and underwent urinalyses and urine culture, ultrasound examination of bladder and uroflowmetry. The radiopharmaceutical was prepared by adding diethylenetriamine pentaacetic acid labeled with 99m-Tc pertechnetate to granular carbon. Sequential images of the abdomen were taken at 6, 24, 48, and at 72 hours if radioactivity was not cleared from the colon. Segmental colonic transit was analyzed visually and semi-quantitatively by calculating the geometric centre from the different anatomic regions of the colon. Patients were categorized as having either slow transit constipation or functional fecal retention. Results were compared between the groups.

Results: Slow transit constipation was found in 17 out of 33 children (51%) with DES compared to 10 out of 40 children (25%) with chronic functional constipation without voiding dysfunction ($p<0.02$). Functional fecal retention was diagnosed in 16 children with DES (49%) and 30 children (75%) without voiding disorders.

Conclusions: Children with DES have a more severe type of constipation (global colonic delay) compared to children with constipation without voiding disorders in whom segmental rectosigmoid retention prevailed. Further trials are needed to draw definitive conclusions.

INCREASE OF ANIMAL SURVIVAL BY PRE-TREATMENT OF X-RAY IRRADIATED RATS WITH MN(II) AMINO ACID SCHIFF BASE COMPLEX

Margarita Malakyan

Scientific Centre of Radiation Medicine and Burns, Yerevan, Armenia

In white rats exposed to X-ray irradiation at 8.7 Gy and 6.0 Gy dose levels with 1.98 Gy dose rate the Mn(II)(Nicotinyl-L-Tyrosinate) chelate complex was studied as radioprotector. These radioprotective studies included single subcutaneous or oral pre-treatment of animals with 10 mg/kg or 20 mg/kg Mn(II)(Nicotinyl-L-Tyrosinate) at times of 24, 3 or 1 hr prior to radiation exposure.

According to the results obtained, pre-treatment with Mn(II)(Nicotinyl-L-Tyrosinate) was reflected in essential improvement of survival indices in the irradiated animals. Thus, in case of irradiation at 8.7 Gy ($LD_{100/30}$) either oral or subcutaneous mode of administration facilitated the increase of 30-day survival indices in animals up to 30-50%.

The survival of animals subcutaneously treated with Mn(II) chelate 1 and 3 hours prior to radiation exposure at 6.0 Gy amounted 100% vs. 45%-55% in Control groups. Upon oral administration the mentioned compound into the organism the less expressed radioprotective effect was produced: survival in 30 days after exposure made only 70%-80%.

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COPPER COMPLEXES OF SCHIFF BASE AMINO ACID DERIVATIVES AS MODULATORS OF IMMUNE RESPONSE AND ANTIOXIDANT CAPACITIES OF THE ORGANIZM

L.G. Zhamharyan[1], V.A. Ayvazyan[1], E.A. Arakelova[1], T.Zh. Hovsepyan[1], M.H. Malakyan[2], A.S. Boyajyan[1]

[1] Institute of Molecular Biology, National Academy of Science of the Republic of Armenia
[2] Scientific Centre of Radiation Medicine and Burns, Ministry of Health of the Republic of Armenia

Introduction: Despite the substantial amount of research aimed at development of radioprotectors, there is still a need in reliable and efficient radioprotectors. In addition, accounting for diverse effects of ionizing radiation targeting many important systems of the organism, recent studies are focused on development of multifunctional radioprotectors. In line with these tendencies, we investigated the ability of newly synthesized copper complexes of aromatic amino acid Schiff base derivatives to modulate the activity of both antioxidant and immune systems of the organism under conditions of ionizing radiation.

Material and Method: Experiments have been performed in white male rats with 160-180 g of weight. The animals were divided into the following four groups: 1. Intact animals (Norm); 2. Irradiated control animals (5 Gy); 3. Animals treated subcutaneously with promising radioprotectors 1 hour prior to irradiation: 10 mg/kg. Cu(II)(picolinyl-L-tryptophanate)2, Cu(II)(nicotinyl-L-tryptophanate)2 and Cu(II)(isonicotinyl-L-tryptophanate)2. Blood samples were collected on the 3, 7, 14 and 28 days after irradiation. Each sample was divided into two aliquots: one was used for obtaining serum for ELISA; another was immediately used for measurement of enzymatic activities. Superoxide dismutase (SOD) and catalase activities in hemolysed erythrocytes were determined using spectrophotometric assay. Serum concentration of the IL-1β was determined by ELISA, using commercial kit (Gen-Probe Incorporated DIACLONE SAS, France) according to manufactures' instruction. Serum concentrations of the immune complex subpopulations containing C1q and C3d complement system split products (C1q-CIC and C3d-CIC, respectively) were determined by ELISA, using commercial kits (IMTEC, Human, Germany).

Results: According to the data obtained, compared to Norm a statistically significant decrease in SOD activity in the lysate of erythrocytes of irradiated control animals was observed. In case of catalase, a significant increase in this enzyme activity was detected in irradiated animals as compared with Norm. Increased levels of the IL-1b and C1q-CIC in the serum of irradiated animals, compared Norm, were observed as well. Noteworthy, when animals were treated with Cu(II)(nicotinyl-L-tryptophanate)2 or Cu(II)(isonicotinyl-L-tryptophanate)2 before irradiation, sharp decrease in SOD activity was observed compared with the irradiated control animals, while treatment with Cu(II)(picolinyl-L-tryptophanate)2 before irradiation leads to SOD activity increase up to Norm. The same effects were observed in case of catalase. All tested prospective radioprotectors influenced positive changes in the levels of IL-1b and C1q-CIC.

Conclusion: Cu(II)(picolinyl-L-tryptophanate)$_2$ is able to reactivate antioxidant capacity of the organism and possess immune modulating properties under the exposure to ionizing radiation.

Acknowledgements: The research was performed due to the financial support of International Science and Technology Center in the frames of ISTC A-1764 Project.

INVESTIGATION OF ANTIRADIATION ACTIVITY OF CU(II) COMPLEXES WITH SCHIFF BASES DERIVED FROM L-TRYPTOPHAN AND ISOMERIC PYRIDINECARBOXALDEHYDES

Margarita Malakyan

Scientific Centre of Radiation Medicine and Burns, Yerevan, Armenia

Radioprotective properties of new organometallic copper complexes with Schiff Bases derived from L-Tryptophan amino acid and isomeric 2-, 3-, and 4-pyridinecarboxaldehydes (picolinealdehyde, nicotinealdehyde, and isonicotinealdehyde) were investigated in white rats.

The studied compounds were subcutaneously or orally administered to the organism at the dose levels of 10 mg/kg and 40 mg/kg as a water suspension preliminary grinding the mentioned compounds into powder and using de-ionized water as a solvent. Then, in 1 hour or 24 hours animals were exposed to single irradiation by X-rays at the lethal dose equal to 880 R ($LD_{100/30}$) with the help of RUM-17 device. Animals irradiated on the background of an appropriate volume of de-ionized water administered to the organism (0.5 ml per a rat with body weight of 200 g) served as a Control. During 30 days after the exposure to ionizing radiation the indices of the average life-span (ALS) of animals and their survival were determined.

According to data obtained, upon all the applied schemes of animal pre-treatment the radioprotective effects were not manifested only in case of Cu(II) complex with the ligand, for the synthesis of which the isonicotinaldehyde (4-pyridinecarboxaldehyde) was used. Two other metallocomplexes provided radiation protection and facilitated survival increase of pre-treated irradiated rats.

The use of Cu(II)(picolinyl-L-tryptophanate)$_2$ for animal pre-treatment revealed that the most pronounced radioprotective effects were recorded. Under subcutaneous administration of 10 mg/kg of this complex 1 hour prior to the exposure the indices of animal survival and their ALS were equal to 50% and 23.7 days, correspondingly, while at 40 mg/kg dose level Cu(II)(picolinyl-L-tryptophanate)$_2$ provided 40% survival of animals with 21.4 days ALS.

Under oral administration of 10 mg/kg Cu(II)(nicotinyl-L-tryptophanate)$_2$ 1 hour and 24 hours before irradiation at 880 R correspondingly 40% and 50% of exposed rats survived to the end of observation period.

On the base of the performed studies it might be concluded that amongst the copper complexes obtained with Schiff Bases derived from L-Tryptophan and pyridinecarboxaldehydes only those are active as radioprotectors, in which 2- or 3- isomeric pyridinecarboxaldehydes are used for the ligand synthesis. The mentioned organometallic copper complexes have a low toxicity profile and exhibit a long window of protection, i.e., they provide protection when administered either 1 or 24 hours before roentgen irradiation. They manifest good radioprotective effects in case of both subcutaneous and per oral modes of administration to animal organism.

Acknowledgements: The research was performed due to the financial support of International Science and Technology Center in the frames of ISTC A-1764 Projects.

MEASUREMENTS OF NATURAL EXPOSURES IN DWELLINGS AND RADON CONCENTRATION IN THE WATER SOURCES IN TONEKABON AND RAMSAR CITIES OF IRAN

M. Amirzadi[1], S.M. Hosseini Pooya[2,3], M. Taheri [2], A. Babakhani[2,4]

[1] Department of physics, Faculty of Sciences, Azad University –Tehran Branch, Tehran, Iran.
[2] National Radiation Protection Department, Iran Nuclear Regulatory Authority, Tehran Iran
[3] Radiation Application Research school, Nuclear Science & Technology Research Institute (NSTRI), Tehran, Iran
[4] Plasma Physics and Nuclear Fusion Research School, Nuclear Science and Technology Research Institute, Tehran, Iran

The natural exposure due to the gamma and radon concentration in 100 number of dwellings in Tonekabon city have been measured using TLD and radon diffusion chamber respectively during four seasons. As well the solved radon concentration in the water sources (e.g. natural water sources and fish pools) in both Tonekabon and Ramsar cities have been measured using active and passive methods (i.e. ZnS scintillation detectors and homemade radon diffusion chambers).

