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Second International Conference on Radiation and Dosimetry in Various Fields of Research

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May 27 - 30, 2014 | Faculty of Electronic Engineering | Niš | Serbia

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NUCLEAR DECOMMISSIONING AND RADIOACTIVE WASTE MANAGEMENT AT THE JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION

Daniele Giuffrida

EC Joint Research Centre, Ispra, Italy

Four of the five centres composing the “Joint Research Centre” of the European Commission (Geel, Karlsruhe, Petten and Ispra), in which various facilities for nuclear research are situated (and in some case, are also still operated), have started a programme in “nuclear decommissioning and radioactive waste management”. This programme aims at globally reducing the radiological impact of these facilities, while respecting national and international good practices in decommissioning and waste management. One of the main complexities in the implementation of the Programme is, in fact, the need to develop and finalize an industrial activity within the framework of a research body belonging to an important administrative entity, the European Commission. In the Programme, scientific knowledge, technical competences, human resources and administrative procedures must play a prominent role. The talk will describe the status of the Programme and its development in the next years, with a specific emphasis on the works foreseen at the Joint Research Centre of Ispra, Italy.

DOSIMETRY STANDARDS IN MEDICAL RADIATION DOSIMETRY: NEEDS AND CHALLENGES

Ahmed Meghzifene

International Atomic Energy Agency, Vienna, Austria

Accurate measurements in medical radiation dosimetry are vital in a wide range of medical applications where the results are critical in reaching decisions relating to patient care. The development of standards by primary dosimetry laboratories followed by their dissemination to secondary standards dosimetry laboratories and to hospitals ensures traceability of measurements to the international system of units (SI). Dosimetry protocols are used in conjunction with the dosimetry standards to ensure safe and effective use of radiation in medicine. Uniformity and consistency are equally important in medical dosimetry, especially for studies or clinical trials involving collaborative centres throughout the world. In recent years, new developments have occurred in dosimetry standards, dosimetry audits and quality assurance guidelines, especially in the field of radiotherapy, nuclear medicine and diagnostic radiology. This presentation will highlight the needs for traceability of measurements in radiation medicine, the recent developments and the most significant challenges in the implementation of dosimetry standards.

RADIOACTIVE IODINE (^{131}I) IN THE MANAGEMENT OF DIFFERENTIATED THYROID CARCINOMA

Jasna Mihailović

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Differentiated thyroid carcinoma (DTC), including papillary thyroid carcinoma (PTC) and follicular thyroid carcinoma (FTC), is one of the most curable cancers, if adequate and on-time management is performed. However, about 20–30% of patients develop recurrences over several decades, while two thirds of recurrences appear within the first decade after initial treatment. Current treatment of well-differentiated thyroid cancers (DTC) includes total or near-total thyroidectomy and postoperative ablation of the thyroid remnant by radioiodine (^{131}I) in most patients. The goals of ablation are: to eliminate thyroid remnants in order to increase sensitivity and specificity of patient monitoring by thyroglobulin (tumor marker) determination and diagnostic whole body scan (dx ^{131}I-WBS); to allow post-therapeutic WBS which may detect previously unknown metastases (occult), and to treat microscopic tumor deposits within the remnant or in lymph nodes or other tissue even if there is no evidence that there is residual tumor. Administration of radioiodine is based on two approaches: a so-called “fixed doses”, and quantitative absorbed tumor dosimetry (based on a calculated patient-specific activity). The usual administered empiric activity for radioiodine ablation ranges between 1.11 -3.7 GBq ^{131}I, depending on the guidelines or personal experience. If there is uptake on dx ^{131}I-WBS one year after the radioiodine ablation additional treatment is needed. Radioiodine treatment should be repeated by using activity ranging from 5.55 GBq to 7.4 GBq with 6 to 12 month intervals between doses, until the tumor ability to concentrate and retain iodine still exist. There is no maximum limit to the cumulative dose of radioactivity that can be administered to patients with persistent disease, provided that individual doses do not exceed 2 Gy of total body exposure. In non-iodine avid tumors further radioiodine therapy should be avoided. Radioiodine therapy is well tolerated and usually without serious complications; the incidence of radiation induced secondary malignancies is very low. Despite the fact that radioiodine treatment has no influence on survival or mortality, it significantly decreases the recurrence rate.