The results show the average gamma dose of 4.02±1.17 μSv.day^{-1} and average radon concentration in air of 234.58 ± 139.345 Bq/m^3 in the dwellings. The maximum concentration of solved radon in water in Ramsar and Tonekabon have been measured 198 ± 30 and 109 ± 16 Bq.l^{-1} respectively.

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THE CHOICE BETWEEN TWO METHODS FOR GLOMERULAR FILTRATION RATE MEASUREMENT IN DIFFERENT STAGES OF RENAL DISEASES

M. Rajić, M. Vlajković, S. Ilić, M. Stević, G. Lilić, M. Kojić, I. Mišić

Department of Nuclear Medicine, University of Niš, Medical School and Clinical Center Niš, Serbia

Aim: To determine the level of accordance between glomerular filtration rate (GFR) obtained by Modification of Diet in Renal Disease (MDRD) Study formula and technetium-99m (^{99m}Tc) diethylene triamine penta-acetic acid (DTPA) clearance in different stages of type 1 diabetes mellitus (DM) and chronic primary glomerulonephritis (GN).

Methods: GFR was estimated in 67 patients with DM (age 19-69 years, serum creatinine 48.0-419 μmol/l) and 52 patients with GN (age 20-70 years, creatinine 65.0-242 μmol/l) as well as in 37 healthy subjects (age range 22-63 years). ^{99m}Tc-DTPA clearance (ml/min/1.73m^2) was calculated from the regression equation based on high correlation between distribution volume of radiopharmaceutical and clearance values obtained by multiple blood samples: $y=-0.0128x^2+3.077x-30.3$ (y=clearance, x= distribution volume). Volume of distribution was calculated from blood sample taken 3 h after radiopharmaceutical injection. Activity of dose and sample was counted in a well counter. MDRD-GFR (ml/min/1.73m^2) was calculated from equation: 186 x serum creatinine (μmol/l/88.4)$^{-1.154}$ x age (years)$^{-0.203}$ x 0.742 if female.

Results: DM (91.6±24.0 vs. 126±20.2) and GN (79.3±14.0 vs. 111±13.3) patients with DTPA-GFR ≥90 ml/min/1.73m^2 as well as healthy subjects (97.2±24.0 vs. 122±11.9) had lower MDRD-GFR than DTPA-GFR ($p<0.0001$). In patients with DTPA-GFR 60-89 and <60 ml/min/1.73m^2 GFR obtained by two methods did not differ.

Conclusion: According to our results, priority may be given to ^{99m}Tc-DTPA clearance method for GFR estimation in the earlier stages of DM and GN. If it is expected that these patients have a mild or a moderate to severe decrease in GFR adequate monitoring of disease progression is better performed by MDRD equation, due to its simpler implementation.

Key words: type 1 diabetes mellitus; primary glomerulonephritis; glomerular filtration rate; ^{99m}Tc-DTPA clearance; MDRD formula.

CLINICAL ROLE OF SOMATOSTATIN ANALOGUES SCINTIGRAPHY IN PATIENTS WITH CARCINOID TUMORS

Marina Vlajkovic[1], Milena Rajic[1], Milos Stevic[1], Slobodan Ilic[1], Milovan Matovic[2]

[1] Center of Nuclear Medicine, Clinical Center Nis
[2] Center of Nuclear Medicine, Clinical Center Kragujevac, Serbia.

Objectives: Since somatostatin receptors are often overexpressed in patients with carcinoid tumors, the purpose of this study was to assess the role of the somatostatin analogue 99mTc-EDDA-HYNIC-TOC (99mTc-Tektrotyd) scintigraphy in diagnosing and staging the patients with carcinoids, and to correlate the scan results with the final diagnosis and biological markers.

Methods: Fifty-five patients (26 female, 29 male; age range: 33-76 years; mean age: 57,8±11,5 years) were studied: 11 patients highly suspected of having a carcinoid and 44 patients who had undergone the surgical removal of the tumor. Whole body and SPECT scans were obtained for all patients. After the reconstruction of the radiopharmaceutical according to the manufacturer's instruction, 740 MBq activity and 8 μg of octreotide were injected to the patients. Blood chromogranin A level was determination in all patients.

Results: Positive scan results, defined as detection of either primary tumor or/and metastatic spreading, were found in 28 patiens, and negative scan results in 27. Overall sensitivity on patient basis was 79%, specificity 85%, positive and negative predictive value 85% and 79%, respectively. The values of serum chromogranin A were increased in majority of the patients with pathological scan and a high correlation was found between the results of 99mTc-Tektrotyd scan and the biological marker (R= 0,784; p<0,001).

Conclusions: The 99mTc-Tektrotyd somatostatin receptor scintigraphy was found as a sensitive method for diagnosing and staging patients with carcinoid tumors. It can be used in clinical practice for preoperative evaluation, localisation of local recurrence or distant metastases.

Research Support: This work has been financed by the Ministry of Science and Technology Development of the Republic of Serbia, under the project 43011

THE PRESENCE OF RA ISOTOPES IN DRINKING WATER IN ALBANIA

Florinda Cfarku, Elida Bylyku

Centre of Applied Nuclear Physics, Faculty of Natural Sciences, Tirana University, Tirana, Albania

The Radium in ground water under oxidizing conditions co precipitates with Mn- and Fe-oxi- hydroxides and thus it is trapped. Fresh waters having been in a longer contact with such geological formations (>10 to 20 days) are enriched with its daughter Radon with 3,8 days half-life. Under reducing conditions and in saline waters, ^{226}Ra and ^{228}Ra usually remain dissolved and waters have higher concentrations. ^{226}Ra as member of the Uranium-Series is a long lived α-emitter. As such it plays a dominant role in drinking water radioactivity and is considered a key nuclide and a tracer for natural radioactivity.

^{228}Ra of the Thorium-Series is reported a low energetic β-emitter with 39 keV maximum energy. Because of the various α-decaying daughter nuclides it is considered as more hazardous. Normally present in considerable lower concentrations, it can exceed ^{226}Ra in water reservoirs of Th-containing geological formations. Once chemically separated, ^{228}Ra forms ^{228}Ac can be used for its quantification.

As a consequence of the ICRP 65 recommendations the European Community in their directives 98/83 EC in 1998 demands for the control of radioactivity levels in water for human consumption. This has been extended in 2001 as well to Radon and long lived daughter nuclides. As a consequence the member states are enforced to transfer these directives into national legislation. An action level of 0.1 mSv/a for the total natural radiation exposure from drinking water has been fixed.

In this study we present the measurements of ^{226}Ra and ^{228}Ra in some drinking water sample from different regions of Albania. The values for ^{226}Ra range from 10 mBq/L to 29 mBq/L and for the ^{228}Ra from 4.7 mBq/L to 14 mBq/L.

Keywords: Radioactivity monitoring, Radium isotopes, Uranium series, water sample, action level.

MCNP MODELING OF BREASTS FOR DOSE CALCULATION IN MAMMOGRAPHY AND PEM: A COMPARATIVE STUDY

T.S. Niknejad, S. Setayeshi

Faculty of Nuc. Eng. & Phy., Amirkabir University of Technology, Hafez St., Tehran, Iran

This study mainly focused on comparison of X-ray mammography and PEM scanning by comparing the amount of dose delivered per scan to different breast tissue types. The calculation is performed using MCNP. Breast is modeled with two tissue types: adipose and fibroglandular tissues. A malignant tumor tissue was also considered within the breast. To account for back-scatter from the body, the torso of the patient was modeled. Moreover, a thin layer of skin modeled to enclose the organ. The absorbed dose of each breast tissue types were calculated using external and internal dosimetry methods for X-ray mammography and PEM scanning. The simulated measurements were compared with reported data.

ANALYSIS OF APPLICATION OF MEAN GLANDULAR DOSE AND FACTORS ON WHICH IT DEPENDS TO PATIENTS AGED 65 TO 80

Suad Kunosic[1,2], Suada Kunosic[3], Samek Davorin[4], Amila Halilcevic[5]

[1] Department of Physics, Faculty of Natural Sciences and Mathematics, University of Tuzla, B&H
[2] Department of Biophysics, Medical Faculty, University of Tuzla, B&H
[3] Department of Physics, General Program Secondary School "Mesa Selimovic" in Tuzla, B&H
[4] Department of Biophysics, Faculty of Veterinary Medicine, University Sarajevo, B&H
[5] Department of Medical Diagnostics /Radiology, Public Health Institution "Health Centre Tuzla", B&H

Every year there are new 1600 cases of breast cancer in Bosnia and Herzegovina. The most effective method for early detection of breast cancer is mammography. To examine risks and benefits of this diagnostic method it is necessary to determine patient doses. Mainly, almost all published data about patient doses refer to two specific age groups: 40-49 and 50 -64 years of age. Very little data about patient doses applied during a routine mammography for patients from 65-80 years of age are available. During the conducted research, one calculated doses for the complete mammographic examination of 42 patients from this age group. The calculated patient doses are related to the whole spectrum of technical, physical, clinical and diagnostic parameters which compose a complete mammographic examination.

IRRADIATION OF BLOOD AND BLOOD PRODUCTS

V. Mijucić, I. Filipović - Lješković

Oncology and Radiology Institute, Belgrade, Serbia

Graft-versus-host disease (GVHD) is a rare but fatal complication almost always, which can be caused by blood transfusion or blood products. Contaminating donor T cells, entered by transfusion, proliferate and then interact with recipient cells leading to the occurrence of clinical GVHD symptoms, usually involving the skin, gastrointestinal tract, bone marrow, liver, spleen and thymus . Risky products are: erythrocytes, platelets, granulocytes and fresh i.e. unfrozen plasma. With today's technological level, complete elimination of contaminating blood lymphocytes from donor s blood by blood filtration is not possible. There, radiation of blood and blood products, in order to devitalize donor lymphocytes, is the only reliable way to prevent diseases caused by blood transfusion graft-versus-host (TA-GVHD).

Blood irradiation is normally performed by a specially designed device (blood irradiator), using long half-life radioactive isotope (Cs139 gamma radiation isotope) as a source of radiation. In the absence of these devices, blood can be irradiated by applying adequate doses of x-rays from standard radioterapeutic equipment (linear accelerator), or by ultraviolet radiation. In order to prevent the occurrence of TA-GVHD, blood and blood products have to be irradiated by a single dose of at least 25 Gy and maximum 37.5 Gy.

Clinical indications for irradiation of blood and blood products to prevent TA-GVHD can be divided into absolute and relative.

Another indication for the irradiation of blood and blood products is the intraoperative autologous transfusion (IOSK) in oncological surgery with aim of devitalization of malignant cells. The dose required is 50 Gy. IOSK procedures in oncological surgery can be safe only if the patient's blood is irradiated before reinfusion. Dose of 50 Gy safely inactivates proliferative activity of cancer cells without adverse effects on blood cells.

Irradiation of blood units may have a potential risk to the patient primarily because of the possibility of malignant transformation of cells with a nucleus that are found in blood products, which theoretically can survive in the blood of the recipient. There is also a danger of occurrence of infectious disease due to reactivation of the virus during irradiation. However, the number of documented cases was far less than the benefits of receiving irradiated blood for the patient, and therefore the need for such products is on the rise.

DETERMINATION OF DEPLETED URANIUM IN THE RIVER IBAR

Zoran Jovanović, Dragoslav Nikezić, Dragana Krstić

University of Kragujevac, Faculty of Science, R. Domanovica 12, Kragujevac, Serbia

During the NATO air strikes in 1999, there was some amount of the contamination of the ground with depleted uranium in the upper basin of the river Ibar. This caused numerous discussion and speculation about radiation danger which were threatening to the people in that area and in the wider region. One of potential dangers of depleted uranium is breaking through water flows, rivers, streams, etc. The aim of the work is to measure the relation of isotope uranium $^{238}U/^{235}U$ in the water of the river Ibar. Measuring of uranium isotope and determining of isotope abundance in the water samples can be done in several ways such as alpha or gamma spectroscopy. Alpha spectroscopy has been applied in this work. According to the findings of this study, there was some disturbance of the natural isotope ratio of $^{238}U/^{235}U$. Instead of 140, it has been found 151.4 at the location I; 163.8 at the location II, and 192.0 at the location III. This small increase of ratio suggests that there is some possibility that depleted uranium penetrated to central Serbia through the river Ibar. Further investigation is necessary to establish whether disequilibrium is natural or it came from NATO strikes.

EFFECTS OF LOW INTENSIVE 900-MHZ RF-EMR ON ANIMAL BLOOD INDICES AFTER SINGLE ACUTE OR FRACTIONAL TOTAL BODY EXPOSURE

S. Bajinyan, M. Malakyan, D. Yeghiazaryan, H. Aghjoyan, L.Vardevanyan

Scientific Centre of Radiation Medicine and Burns, Yerevan, Armenia

Functional indices of blood plasma and erythrocytes of white rats exposed to low intensity radio-frequency electromagnetic radiation (RF-EMR) were studied.

In order to perform irradiation each experimental group of 20 animals was placed in well-ventilated plastic box (25 x 22 x 15 cm^3) and exposed to whole body treatment with microwaves of 900-MHz frequency using a generating unit of X1-42 panoramic instrument with 8-10 mWt output power and 7 $\mu Wt/cm^2$ power density. Two modes of irradiation were used: a) 1-time action during 2 hours, i.e. single 2-hour acute exposure; b) fractional exposure to RF-EMR during 4 consecutive days for 0.5 hour daily. Sham-treated rats served as a Norm.

On days 1, 5, 10 and 20 after the last exposure 5 rats per observation day were sacrificed under light anesthesia with ethyl ether and blood samples were drawn to determine intensity of lipid peroxidation in blood plasma (LPO_{pl}) and erythrocytes (LPO_{er}), integral antioxidant activity of water-soluble non-enzymatic antioxidants (AOA WSNEAO) of rat blood plasma, erythrocyte membrane potential E_m, K^+ permeability across the erythrocytes membranes (P_K), functional state of the Ca^{2+}-activated K^+-channels of erythrocytes ($P_{Ca\text{-}K}$).

According to data obtained, 900-MHz RF-EMR caused statistically significant changes in the studied parameters both in early and late observation periods. Hence, the character and the dynamics of changes depended on the mode of irradiation. Thus, on day 1 after 2-hour acute exposure an enhanced intensity of LPO_{pl} was observed along with inhibited AOA WSNEAO. However, on the other observation days a significant decrease of LPO_{pl} was accompanied with the pronounced elevation on AOA WSNEAO. In case of rats fractional exposure to RF-EMR very low values of LPO_{pl} indices were obtained on days 1 and 5 that was associated with the high AOA WSNEAO of blood plasma. Then, in the late periods an increase in LPO_{pl} activity on day 10 and recovery of this parameter on day 20 were concurrent with the corresponding low level of AOA WSNEAO on day 10 and normalization of LPO_{pl} on day 20.

Significant high indices of LPO_{er} were registered in animals in all periods of investigation either after the single prolonged or fractional exposure to 900-MHz EMR.

On day 1 post the single 2-hour acute exposure and on days 10 and 20 after fractional irradiation a hyperpolarization of erythrocytes membranes with a significant increase of E_m absolute value was recorded.

Only on day 20 after fractional irradiation significant high levels of erythrocytes P_K and $P_{Ca\text{-}K}$ were obtained, while in other study periods there were no essential changes of these indices. In case of single long-lasting exposure of animals to 900-MHz EMR an enhanced total K^+ outflow from erythrocytes was observed in the late periods that were maximally expressed on day 10. As to Ca^{2+}-depended K^+-channels of erythrocytes, the pronounced activity was observed on day 1 with certain attenuation on day 5, while at later period a significant exhaustion of $P_{Ca\text{-}K}$ was noted.

Thus, a conclusion can be drawn that low intensive EMR with 900 MHz frequency possesses an apparent biological activity and upon total influence on the organism facilitates development of long-lasting effect manifested as changes in functional characteristics of blood plasma and red blood cells.

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PROPOSED USE OF MAGNETIC RESONANCE IN THE EVALUATION OF THE SAFETY OF MECHANICAL DEVICES FOR PHYSICAL TRAINING: A STUDY OF SUBJECTS UNDERGOING TRAINING WITH EXPERIMENTAL APPARATUS

Messa Luca Valerio[1], Paradiso Claudio[2], Messa Enrico Matteo[3], Messa GianLuca[4], Arrigucci Umberto[5]

[1] Biomedical Engineer, Siena, Italy
[2] Neurophysiologist, Grosseto, Italy
[3] ECDL Operator, Siena, Italy
[4] Internal Medicine, Siena, Italy
[5] U.O.C.- NINT, AOUS, Siena, Italy

Background. Magnetic Resonance, through the use of imaging (Magnetic Resonance Imaging – MRI), is a widespread method in clinical practice, due to its high resolution of contrast, in the absence of ionizing radiation. We used this technique of investigation to assess the changes induced on the cervico-dorsal axial musculature by the use of an experimental mechanical device.

Materials and Methods. The study was performed before and after a training period, which consisted of lifting a weight of 6kg using a newly developed system of pulleys: 2 subjects, in a group of 9 healthy volunteers (6 males and 3 females aged between 22 and 64 years), who participated in the study, were evaluated with MRI (AVANTO 1,5T , AG SIEMENS Erlangen, Germany), at the beginning and at the end of the training period.

In all the subjects was assessed the Surface Electromyography (EMG), with electromyograph MEDELEC SAPPHYRE 1P, derived from muscles Upper Trapezius, Lower Trapezius and Teres Major, during 4 phases of the Motory Task: Rest position (1), Contraction during lifting (2), Return phase (3), Final phase of rest (4). The Motory Task was of 2 + 2 minutes of performance duration with a recovery interval of 2 minutes and it was performed daily (morning and evening) for 30 days.

Results. The EMG demonstrated in all the subjects a uniform percentage of activation in Phase 2 compared to Phase 1, on average equal to +166% for the Lower Trapezius and +192% for the Teres Major, associated to a corresponding de-contraction of 66% for the Upper Trapezius, detected in the same Phase 2.

This finding confirms the involvement of muscles with a fulcrum on the cervico-dorsal spine and possibly agents on the stretching of the spinal tract, during the Motory Task performance.

In subjects undergoing MRI, after 30 days of physical training, the morphometric analysis showed a slight change of the maximum transverse thickness also of the deep muscles compared to that observed at the initial examination. This suggests a persistent increase in muscle tone.