APPLICATION OF METAL-OXIDE-SEMICONDUCTOR STRUCTURES CONTAINING SILICON NANOCRYSTALS IN RADIATION DOSIMETRY

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Registration of ionizing radiation remains one of the most important problems in the field of control of nuclear wastes, nuclear power stations, in medicine and space investigations. Radiation sensors based on metal oxide semiconductor (MOS) structure are useful because of their good sensitivity as well as excellent compatibility with the existing microelectronic technology.

In this talk recent data on preparation of MOS structures containing Si nanocrystals in the gate dielectric and their response to gamma and ultraviolet radiation will be presented. A new approach for preparation of dielectrics composed of two regions, SiO_2 containing Si nanocrystals and SiO_2 on top will be described. The two-region dielectrics are obtained from homogeneous SiO_x films by a two-step annealing process at 1000 ^oC. Cross-sectional transmission electron microscopy proves the formation of two-regions. A third silicon oxide film between the c-Si wafer and the layer with nanocrystals is grown by thermal oxidation. The dosimetric operation of the MOS structures with three region gate stack is based on generation of electron-hole pairs in the SiO_2 when the structure is exposed to ionizing radiation and separation of the generated carriers by the local internal electric field created around each nanocrystal by a preliminary charging of Si NCs. The structure charging with electrons before irradiation is carried out by applying voltage pulses on the gate electrode with appropriate amplitude and duration. By varying the pulse parameters the value of the initial flatband voltage, determined from the capacitance-voltage characteristics of the MOS structures, can be varied. Upon a negative charging of the Si nanocrystals no spontaneous nanocrystal discharge occurs for more than 2 weeks. The γ-irradiation with doses in the range 0-100 Gy causes approximately linear variation of the flatband voltage. Illumination by 395-400 nm UV light through a semitransparent gate electrode also causes discharge of previously charged structures. The rate of UV discharge depends on the internal electric field in the gate dielectric and on the applied gate voltage during illumination. The obtained results are compared with those of other groups using conventional floating gate device and some advantages of the proposed sensors are indicated.

ADVANCED SEMICONDUCTOR DOSIMETRY IN RADIATION THERAPY - PROGRESS IN SEMICONDUCTOR DOSIMETRY FOR QUALITY ASSURANCE IN RADIATION THERAPY

Anatoly Rozenfeld
on behalf of CMRP collaboration

Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia

Introduction: The Centre for Medical Radiation Physics (CMRP) has a long history of development of semiconductor dosimetry for QA in radiotherapy, radiation protection including space and avionics, and are constantly spreading the application of these dosimeters into new fields. The advantages of semiconductor dosimetry are in real time application and extremely high spatial resolution that are not achievable with other detectors. This presentation is overview of the progress achieved at the CMRP on development and applications of semiconductor dosimetry for medical aplications.

1D and 2D High Spatial Resolution Unified Dosimetry Systems: In modern radiation therapy such as IMRT, VMAT, SRS and Tomotherapy, quality assurance (QA) of small radiation fields with steep dose gradients is paramount. The new Magic Plate (M 512) and Dose Magnifying Glass (*DUO* and *OCTA*), monolithic silicon pixilated detectors with spatial resolution of dose mapping 0.2-2mm, have been developed. These dosimeters are used in phantom and may replicate movable organs for QA in motion adaptive radiotherapy. The applications of these detectors in X-ray SBRT and proton SRS QA, as well as for dosimetry in Multi-Slice Computed Tomography (MSCT) will be presented.