Conclusions. This data, although obtained in a limited series, suggest the validity of the use of MRI in the study of the effects induced by physical training exercises performed by the proposed equipment.

The results confirm the validity of the proposed MRI for an extended research on the function evaluation of the new generation mechanical devices for physical training order to achieve security that their use does not produce, to the musculoskeletal apparatus, damages which, in some cases, could be higher than expected benefits.

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NON - IONIZING RADIATION MEASUREMENTS IN VOJVODINA

**Ištvan Bikit, Dušan Mrđa, Nikola Jovančević,
Mile Ugarčina, Nebojša Krstić, Slavko Todorović**

Department of Physics, Faculty of Sciences, University of Novi Sad, Trg D.Obradovica 4., Novi Sad, Serbia

The number of sources of Non - Ionizing radiation, especially cellular phone network stations, is steadily increasing. Due to the fact that the impact of electromagnetic fields (EMF) on human health is not yet fully understood, the public concern on the increasing EMF levels in cities is present.

In this work, the results of the first systematic survey of EMF levels in Vojvodina are presented. During the year 2011, in more than 10 major cities low-frequency and high-frequency EMF are performed environmental "spot" broadbend and frequency-selective measurements. In each city one radio emission antenna, one cellular phone network station, one high voltage power transmission line and transformer station was measured at about 10 locations. In the low-frequency region (to 100 kHz) the electric field strength and magnetic induction have been measured while in the high-frequency region (100 kHz to 300 GHz) the electric field strength was measured.

Analyzing the collected data, it is shown that even in the worst case scenario the total impact of the EMF levels is not bigger than 60 % of the authorized limiting values.

ASSESSMENT OF SAR IN THE HUMAN HEAD CAUSED BY MOBILE PHONES WITH THE MEASUREMENT OF THE EMITTED ELECTRIC FIELD

Branko Stepanovski[1], Gjorgi Spasovski[1], Trajche Trajchev[2]

[1] Military Medical Center Skopje Macedonia
[2] EKO DETEKT Accredited laboratory for testing of non-ionizing radiation

Introduction: Using specialized and calibrated equipment for assessment of non-ionizing radiation from mobile phones (Willtek Handheld Spectrum Analyzer 9102B, Antenna Coupler 4916 and RF Shield 4921) the electric field strength (E) has been measured. This field, using the attenuator (water phantom) and the appropriate calculations allows assessment of SAR - 2,5 mm depth, in the human brain.

Content: The primary goal of this research is based on measurements of the emitted electric field (E) from mobile phone to assess the Specific Absorption Rate SAR, at some point in the brain of the user.

To achieve this, it is necessary to establish such conditions that the field strength (E) before reaching the sensor of the instrument is weakened (by passage hrough a water phantom), as much as it would undermine the field passing through the tissues of head (skin, ear shell, skull bone, brain liquid) and reach the point at a depth of 2,5 mm in the human brain.

The equation for transformation of the measured electric field E into the operational quantity SAR, in near field conditions, according the standard EN 50413, has the following shape:

SAR = σ/(2ρ) *|Ei|2 where:

σ - specific conductivity at the point of measurement in brain tissue (S/m)

ρ - mass density at the point of measurement in brain tissue (kg/m3)

Ei - rms electric field strength at the point of measurement in brain tissue (V/m)

To calculate weakening (attenuation) of the input electric field and to achieve value for Ei (attenuated electric field due to passage through the tissues of the head) is used following equation, where:

εr(пр) – average relative dielectric constant of the head tissues;

r – distance between the mobile phone antenna and the point 2,5 mm deep in the brain (average value for grown person is 3 cm).

Results: In the case of optimal received signal of the tested mobile phones, assessed SAR values are close to the values that are declared by the manufacturers, for those mobile phones (valid for an ideal case). In case of weakening of the received signal of mobile phones (real-life situation), SAR values can be increased multiple times.

Conclusion: Possibilities of the measuring equipment and the applied mathematical model opens up the doors for the following research: with change of the received signal for the tested phones, SAR assessment are made for many different real-life situations, for the same phone (in places where received signal of mobile phones is lower). For such places SAR grows dramatically, due to its dependence on |Ei|2. Then with change of the attenuation factor (changes of the thickness of water phantom), it can be determined SAR for different depths in the brain or in any other tissue, and finally with a accurately calculated SAR we can assess temperature increase at the point of measurement, located in brain tissue.

SUN'S UV RADIATION AND OZONE LAYER THICKNESS: RESULTS OF MONITORING DURING THE YEAR 2011

Z. Mijatović, R. Kobilarov

Department of Physics, Faculty of Sciences, Trg Dositeja Obradovića 4, 21000 Novi Sad, Serbia

Monitoring of Sun's UV radiation in Serbia started in 2003 while of ozone layer thickness in 2007. The station for monitoring is placed at the campus of University of Novi Sad, 45.33 N, 19.85 E, 84 m a.s.l. Standard instrument, Yankee UV-B biometer, and procedures proposed by WMO are applied for Sun's UV radiation monitoring. For ozone layer thickness measurements the Microtops II Ozonemeter is used. Obtained results for the year 2011 are presented and compared with the results obtained for the previous years.

IS THE TERRESTRIAL MAGNETOSPHERE A NATURAL RADIATION SHIELD ON MOON SPACE MISSIONS?

R. Koleva, B. Tomov, T. Dachev, Y. Matviichuk, P. Dimitrov

Space and Solar-Terrestrial Research Institute, Bulgarian Academy of Sciences

One potential method of radiation mitigation on extra-terrestrial missions is in the form of magnetic fields. For Moon missions the Earth magnetosphere is a source of magnetic field, as the Moon spends about 25% of its orbit inside it. Recent modeling results have conflicted in their conclusions as to whether the Earth's magnetotail at lunar distances is sufficiently strong to provide shielding from GCR with energies greater than 10 MeV. Using RADOM data from Chandrayaan-1 satellite we try to reveal a possible shielding. The first results show that during solar cycle minimum the magnetotail does not mitigate doses on Moon orbiter. However there is certain evidence that acceleration processes inside the magnetosphere could enhance the flux of energetic electrons at Moon orbit.

THE RESPONSE OF A1 DORSO-MEDIAL AND L1 DORSO-LATERAL GYPSY MOTH NEUROSECRETORY NEURONS AFTER ACUTE EXPOSURE TO MAGNETIC FILEDS

Larisa Ilijin, Milena Vlahović, Marija Mrdaković, Dajana Todorović, Dragana Matić, Zlatko Prolić, Vesna Perić Mataruga

Department of Insect Physiology and Biochemistry, University of Belgrade, Institute for biological research „Siniša Stanković“, Belgrade, Serbia

The effect of magnetic fields on the physiology of neuroendocrine system and developmental processes in insects are poorly examined. Neurohormones are synthesized and secrete in neurosecretory neurons. Insects' neuroendocrine system, *via* neurohormones, regulates the basic life processes and reacts quickly to environmental changes including magnetic fields effects.

The aim of our work was to overview specific and non specific responses to the acute effects of magnetic fields on different neurosecretory neurons. Neurohormones synthesized in *A1 and L1* neurosecretory neurons represent the major regulatory proteins of all biochemical, physiological and behavioral processes, and trophic factors regulating the synthesis of juvenile hormones (allatotropic factors – synthesized in A1 neurons and allatostatic factors – synthesized in L1 neurons) (Veelaert et al, 1995).

The morphometric changes (the size of neurosecretory neurons and nuclei, number of nucleoli in nuclei) and number of protocerebral dorso-medial A1 and dorso-lateral L1 neurosecretory neurons, were analyzed in *Lymantria dispar* larvae after a 3 day exposure to strong static (SMF, 235 mT) and extremely low frequency magnetic fields (ELF MF, 2 mT).

A decrease of all analyzed morphometric parameters in comparison to the control group of caterpillars were showed after acute exposure to SMF and ELF MF. In these neurosecretory neurons an increase in amount of large grained neurosecretory material was observed after exposure to SMF, while acute exposure to ELF MF led to a decrease in amount of neurosecretory material. The acute exposure of dorso-lateral L1 neurosecretory neurons to SMF did not influence all analyzed morphometric parameters, while ELF MF has increased the number and size of neurosecretory neurons. Significant decrease was observed in the size of L1 nuclei. After exposure to both magnetic fields in cytoplasm of L1 neurons a large amount of large grained neurosecretory material was present.

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PROTECTIVE EFFECT OF MELATONIN ON THYMUS OF RATS EXPOSED TO MICROWAVE RADIATION

Branka Djordjevic, Dusan Sokolovic, Andrej Veljkovic, Milena Marinkovic, Jelena Basic, Gordana Kocic, Jelenka Nikolic

Department of Biochemistry, Medical Faculty, University of Nis, Serbia. Bul. dr Zorana Djindjica 81, 18000 Nis, Serbia

Thymus plays an important role in the immune system development which can be modulated by numerous environmental factors, including MWs. Oxidative stress is the key mechanism of the microwave induced tissue injury. Melatonin, a lipophilic indoleamine primarily synthesized and released from the pineal gland is a powerful antioxidant and imunomodulator. We aimed to clarify if melatonin treatment may favorably impact on thymus tissue injury in rats exposed to microwave radiation. We explored the effects of a 3-week daily (2 mg/kg i.p.) administration of melatonin in adult rats exposed to microwaves (4 hours/day) produced by a mobile test phone (SAR 0.043-0.135 W/kg). Wister rats were divided in four groups: I (control) - rats treated with saline, II (Mel) - rats treated with melatonin, III (MWs) - microwave exposed rats, IV (MWs + Mel) - MWs exposed rats treated with melatonin. We evaluated oxidative stress parameters (malonyldialdehyde and carbonyl group content), antioxidant enzyme activity (catalase) and activity of enzyme xanthine oxidase which has prooxidative effects. Melatonin treatment markedly improved thymus tissue injury in animals exposed to microwaves. Melatonin significantly prevented the increase in malonyldialdehyde ($p < 0.05$) and carbonyl group content ($p < 0.001$) registered previously under exposure to microwaves, and reversed the effect on catalase ($p < 0.001$) and xanthine oxidase ($p < 0.001$) activity. In conclusion, melatonin exerts potent antioxidant effects in thymus of rats exposed to microwaves.

Keywords: Melatonin, Microwaves, Thymus, Oxidative stress.

MODELING OF PENETRATING ELECTROMAGNETIC FIELDS OF MOBILE PHONES IN EXPERIMENTAL ANIMALS

Dejan Krstić[1], Darko Zigar[1], Dejan Petković[1], Nenad Cvetković[2], Vera Marković[2], Nataša Đinđić, Boris Đinđić[3]

[1] Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, Niš, Serbia, e-mail: dejank@znrfak.ni.ac.rs
[2] Faculty of Electronic Engeenering, University of Niš, Aleksandra Medvedeva 14, Niš
[3] Medical Faculty, University of Niš, Bulevar Zorana Đinđića 81, Niš

This paper presents an example of a numerical modeling of electromagnetic field components originating from a mobile phone that was used in the experiment of investigating biological effects of penetrating fields on experimental animals - rats. The components of the electromagnetic field in the body of rats and all its organs have been calculated, as well as the absorbed energy density and SAR.

***Key words**:* modeling, EM field, numerical methods, experimental animals

IMMUNOPATHOGENIC ROLE OF GSM-900MHZ ELECTROMAGNETIC FIELD EXPOSURE THROUGH EARLY THYMUS INVOLUTION IN RATS

Boris Djindjic[1], Jovica Jovanovic[2], Natasa Djindjic[3], Dejan Krstic[4], Darko Zigar

[1] Instute of Pathophysiology, Medical Faculty, University of Nis
[2] Instute of Occupational Healt, Medical Faculty, University of Nis
[3] Medical Faculty, University of Nis
[4] Faculty of Working and Environmental Protection, University of Nis

Alterations in immune functions may results in ineffective responses against pathogens, reduction in tumour surveillance, and development of immune-mediated-diseases. The generation of the immune system requires a series of carefully timed and coordinated events during the prenatal and early postnatal period of mammalian development. Exposure to toxic compounds, at levels producing limited transient effects in adults, results in long-lasting or even permanent immune deficits when it occurs during early in childhood. The exposure to (Global System for Mobile communication) GSM electromagnetic field (EMF) has been implicated in many immune and neurochumoral disorders, but the variability of results still did not revealed exact pathogenetic mechanism.

The aim of this study was to investigate possible immunopathogenetic role of GSM-900 MHz electromagnetic field exposure through effects on thymus` functions and to examine the possible role of oxidative stress in this process.

Experiments were performed on 20 Wistar Albino rats (6–8 weeks old), bred at the Vivarium of the Institute of Biomedical Research, Medical faculty, Nis, under conventional laboratory conditions. All animals in control (2 cages, with 3 female and 2 male each) and the same number in experimental group were housed collectively in a pure (i.e. lacking any metallic fittings) polycarbonate cages 30x40x40cm. The animals were exposed to EMF for 60 days (4 h/day). The EMF was produced by a mobile test phone connected to a Communication Test Set (model 4202S; Wavetek, Germany) and controled by PC. In the present study, an electromagnetic near-field signal for GSM-900 MHz with continuous wave, mobile phone system was used. EMF parameters in cage were measured several times during experimental exposition. Electrical field was estimated by EMF meter AARONIA SPECTRAN HF6080 with E=9.88-18.36 V/m and magnetical field B=4.68-8.69 μT. The whole-body specific energy absorption (SAR) rate was estimated as 0.043-0.135 W/kg using data for a rotating ellipsoidal model of a rat. The intensity of lipid peroxidation in the brain tissue was measured by determination of malondialdehyde-MDA, and determination of protein oxidative modification was measered by carbonyl group concentration. After removal of thymus, thymocyte suspension was made and cell viability was determined by triptan blue. Obtained results were presented as total count of nonviabile cells.

There are increasing apoptosis and cell necrosis of thymocytes after 2 months exposure to EMF compared to control $111.75\pm33.56x10^6$ vs. $70.5\pm34.9x10^6$, ($p<0.05$). Exposure to EMF increases oxidative stress and lipid peroxidation 4±0.12 vs. 3.18±1.2 nmol/mg proteins ($p<0.01$). EMF produced a significant increase of carbonyl groups content, an index for oxidative modification of proteins, in brain after 60 days 28.97±5.59 vs. 22.51±6.37 nmol/mg proteins ($p<0.01$).

We demonstrated that EMF from mobile phones has immunopathogenetic role and caused early thymus involution, increasing apoptosis and cell necrosis of thymocytes after 2 months of exposure. Second, EMF increase oxidative damage in brain by increasing the levels of lipid peroxidation and proteins' oxidative modification, thus indicating on possible pathogenetic mechanism linking immune and neurohumoral disorders.

Key words: mobile phones, oxydative stress, thymus

ELECTROMAGNETIC COMPATIBILITY BETWEEN LTE USER EQUIPMENT AND EEG SIGNAL

A.E. Maganioti, L.S. Pragiatis, C.N. Capsalis

National Technical University of Athens, Department of Electrical Engineering, Division of Information Transmission Systems and Material Technology, 9 Iroon Polytecneioy str., Athens, 15773, Greece

The present work investigates the electromagnetic compatibility (EMC) issue that occurs when an electroencefalographer (EEG) is functioning in an environment infested with electromagnetic radiation of 4th generation mobile services.

In medical environments, the influx of technology over the past several years has permeated hospitals. Concern over electromagnetic interference (EMI) with medical devices due to mobile radio frequency (RF) equipment emissions has been identified as a very popular topic in the technical world of electromagnetic interference during the past years. What is more, The European Union has gotten much of attention with regard to the regulation of EMC and medical electronics. In this context, several studies have been conducted concerning the risks arising via RF sources of radiation and the potential for unintended consequences like EMI on specialized medical equipment [1,2]. However, the array of literature that deals with mobile radio signals' impact to health care, lacks research on the latest technology of 3+ and 4th generation protocols.

The current study involves the conduction of an experiment which evaluates the possible interference of a 3GPP Long Term Evolution (LTE) user equipment (UE) on the EEG signal. The experimental setup was situated in a Faraday screen room so that no electromagnetic interference would affect the measurements. In the Faraday room a head phantom was placed, while the supposed bioelectrical brain activity was recorded from 32 electrodes, placed on the scalp of the model-head, positioned according to the international 10-20 system of electroencephalography [3]. The signal was amplified, before entering a 32-bit analogue to digital converter. The recording frequency was at 1 kHz.

The signal was generated by an Agilent N5182A MXG RF Vector Signal Generator, placed outside the Faraday room. Subsequently, it was led to a log periodic broadband yagi antenna Series HyperLOG® 7060, with 5 dBi gain. The antenna was positioned at 1 m from the head phantom, which is an adequate distance to immunize that the electrodes were situated at the far field. The vector signal generator used for the signal transmission, introduced the innovation of non-monochromatic radiation emission.

LTE operates in several spectrum areas from 737 to 2595 MHz. Furthermore, it supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz, both frequency division duplexing (FDD) and time division duplexing (TDD) and various modulation schemes such as QPSK, 16 and 64 QAM. The measurements were performed using all possible combinations from the aforementioned parameters, as verified by the standard [4]. The EIRP of the emitted signal was constantly 10 dBm.

The results showed that the measured signals with the generator switched off are significantly different from those when it is operating in 942.5 and 2140 MHz frequencies, in all possible bandwidths and modulations, as far as FDD is concerned. As for the TDD, these differences occur in all bandwidths of 1880 MHz, while in 2017.5 MHz frequency only when the bandwidth is set on 5 MHz. In the rest cases the LTE signal seems to be electromagnetic compatible with the EEG.

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ELECTROMAGNETIC NEAR-FIELD LEVEL OF MOBILE PHONES AND THE EMBEDDED DOSIMETRIC INFORMATION

Simona Miclaus[1], Annamaria Paljanos[2], Paul Bechet[1]

[1] Nicolae Balcescu Land Forces Academy, Sibiu, Romania
[2] Technical University of Cluj Napoca, Romania

Non-ionizing radiation dosimetry for mobile telephone user's protection is presently based on the approach of measuring/calculation of the specific absorption rate of energy deposition (SAR) inside the human head. For European countries, exposure guidelines indicate that SAR values should not exceed 2 W/kg if averaged on any 10 g of head tissue. Besides SAR, no other specification is given in exposure protection standards, in case of radiofrequency (RF) sources used in their near-field, as the case of mobile phones is. While SAR is measured in phantoms by standardized procedures, it is very hard to precisely measure the electromagnetic field strength emitted by the terminal, at a few millimeters distance from its emission antenna, in air, where the head usually stays. Reference levels in standards refer to field strength in terms of equivalent plane wave (far-field condition) and procedure of human exposure assessment excludes near-field measurement techniques, which is, in fact, the case of the very proximity of a mobile terminal.