Advanced MO*Skin* dosimetry: A new real time MOSFET dosimeter, the MO*Skin*, has found many applications for fast skin dosimetry in diagnostic and interventional radiology on MSCT and C-arm respectively. The MO*Skin* is lucent on C-arm X-ray imagers and does not produce a perturbation of the beam. The MO*Skin* has been used intensively on LINACs for skin dosimetry and TPS verification on interfaces. Further development of the MOSFET technology has led to a floating gate (FG) MOSFET, which is erasable and passive. An on-chip wireless dosimetry system with a size 1x1x1mm^3, the “Talking Cube” is in the process of development as an implantable, minimally invasive clinical dosimeter and for personal passive dosimetry. First results of the “Talking Cube” (FG)MOSFET dosimetry research will be presented.

Spectroscopy dosimetry with pixilated silicon detectors: The development of high resolution pixilated detectors has changed the concept of solid state dosimetry, which no longer requires tissue equivalency of the detector. Examples of this are new dosimetry systems Brachy*View* and Panoptes. Brachy*View* is based on a TimePix detector array within a rectal probe, providing 3D dosimetry through real time radioactive source tracking in a prostate while Panoptes provides 3D dose reconstruction of the eye plaques loaded with I^{125} seeds by merging 2D dose projections obtained using a custom made semicircular pixilated detector.

WHAT IS HYPOTHESIS TESTING? STATISTICAL VERSUS BIOLOGICAL SIGNIFICANCE

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Clinicians and researchers both must often make decisions about real-life situations. In order to distinguish a fluke from real effects scientists use tests of statistical significance together with appropriate descriptive statistics that provide an indication of the magnitude of an effect.

If we decide there is an effect and it is, or we decide there is no effect when none exists, then we are fine, because we have made a correct decision. But sometimes we are not correct. Finding statistical significance when there is no effect is known as Type I error. A type II error occurs when the null hypothesis is false, but erroneously fails to be rejected. In fact, research studies often draw erroneous conclusions (1,2). Wisely used, statistics helps to quantify the contribution of chance and gives us some rules to reduce the likelihood of making these mistakes.

In this lecture I will be talking about some simple rules and tools for estimating the effects in question, without diving deep into the details of how the statistical tools work, or specifications of how to relate these tools to a particular study design. It will be explained why observing low-probability data is like a “free pass” for claiming that there is a significant difference or association – typically P less than 0.05 is enough for a biologist or a clinician to postulate an effect (a physicist is usually satisfied only with much lower probabilities). It will be reasoned that decisions based purely on the calculated P-value (just to comply with theories of rational decision making) without measures of effects and their uncertainties may be of little help in making biological inferences from the data (3). Types of variables, confounding, mediation and suppressing effect will also be introduced to better differentiate between true change in performance, practice effect, and chance variation.

Throughout the lecture I will be using statistical software to demonstrate the key points on a clinical dataset collected on patients diagnosed with cerebral arteriovenous malformation. The underlying hypothesis here is that a previous treatment with embolization reduces a patient's chance of being completely cured after stereotactic radiosurgery (4). Bivariate and multivariable analysis that adjusts for confounding will be performed and discussed with respect to the study outcome. Finally, I will mention how to communicate results from statistical testing and formulate the conclusion.

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USING ARCHIVAL ANIMAL DATABASES TO RE-EVALUATE DOSE AND DOSE-RATE EFFECTIVENESS FACTOR (DDREF) ESTIMATES