With present protective guidelines and standards, in May 2011, International Agency for Research on Cancer classified *mobile phone radiation as "possibly carcinogenic to humans"*. Many studies sustain a connection exists between phone radiation (quantified by SAR) and some forms of brain cancer. These indicate more research is needed.

In this regard, and starting from the challenge of investigating the RF near-field of a mobile phone, we aimed at two objectives: 1) to establish an association between emitted near field of a phone and its listed SAR; 2) to analyse the E-field evolution in time, during the first 10s of call initiation, in the "hot spot" of each terminal and to identify the influence of RF link parameters on this near-field evolution. Choosing the period of call initiation in our study as the duration of interest is based on the fact that the highest power of the phone is emitted during this period (call initiation).

In our study, a sample of 50 different mobile phone models was chosen and they belonged to three mobile operators in Romania. For the near-field measurements, an ESM-30 RADMAN XT exposimeter (Narda Safety Test Solutions, Germany) was used, set as data-logging device by using ESM-TS interface (Narda) to a computer. Data acquisition of both E- and H-field components was made. The probes are sufficiently small to enable reliable near-field measurement of 900/1800MHz just next to the terminals.

Experimental data provide a starting point on how reactive-near field could give complementary information valuable to complete health protection advices to consumers, besides SAR values.

Our results show that no correlation exists between emitted reactive near-field and SAR, and explanation for lack of correlation is argued. Very close to the antenna of mobile telephones very high field strengths could be measured. If we would compare them with E-field limit accepted for population safety in the far-field condition, which is of 41.25 V/m (at 900 MHz), we will see that much higher field levels were obtained in more than 50% of the cases. Starting from SARs of 0.7 W/kg, maximum E-field may overcome 100 V/m (2.4 times higher than reference level, in far-field condition).

E-field measured in the call initiation period and its dynamics (increase and decrease, until "nominal" power is achieved) allowed classification in three "call initiation curve" families, corresponding to the three mobile operators (to three different distances to the base stations). Phones are decreasing their E-field level during call initiation period, following the same law, for the same corresponding base station. But between operators (i.e. distances to corresponding base-station), call initiation curves owe specific "footprint". As a rule, the curve is more flat when distance to the base station is higher and field values stay higher than in the case when the base station is nearer to the phone. If one represents average rates of E-field decrease in "calling phase" as a function of distance terminal-base-station for the three groups of phones, one observes that for phones nearer to the base station, decrease rate of field is higher. The most important result was the empirical finding of the mathematical law by which the emitted near-field rate diminishes with distance-to-the-base station.

GROWTH INHIBITION AND DAMAGE OF MICROTUBULE STRUCTURE IN NEUROBLASTOMA CELL LINE DUE TO RADIOFREQUENCY EXPOSURE

I. Pavicic, A.M. Marjanovic, I. Trosic

Institute for Medical Research and Occupational Health, Zagreb, Croatia

Recently published studies recognized that GSM (Global System of Mobile) modulated radiofrequency radiation (RF) may affect biological systems as a result of interference with polar intracellular macromolecular chains (1, 2). The aim of study was to evaluate whether 915 MHz radiofrequency (RF) radiation affects the microtubule cytoskeleton and/or growth of neuroblastoma cell line (SH-SY5Y). RF field was generated inside a Gigahertz Transversal Electromagnetic Mode chamber (GTEM-cell) equipped by generator, power amplifier and signal modulator. Cell samples were exposed to RF field of 915 MHz, electric field strength of 30 V/m. Average specific absorption rate (SAR) was calculated at 1.6 W/kg. Cell exposure treatment lasted for 1, 2, and 3 hours. Irradiated cell groups were matched with negative- and positive control samples. Microtubule proteins were treated immunocytochemicaly, thereafter marked by IgG anti-β-tubulin (SIGMA Chemical CO, St. Louis, USA) and analyzed using a fluorescent light microscope (1000x magn.). Cell growth was determined by cell counts for each hour of exposure during ten post-exposure days. In comparison with control cells, the microtubule structure clearly altered after 3 hours of irradiation ($p<0.05$). Significantly decreased growth was noted in cells exposed for two and three hours on third, fourth and fith day after irradiation ($p<0.05$). GSM modulated radiofrequency radiation (RF) may affect microtubule complex followed by growth impairment of neuroblastoma cell line SH-SY5Y.

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BIOLOGICALLY RELEVANT THEORY ABOUT RADIOFREQUENCY RADIATION IMPACT ON CELL REDOX PROCESSES

A.M. Marjanovic, I. Pavicic, I. Trosic

Institute for Medical Research and Occupational Health, Zagreb, Croatia

Over the years due to rapid technological progress, radiation from man-made sources exceeded those of natural origin. There is a general concern regarding growing number of appliances that use radiofrequency (RF) radiation with particular emphasis on mobile communication system (1). Since non-thermal biological effects of RF radiation are still uncertain as well as their mechanisms, laboratory studies on tissues, cells and cell free system are of extraordinary importance in bioelectromagnetic research (2). We believe that such investigations play a supporting role in public risk assessment. Cellular systems with the potential for clear response to RF exposures should be used in those studies. It is known that organism is a complex electrochemical system where among many others, processes of oxidation and reduction regularly occur (3). During these reactions electrons are transferred from one molecule to another forming small amount of free radicals. Most important class among radicals is certainly presented by reactive oxygen species (ROS). Depending on concentration, ROS can have both beneficial and deleterious effects. Positive effects are connected with cell signalling, defence against infectious agents and mitogenic response. On the other hand, excessive production which overloads antioxidant defence mechanism leads to cellular damage with serious potential for disease development (4). ROS concentration increase within the cell caused by RF radiation seems to be biologically relevant hypotheses to give clear insight into the RF action at non-thermal level of radiation (5).

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HYPERSPECTRAL REMOTE SENSING OF REFLECTED AND EMITTED RADIATION AS A MEANS FOR PRESERVATION OF TERRESTRIAL ECOSYSTEMS

Dora Krezhova

Space Research Institute and Technologies, Bulgarian Academy of Sciences

Remote sensing techniques are increasingly valued as useful tool for investigation of the influence of environmental changes on the terrestrial objects for providing large-scale basic information on landscape characteristics. They are used for biodiversity determination, land change detection, monitoring of conservation areas, habitat and plant species mapping.

In this study two hyperspectral remote sensing techniques, reflectance (reflected radiation in the visible and near infrared spectral ranges) and fluorescence (emitted radiation under controlled illumination conditions) were used for investigation of the responses of some species of plants and trees to adverse changes in the environment (enhanced UV-B radiation and some stress factors). Green vegetation species all have unique spectral features, mainly because of the chlorophyll and carotenoid, and other pigments and water content. Spectral reflectance and chlorophyll fluorescence are functions of tissue optical properties and biological status of the plants, and the illumination conditions. During the last decade they find widening application as a means for monitoring and revelation of stress and diseases as well as for early diagnosis of symptoms at different stages of infections.

Hyperspectral reflectance and fluorescence data were collected by means of a portable fiber-optics spectrometer in the spectral ranges 450-850 nm and 600-900 nm, respectively. Spectral reflectance analyses were performed in four most informative for the investigated species regions: green (520-580 nm), red (640-680 nm), red edge (690-720 nm) and near infrared (720-780 nm). The statistical significance (at $p<0.05$) of differences between the reflectance of healthy (control) and injured (stressed) species were assessed by means of the Student's t-criterion. Fluorescence spectra were analyzed at five characteristic wavelengths located at the maximums of the emitted radiation and at the forefronts and rear slopes. The strong relationship, which was found between the results from the two remote sensing techniques and some biochemical analyses (stress markers), indicates the importance of hyperspectral reflectance and fluorescence data for conducting, easily and without damage, rapid health condition assessments of vegetation. This study exemplifies the benefits of integrating remote sensing and ecology and conducting of interdisciplinary investigations of terrestrial ecosystems.

Keywords: hyperspectral reflectance, fluorescence, environmental stress, ecosystems

DIELECTRIC ANALYSIS OF SUNFLOWER AND OLIVE OIL SUBMITTED TO MICROWAVE RADIATION

Margareta Pecovska Gjorgjevich, Julijana Velevska, Metodija Najdovski

Faculty of Natural Sciences and Mathematics, P.O. box 165, Skopje, R. Macedonia

The effect of microwave heating on the dielectric properties and oxidation processes of virgin and refined olive and sunflower oils were determined by dielectric and UV- spectroscopy. Samples were heated in the microwave oven (850 W, 2,450 MHz) for 0 to 14 minutes. The results show degradation of dielectric characteristics, conductivity and oxidative stability of investigated oils, increasing with the exposure time. Dielectric loss ε" decrease with increasing time of MW radiation and its maximum shifts towards higher frequencies. Conductivity of sunflower oil is increasing for two orders of magnitude, while olive oil conductivity shows very low change with MW treatment. UV spectrum shows increasing of absorptivity at 229 nm indicating production of lipid oxidation, due to formation of conjugated dienes and second peak at 269 nm due to trienes. In order to evaluate the magnitude of degradation, we compared the results of MW and conventional heating in lower temperature range until 50 ^{o}C. The differences between sunflower and olive oils characteristics were discussed.

THE EFFECT OF MELATONIN ON BODY WEIGHT AND BEHAVIOUR OF RATS DURING THE EXPOSURE TO MICROWAVE RADIATION

Dusan Sokolovic[1], Branka Djordjevic[1], Andrej Veljkovic[1], Milena Marinkovic[1], Jelena Basic[1], Gordana Kocic[1], Jelenka Nikolic

[1] Department of Biochemistry, Medical Faculty, University of Nis, Serbia. Bul. dr Zorana Djindjica 81, 18000 Nis, Serbia

Over the last two decades, due to the development of new technologies, the number and diversity of appliances (TV sets, mobile phones, PC monitors, etc.) with sources of microwave radiation (MWs) significantly increased. Nowadays we are faced with growing public concerns about the effects of chronic exposure to MWs (0.3 to 300GHz) and theirs' potentially harmful effect on human health. We aimed to clarify (1) if exposure to microwaves may cause changes in body weight and behavior of rats and (2) weather melatonin treatment may favorably impact those changes. We explored the effects of a 3-week daily (2 mg/kg i.p.) administration of melatonin in adult rats exposed to microwaves (4 hours/day) produced by a mobile test phone (SAR 0.043-0.135 W/kg). Wister rats were divided in four groups: I (control) - rats treated with saline, II (Mel) - rats treated with melatonin, III (MWs) - microwave exposed rats, IV (MWs + Mel) - MWs exposed rats treated with melatonin. Significant body weight decrease was observed in animals exposed to MW radiation, when compared to controls ($p < 0.001$). Furthermore, melatonin significantly prevented decrease in body weight ($p < 0.05$) in irradiated animals. Microwave radiation exposed animals showed anxiety related behaviour (agitation, irritability) after only 10 days of exposure. After the radiation source removal, changes in behaviour were less noticeable. Melatonin administration to irradiated rats caused a decrease in stress related behaviour. In conclusion, microwave radiation causes body weight decrease and anxiety related behaviour in rats, however melatonin causes reverse of those effects on both body weight and behaviour of irradiated animals.

Key words: melatonin/ microwave radiation/ body weight/ behaviour

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SAFETY ASSESSMENT OF DIAGNOSTIC ULTRASOUND IN CLINICAL SETTINGS

Veljko Karadžić[1], Olivera Šveljo[2], Dragana Bajić[1], Nataša Prvulović[2]

[1] Faculty of Technical Sciences, Novi Sad, Serbia
[2] Diagnostic Imaging Centre, Oncology Institute of Vojvodina, Sremska Kamenica, Serbia

Ultrasound is the second most frequently used method for medical imaging. It is considered to be completely safe for the patients. However, the increasing urge for quality enhancement of medical images requires the increase of the acoustic power to which a patient's body is exposed. The possible phenomena that might occur due to ultrasound are presented in Fig. 1, while the known effects that are result of increased heat are presented in Table I.

Table I. Effect of tissue heating

Temperature range [°C]	Consequences
37-39	None
39-43	Some, after exposure of sufficient duration
>41	Threshold for fetus, after long exposures
44-46	Protein coagulation
>45	Enzymes decomposition
>41.8	Cancer cell reproduction cessation

Table II. Maximal safe duration of ultrasound exposure

	Maximal duration [minutes]		
Body temperature [°C]	TI=0.4	TI = 0.5	TI = 0.6
37	724	**630**	548
38	181	**157**	137
39	45	**39**	34
40	11.3	**9.8**	8.6
41	2.83	**2.46**	2.14

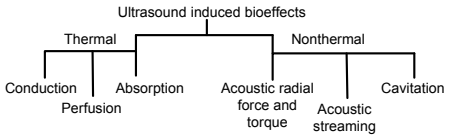

Fig. 1. Some of the ultrasound induced tissue phenomena

This paper considers the technical parameters that are used for risk estimation and prevention of the unsolicited events that might occur as a consequence of growing acoustic power in the new generations of ultrasound devices. The maximal duration of safe ultrasound examination is estimated, based upon the tissue heating model and thermal index value.

A maximal safe duration of tissue exposure to a given temperature is defined by empirically obtained relationship:

$$t = 4^{42.15-T} \quad [\text{min}] \cdot \tag{1}$$

In this relationship, T is a tissue temperature in °C and t is maximal safe duration in minutes, after which a harmful consequence might occur.

The Output Display Standard (ODS) has standardized the algorithms for thermal (*TI*) and mechanical (*MI*) indices that are monitored in a real-time manner at the imaging device. These indices are relative indicators of the temperature increase and of the possible cavitations occurrences. According to ODS thermal index is defined by:

$$TI = \frac{W_0}{W_{\text{deg}}} \tag{2}$$

Here W_0 presents an averaged acoustic source power (or some other power parameter) and W_{deg} is a power required for 1 °C increase of the tissue temperature, estimated according to the specific tissue and thermal models.

On the basis of the equations (1) and (2) we have derived a simplified model for tissue heating and maximal safe exposure time, based on the recorded thermal index *TI* and patients body temperature T:

$$t = 4^{42.15-(T+TI)} \quad [\text{min}] \cdot \tag{3}$$

This model does not take into account the heat dissipation during the real medical examination. It was also assumed that the ultrasound probe is stationary (i.e. that rate over the time is constant), which does not hold during a medical examination. However, this model gives a lower bound of safe exposure, while the real duration of safe exposure would certainly exceed the calculated one.

The proposed model is tested in Diagnostic Imaging Centre, Institute of Oncology, Sremska Kamenica, during 25 standard abdominal ultrasound examinations maximal values of thermal index *TI* were recorded, ranging from 0.4 to 0.5. The results, showing the lower bound of maximal allowed exposure time of ultrasound examination as a function of patient's temperature and measured maximal *TI*, are presented in Table II. The values that correspond to the maximal recorded *TI* are underlined. The values in Table II may serve as a guideline for abdominal ultrasound medical examination duration. Further research would include the parameters that were not taken into the account, i.e. the dissipation and the more accurate probe model.

This paper is an outcome of the master thesis and was presented in part in.

IN-SITU MEASUREMENTS OF ELECTRIC, MAGNETIC AND ELECTROMAGNETIC FIELDS IN THE ENVIRONMENT

Branislav Vulević, Čedomir Belić, Trajan Stalevski

Public Company Nuclear Facilities of Serbia, Belgrade, Serbia
Non-Ionizing Radiation Protection Division

With regard to electromagnetic fields (EMF) protection, the relationship between exposure to EMF and health is controversial. A variety of epidemiological studies have suggested that EMF, over virtually all the frequency spectrum (0 Hz – 300 GHz), might be a risk factor for several health endpoints, including cancer and neurodegenerative disease. These associations are not explained by any confirmed biological mechanisms, and there are doubts as to their causal nature, as the available evidence is inadequate to make sound scientific conclusions.

Previous research of electric, magnetic and electromagnetic fields (up to 300 GHz) in the environment, conducted by the authorities around the world, showed dramatically smaller amounts than those currently effective as reference levels recommended in International Commission on Non-Ionizing Radiation Protection Guidelines (ICNIRP). However, with the development of new measurement methods comes up the question for great many problems to be solved by the contemporary science.

Based on the experiences gained in developed countries and the results of broadband measurements of electric and magnetic fields in the vicinity of the most numerous artificial sources of electromagnetic fields (transformer substations, power lines, GSM base stations of commercial mobile telephony, radio and TV transmitters) in the environment, the objective of this work is to circumscribe the basis of in-situ measurements and so contribute to the development of non-ionizing radiation protection in Serbia.

Key words: *non-ionizing radiation, electromagnetic fields, in-situ measurements.*

REMOTE CONTROL OF THE FIELD ANALYZER EFA-300

Trajan Stalevski, Branislav Vulević, Čedomir Belić

Public Company Nuclear Facilities of Serbia, Belgrade, Serbia
Non-Ionizing Radiation Protection Division

This paper describes an original program that provides remote control of the field analyzer EFA-300. The field analyzer EFA-300 is intended for measuring magnetic and electric fields in the workplace and in public spaces. The magnetic (B) or electric field (E) is measured over the entire frequency range up to 32 kHz in real time.

The program enables monitoring of measured B or E-field in real time, transferring stored data from the instrument to computer, analyzing and graphical presentation of measured data. The sample rate with computer is five times grater than the achieved sample rate with the built-in instrument functions. Also, program provides concurrently measuring of B or E-field in three axes.

When the measurement of B or E-field is performed outdoor, measured data are transferred to company server via GSM network. With the additional program, remote clients can also monitor measured data in real time via Internet. Beside the main application, company server hosts a web server, which enables access to measured data via Internet with web browsers. Access to the web server is protected with proper usernames and passwords.

The communication between computer and instrument is realized over serial interface RS-232. The program is entirely written in graphical programming language LabVIEW 8.6.