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Evaluation of biological effects of radiation exposure is critical for development of risk estimates for life shortening, cancer development etc. International and national agencies of most countries develop guidelines for occupational and public radiation exposures. In USA the National Council on Radiation Protection (NCRP) estimates that in 2009 Americans were exposed to 1.9 million person-Sieverts, a quantity that would correspond to roughly one hundred thousand excess cancer inductions if applied to a healthy adult population. The estimates of risk per unit dose are based, predominantly, on the ongoing lifespan survival study (LSS) of the survivors of the atomic bombs in Hiroshima and Nagasaki. These survivors were exposed to acute whole-body gamma and neutron irradiation whereas most contemporary exposures have different characteristics. Most radiation risk estimates apply different corrections when projecting dose dependent risk estimates onto exposures that are protracted, concentrated in particular tissues, or involve different sources of radiation. Uncertainty in these corrections and uncertainty in LSS data lead to uncertainty in the estimates of radiation risk. In 2006 the committee on the Biological Effects of Ionizing Radiation (BEIR) issued their seventh report revisiting radiation risk estimates and attempting to quantify their uncertainty. According to this report, the single largest source of uncertainty in projecting risks observed in the atomic bomb survivors to the general population is the dose and dose rate effectiveness factor (DDREF), a factor designed to adjust for increased carcinogenesis following acute exposures when compared to protracted exposures (NRC 2006). The risk estimates for doses smaller than 1.5 Gy and delivered in a protracted manner are obtained when a dose is divided by dose rate effectiveness factor (DDREF). However, a recent analysis by Jacob *et al.* 2009 has shown evidence that the risks observed in chronically exposed worker populations (exposed to a cumulative dose smaller than 1.5Gy) are similar to those observed in the atomic bomb survivors despite the fact that radiation exposure was protracted. This suggests that the DDREF values used by radioprotection agencies may need to be re-evaluated. We used the BEIR VII committee methodology to analyze additional animal data not included in the BEIR VII report. We show that this methodology does not generalize to new datasets, producing confident, but contradictory predictions. We then updated this methodology by accounting for within group and between group variation and show that this result is more consistent from group to group, although not free from contradictions. While we do not propose a better estimate of DDREF, but suggest that the current estimates of DDREF are in need of revision.

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THE ACTIVITY OF POLYAMINE OXIDASE AND DIAMINE OXIDASE IN THE THYMUS TISSUE OF RATS EXPOSED TO MICROWAVE RADIATION

Branka Đorđević[1], Dušan Soković[1], Andrej Veljković[1], Milena Despotović[1], Jelena Bašić[1], Goran Ristić[2], Dejan Krstić[3]

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Polyamines play a major role in very basic genetic processes such as DNA synthesis and gene expression. They have long been associated with cell growth and cancer. These amines are oxidised by polyamine oxidase and diamine oxidase to generate oxygen radicals, hydrogen peroxide and reactive aldehydes, which are likely to exert local mutagenic and cytotoxic effects in vivo. Mobile phone radiation has been recently classified as Group 2B (possibly carcinogenic) by International Agency for Research on Cancer. We have investigated the polyamine metabolism in the thymus tissue of rats that were exposed to the mobile phone radiation (4 hours/day) for 3 weeks. Wistar rats were divided in two groups: I (control) and II (microwave exposed rats). Mobile phone radiation in microwave range was produced by the mobile test phone (E= 9.88 - 18.356 V/m; B=4.68 - 8.69 μT). The whole body average specific energy absorption rate (SAR) rate was estimated to 0.043-0.135 W/kg using rotating ellipsoid rat model. Polyamine oxidase and diamine oxidase activities were analysed. The activity of polyamine oxidase was significantly increased (8.83±1.07vs. 7.53±0.66 U/mg of protein; p<0, 05), while the activity of diamine oxidase was significantly decreased (7, 60±1, 19 vs. 9.08± 1.69 U/mg of protein; p<0.05) in the thymus tissue of exposed rats. The significant increase of polyamine oxidase activity after MW exposure in thymus of rats suggests intensified polyamine degradation. Hydrogen peroxide and aminoaldehydes, produced during polyamine degradation have cytotoxic properties and cause increase in oxidative stress. Decreased diamine oxidase activity in the thymus of microwave exposed rats suggests decreased putrescine catabolism with consequent increase in putrescine concentration. The increase in putrescine concentration in the thymus tissue of microwave exposed rats might have some protective role.

Keywords: Polyamines, microwaves, thymus, polyamine oxidase, diamine oxidase

SPLITTING OF UVC RADIATION DOSE REDUCES OXIDATIVE STRESS BUT INCREASES DAMAGE IN PHOTOSYNTHETIC APPARATUS IN PEA (PISUM SATIVUM L.)