LONG TERM EFFECTS OF STRONG STATIC MAGNETIC FIELD ON LYMANTRIA DISPAR L. – FITNESS RELATED TRAITS, SUPEROXIDE DISMUTASE AND CATALASE ACTIVITY

Vesna Perić Mataruga, Larisa Ilijin, Marija Mrdaković, Milena Vlahović, Milena Janković - Tomanić, Dragana Matić, Zlatko Prolić

Department of Insect Physiology and Biochemistry, Institute for Biological Research "Siniša Stanković", University of Belgrade, Belgrade, Serbia

The global environmental changes including electromagnetic polution have been associated with both direct and indirect effects to the living organisms regardless of the complexity. Effects of magnetic fields have been investigated in the study of orientation and fitness-related traits of insects but their influence on physiological processes are poor understood. This study was aimed to determine the effect of strong static magnetic field of ~ 240 mT maximum induction (10,000 times higher than the Earth's) on the fitness-related traits (larval mass, survival, duration of larval devlopment) and antioxidative defense (superoxide dismutase and catalase activities) of *Lymantria dispar*. The experimental groups of *Lymantria dispar* L. were: control group (kept out of influence of the magnet) and treated group larvae kept in a strong static magnetic field from the hatching to the third day of fourth larval instar than sacrificed and activity of superoxide dismutase (Mistra and Fridovich 1972) and catalase (Beutler, 1982) was determined in midgut tissue. Paralel experimental groups were organised for the estimation of the fitness-related traits (larval mass, duration of larval development and survival). Significant differences in larval mass, duration of larval development, superoxide dismutase and catalase were observed, but there was no differences in the survival between experimental groups (control and treated). Scientific information provides on insects, as relatively simple model systems, could be useful for future studies of the processes underlying in response of complex organisms and humans to the influence of magnetic fields.

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MAGNETIC FIELD DOSIMETER

Marjan Blagojević[1], Ljubomir Vračar[2]

[1] IRC Sentronis AD Niš
[2] Faculty of Electronic Engineering Niš

Human body is constantly exposed to magnetic fields, primarily to the Earth's magnetic field. The Earth's magnetic field is constant and has an intensity of 30 to 50μT, depending on the geographical location. Human exposure to magnetic fields has significantly increased following technical progress. Modern technologies, like MRI in medicine, lead to human body exposure to magnetic fields with an intensity of several Teslas. Today, multiple magnetic field sources are publicly available: strong AC and DC transmission lines, high speed magnetic levitation trains, small permanent magnets, etc. Also, there are a number of sources who cause professional exposure of their staff: thermonuclear reactors, magneto-hydrodynamic systems, superconducting generators, welding machines, galvanizing power facilities, etc. There are different interaction mechanisms between the living matter and the magnetic field. Several of those mechanisms are presented in this paper. This is why the magnetic field exposure risk is studied and why it is necessary to develop a magnetic field dosimeter. The dosimeter is designed for professionally exposed workers and patients. Integrated 3D Hall sensor is selected as a magnetic field sensor, it has four operating ranges: 20mT, 200mT, 2T, and 20T. This enables the sensor to measure from weak to extremely strong magnetic fields. The signal processing electronics is based on a popular PIC18F4520 microcontroller. The microcontroller controls the sensor's supply performs measurements using an AD converter, and records the data on the SD card. The data on the SD card are transferred to a PC, where they are later processed.

NUMERICAL ESTIMATION OF ENERGY DISTRIBUTION AND SPECIFIC ABSORPTION RATE IN THE VICINITY OF THE BASE STATION ANTENNA SYSTEM

Milos Davidović[1], Milena Davidović[2], Srboljub J. Stanković[1]

[1]Institute for Nuclear Sciences "VINČA", Laboratory for Radiation and Environmental Protection, Belgrade
[2]Faculty of Civil Engineering, University of Belgrade

With the proliferation of various wireless technologies there is an increasing amount of concern about influence of electromagnetic radiation on general population. International and national level recommendations and regulations [1,2], aim to reduce this concern. These documents recommend procedures and techniques that should be carefully applied in direct measurements and numerical evaluation of electromagnetics fields.

In this paper numerical results for energy distribution and specific absorption rate (SAR) in the vicinity of commonly encountered base station antenna system are given. Radiation patterns for both base station antenna and electric field probe used for practical measurement are numerically obtained and compared to the manufacturer datasheets [3] and calibration records [4]. Plots of intensity of electromagnetic field are presented at characteristic distances from the radiation source.

To simplify numerical calculations all considered structures were represented as objects made out of perfectly conducting material. Base station antenna is simulated as an array of half-wavelength dipoles which are either perfectly vertically aligned (corresponding to zero mechanical downtilt) or have a specified mechanical downtilt. Simple and very useful method for visualization of energy distribution around radiation source is also presented based on energy flowlines [5].

Numerical scheme is based on Galerkin method of moments and RWG basis functions [6]. Numerical quadrature used during filling of impedance matrix was tailored specifically to considered problem and uses different numerical schemes in different parts of matrix. Modern technique of singularity cancellation [7], which aims to complement almost exclusively used singularity subtraction/extraction, is discussed.

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SIGNAL OF INDICATED MAGNETIZATION AS A RESPONSE OF BIOLOGICAL MATTER ON CHANGES OF SOLAR RADIATION AND GEOMAGNETIC ACTIVITY

Spomenko J. Mihajlović[1], Aleksandar Tomić[2]

[1] Republic Geodetic Authority, Bul. V. Misica 39, 11000 Belgrade, Serbia
[2] Faculty of Mechanical Engineering, University of Belgrade, Kraljice Marije 16, 11120 Belgrade, Serbia

In geomagnetic activity continuously is recording the emission of extremely low frequency radiation (INF radiation). Changes of intensity /power and frequency characteristics of INF radiation, which begins from solar-geomagnetic activity, could be some of indicators of geo-physical, bio-physical and chemical processes in atmosphere, biosphere, in live matter.

Electro-magnetic and geo-magnetic fields spectrum in a live environment (natural and artificial), could arouse directly or indirectly changes of bio-chemical and bio-physical processes in biosphere. Changes of spectral characteristics of radiation (power, energy, frequency), could be factors of risk of many reactions and processes in live and biological matter.

Complex mechanism and interaction between exterior fields and radiation and internal, local bio-electro-magnetic fields, could affect directly or indirectly on bio-rhythm in human's organism, on work of some organs in human's body, on the metabolism of human's body. Changes could be indicated on cells metabolism level, and could arrive disturbers of regulation functions and processes in cells, and could cause changes of transport functions in cells, and in some organs in human's body.

In this work will be shown the results of recording of induced magnetisation changes, which occurs in biological matter as a consequence of registered changes of solar-geomagnetic activity. Changes of spectral characteristics of induced magnetization in examples of biological matter, could be response of biological matter or maybe „that biological effect ", on changes of complex and dynamic mechanism of solar-geophysical processes and we them related changes of magnetic and electro-magnetic fields and radiations.

In Republic Geodetic Authority, on Geomagnetic observatory Grocka (GCK) and in Laboratory for Paleomagnetic researches, on Mechanical Faculty on Department for biomedical engineering, on Military-Medical Academy in Belgrade, (VMA), and in Institute for Bilogocal Researching „Sinisa Stankovic", in Belgrade, in period 2005-2009, are done experimental magnetic measurements of gradient of total intensity vector of magnetic field (changes of total vector of induced magnetisation) of different examples of biological matter (test sample of blood, skin, water, fuleren, fliers). The results of researching of biophysical characteristics of skin are analysed and some of more important reactions of skin on radiation factors in environmental (atmosphere, biosphere) are given. The examination of measurement and researching of biological characteristics of skin is given.

The results of biomagnetic experimental measurements and researching, which are shown in this work, could be one of appendix for understanding and interpretation of biological effect – as a response of live bilogical matter on all-present changes of intensity of magnetic and electro-magnetic fields spectrum and radiation in live environment.

Key words: magnetism, indicated magnetisation, radiation, bio-electromagnetism of cells, bilogical effects.

COMBINED EFFECTS OF X-RAY AND ELECTROMAGNETIC RADIATION ON THE ACTIVITY OF THE CATALASE ENZYME IN LIVER TISSUES

A.U. Eminov

A.I. Karayev Institute of Physiology, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

Effects of ionizing and non-ionizing radiation on biological system declare themselves as changes of physicochemical and biochemical indicators in cells.

The aim of the present research was to study the effects of low-intensity decimeter non-ionizing electromagnetic radiation (EMR) on the activity of catalase enzyme in liver tissues of rats after exposure to different doses of X-ray radiation. It was demonstrated that 20 minutes' long exposure of animals to 460 MHz EMR every day for 10 days, with 10 mcW/cm2 power flow, leads to partial restoration of catalase content in liver. Exposure of animals to low (2 Gr), average (4 Gr) and lethal (6,9 Gr) doses of X-ray radiation has oxidizing effects that enhance free radical oxidation processes, which leads to decrease of the activity of antioxidant protection enzyme catalase in liver.

All parameters were determined an hour, 3 and 6 days after exposure to different doses of X-ray radiation and low-intensity EMR separately as well as after successive exposure to both types of radiation.

Catalase content was 16%, 22%, 39% lower than the intact animals' indicator (265,36±5,02 un./ml homogenate) an hour after exposure to low, average and lethal doses of X-ray radiation, 21%, 28%, 54% lower in 3 days, and 5%, 17%, 49% lower 6 days after the experiment.

The activity of catalase enzyme was 12% and 14% lower than the intact animals' indicator an hour and 3 days after influence low-intensity EMR and respectively and close to the intact animals' indicator in 6 days (P>0,05).

On successive exposure to low, average and lethal doses of X-ray radiation and then low-intensity EMR, the parameter was 9%, 11%, 11% lower in 1 hour, 1% (P>0,05), 8%, 10% lower in 3 days, and 1% (P>0,05), 7%, 24% lower in 6 days than the intact animals' indicator. As compared with results of exposure to low, average and lethal doses of X-ray radiation, the obtained results increased 8%, 14%, 46% an hour, 25%, 14%, 75% 3 days, and 6%, 12%, 49% 6 days after exposure to both types of radiation.

The obtained experimental data thereby indicate the ability of low-intensity non-ionizing EMR to prevent harmful effects of ionizing radiation on organism to a certain degree.