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Pea plants grown hydroponically under white light and long day photoperiod were treated with 90 min daily dose of UVC radiation from Sylvania G30W UVC lamp. Radiation was given for 3 days in single daily dose (1x90 min) or in split (2x45min and 3x30min) applications. Effects of treatment were measured by means of total protein content, photosynthetic pigments content, peroxidase (POD) activity and POD native polyacrylamide gel electrophoresis (PAGE). Tissue samples were taken from apical (undeveloped), axial fully developed leaves and fully developed leaves from uppermost lateral branch. Along leaf curling, drying, death and other expected UVC effects, morphometry showed a small decrease in length in all exposed groups, especially in group that received single application (1x90min). This could explain the biomass shift towards increase in root fresh weight in this experimental group. Leaf curling and drying was most pronounced in uppermost lateral branch leaves. A significant reduction of total protein content in undeveloped leaves was equal among exposed groups which suggests that response maximum was reached, while no change was observed in developed leaves. Young undeveloped leaves responded to UVC dose with over 2x higher POD activity while splitting the dose brought to elevated POD activity but closer to control levels. Developed leaves responded in similar way to UVC and splitting the dose in 3 applications even attenuated POD activity to value less than control level. Native PAGE revealed presence of two POD isoforms in young leaves, present in all experimental groups in equal amounts. As leaves developed, second isoform disappeared. UVC treatment induced reappearance of the second isoform, and relative amount of it in older leaves was inversely proportional to the number of splits in daily dose. Photosynthetic apparatus showed progressive damage and loss in photosynthetic pigments as number of splits in daily dose increased. Number of daily interruptions of normal development caused by split UVC doses during 3 days of treatment was most probably the cause of such result. Older leaves seemed to follow this pattern but without such obvious differences. We conclude that splitting of UVC radiation dose can significantly reduce oxidative stress on plant, especially in young tissue, while it can increase damage to photosynthetic apparatus by reducing amount of photosynthetic pigments proportionally to number of daily UVC interruptions to normal development.

DISTRIBUTION OF PHYSIOLOGICAL GROUPS OF MICROORGANISMS IN THE WATER AT THE LOCALITY VUKOVCI AS AN INDICATOR OF THE PRESENCE OF EMERGENT IN WATER

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Introduction: Large number of different chemicals destructive impact on the environment and human health, often due to ignorance and lack of understanding of the toxicological implications. Generally, emergent and other chemicals tend to precipitate to sediment particles, which are often resistant to biodegradation, slowly they have the ability to bioaccumulate in aquatic organisms. Emergency substances, low dose and pseudo-persistence can produce a very strong chemical and ecological stress, which can completely change the balance in the environment. Recognize and point presence of these kinds of chemical substances at the locality Vukovci (42,27815; 19,12345) was used screening study. Indeed a significant presence of organic components that are not definided, which it is a reason for performed and microbiological analysis of water in the presence of physiological groups of microorganisms. Location Vukovci located at the bottom, sediments of the River Morača. In this part of the Zeta plain, Morača get the look of a typical lowland river. Samples for determining the presence of the screening analysis and identification off emergent, and the organic components are collected in the water along with the samples for microbiological are analyzed in November 2012. Samples were taken from both sides of the river course for the study sites. Evidence showed that in the water there emergent and chemical components. Their presence was determined at the Institute of Analytical Chemistry Slovak University for Technology in Bratislava in Slovakia, while the results microbiological parameters defined in Hydrobiological Institute of Montenegro, Department off Biology.

Results and Discussion: During the study, water samples from the river Morača in locality Vukovci, noted the significant presence of bacteria lipolytic: 4,900 /1 ml per sample, also 20,000 colonies proteolytic bacteria/ml of sample. These organisms performing the reduction and decomposition of a chemical compound to simpler forms, by utilizing the energy for their growth. As concerns over the presence of emergent in water are: detergents, personal hygiene and the presence of flammable substances and residues corrosives. In his PhD thesis, source, find and fate of pharmaceuticals in surface waters, associated with the finding of coliform bacteria in water. The presence of bacteria in the water showing evidence of organic influence on quality on locality Stand and also undertake its sanitation. Microorganisms have the option of adapting the existing organic pollutants due to the relevant mutations will spread through the population. This process is known as adaptation, characterized by longer and less reproducible initial period, before degradation can be observed. After the adaptation of the population will be able to next time breaks down a substance without the lengthy initial phase.

Conclusion: The identification of physiological groups of microorganisms in the study locality Vukovci certainly can be correlated with the presence of emergent in water or their compounds, which are produced in the process of transformation. The water is conducted daily transformation processes, such as biodegradation, absorption-photolysis, hydrolysis, and oxidation-reduction-oxidation, which leads to the release and receiving of electrons, which impacts on the properties of their toxic properties and. In emergent which the organic component, as well as other organic components in water, almost all of the redox-reactions promote significant microorganisms.

IMPACT OF CLIMATE CHANGES ON INCREASED LEVELS OF AFLATOXINS IN FEEDSTUFFS AND RAW MILK FROM REPUBLIC OF MACEDONIA

Elizabeta Dimitrieska-Stojkovic, Biljana Stojanovska-Dimzoska, Gordana Ilievska, Katerina Davceva, Risto Uzunov, Aleksandra Angeleska, Zehra Hajrulai-Musliu, Aleksandra Angelova

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Since the beginning of the 21st century there are a numerous reports and modeling simulations by competent expert bodies, as well as published articles, showing that climate changes affect significantly the agricultural production, treating, thereby, food safety as well as public health. Drought stresses reduces the crop plants resistance, and extreme precipitations and heat waves increases the possibility of growth of plant pathogenic moulds, which produce the toxic metabolites – mycotoxins, both prior to and post harvest. Aflatoxins are highly toxic, mutagenic, teratogenic and carcinogenic fungal metabolites from *Aspergillus* found in foods and feeds. The attention to the presence of aflatoxins in feed is important due to the possible contamination of the milk produced by animals fed with aflatoxin-contaminated feed. Aflatoxin M_1 (AFM_1), the hydroxylated metabolite of Aflatoxin B_1 (AFB_1), may be found in milk and milk products obtained from livestock that have ingested contaminated feed. At the end of 2012 and beginning of 2013 the risk of mycotoxins was brought to public attention in Balkans and Central European countries following the European Commission Rapid Alert System for Food and Feed, where ten alerts for the presence of increased amounts of AFB_1 in maize panel, have been reported. Additionally, several investigations from the countries in this region revealed an increased occurrence of *Aspergillus* strains capable of production aflatoxins. This paper presents part of the results from the survey on AFB_1 and AFM_1 in samples from Macedonia, conducted during the 2013. In total 117 samples of feedstuffs and 3099 samples of raw milk were tested for the presence of AFB_1 and AFM_1, respectively. AFB_1 has been detected in 47 % of the samples tested; the revealed average concentration has been 5.30 μg/kg, and in comparison to the years before, when AFB_1 has been sporadically detected, this was a significant increase. Unlike the previous years, when AFM_1 was detected over the limit of detection of the method being applied only in few cases, during this survey the prevalence has been 31.4 %. This was not unexpected, having on mind the fact that Macedonia is highly dependent on import of feedstuffs from the region. Since the border control has been performed on the risk analysis and risk assessment from the obtained data in the previous years, the reason for detection of such increased levels of aflatoxins in feedings and milk is quite understandable.

EXAMINATION OF THE HAZARDOUS AND HARMFUL SUBSTANCES CONTENT IN THE WATER USED FOR IRRIGATION OF AGRICULTURAL SOIL IN THE BASIN OF RIVER TIMOK

Radmila Pivić, Aleksandra Stanojković-Sebić, Zoran Dinić, Dragana Jošić

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The paper presents the results of the presence of hazardous and harmful substances content in the water for irrigation, sampled during the vegetation season 2012/2013 in the basin of the river Timok, from Knjaževac to Visočni hill (Mokranja). The investigation was carried out in three cycles of monitoring at 17 selected sites, which gravitate on the agricultural soil that was irrigated.

The content of the following trace elements and heavy metals was determined: Cr, Ni, Pb, Cu, Zn, Cd, B, As, Fe, Hg.

The obtained results imposed that the contents of trace elements and heavy metals in the study water samples were, generally, below the recommended limits. In one sample, during the first cycle of sampling, was recorded increased copper content, exceeding the recommended limits (0.2509 mg l^{-1}). As nearby the sampling location there is a village, whose wastewaters gravitate to the sampling point, it is possible that the reason for the increased concentration of this metal is the use of copper-based products. During the other cycles on that location there is not registered higher content of this element above the recommended limits.

One water sample from the Timok river, sampled in the second cycle of monitoring, showed a slight increase in the nickel content above the recommended limits (0.124 mg l^{-1}). Since the location of this sample is also in the zone under the village, the assumption is that the increase in the content of the tested element was caused by an anthropogenic activity, as in other sampling cycles increased nickel content was not registered.

Based on the obtained data on the content of hazardous and harmful substances in the water for irrigation of the Timok River, it can be concluded that the water studied is usable for irrigation of agricultural crops and soils, but along with restrictions and frequent quality checks during the summer months.

Key words: Trace elements, heavy metals, irrigation water, soil

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ERGOMETRIC ANALYSIS BY CORRELATIVE METHODS OF THE THERMAL RADIATION EMISSION DEVELOPED WITHIN HAND FOLLOWING A CONTROLLED EFFORT

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The hand-arm ensemble represents the anatomical structure required to develop multiple activities involving effort, precision, stamina and performance of repetitive or random motions etc. and also the determination of an ergonomic comfort condition. The actions developed on prolonged durations requiring effort, repetitive and random motions and accurate displacement of some various weight objects represent a source of local temperature growth at tissues level. This thermal radiation gradient analyzed in a correlative manner with respect to the physiological mechanisms developed within tissues and also considering initial anthropometrical data allows the evaluation by means of ANOVA method of the induced and/or developed fatigue degree, of the ergonomic coefficients related to static and dynamic posture and last but not least allows the evaluation of the operating limits of the hand-arm ensemble. Also we considered the combined action of the thermal radiation emission occurred following the development of a controlled effort with the electromagnetic radiations manifested in a specialized medical ward.

The subjects' sample taking part in this experiment was determined by taking into account several initial criteria of anthropometric type, age, effort degree, motion type and were followed during a certain time period corresponding to the induced effort activity in order to find the thermal radiation emission gradient by thermo-vision methods and then the interactions with the environment loaded by electromagnetic radiation in the specialized medical offices.

The surveillance, determination and correlative analysis procedures are part of the final chapter of the paper, where we highlight the aspects regarding the development of the thermal radiation emission effects in the hand-arm ensemble, following the induction of a certain controlled effort condition and the interactions with the environment are evaluated.

IMPORTANCE OF THE STRUCTURAL INTEGRITY OF PIPELINES TRANSPORTING GAS AND OIL: THEIR DEFECTS

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Pipelines have become very important vectors for transporting of Gas and Oil. From the amount and the quality of the Gas and Oil transportation is depended much of our industrial sector and our individual life such are hitting, transport etc. In order to ensure such commodities the structural integrity of the pipelines is very important. These pipelines are hidden in the sea or underground where people do not see them, they can notice their presence only when some defects occur in these pipes such may be leak or brake which pollutes the environment. Also a leak in the pipeline reduces the gas supply for many sectors of Industry. Taking in the consideration the difficult terrain these pipes operate and to ensure the safety for people and to reduce pollution in the environment, pipeline structural integrity is very important to be evaluated and analyzed. Features are to be taken into consideration by them who construct the pipelines, the engineers.

We through our investigation have achieved an outcome which suggests that when building pipelines should secure safety for people, continues supply to feed the economy and make economic calculation in order to secure all the above at low cost. In order to ensure all the above we should focus on their structural integrity. Some of the elements we will focus on, such are damages from scratches, fatigue, bursts, puncture overload etc. Also displacement, distortion and ovalisation should be well inspected. Evaluation of all the above elements will lead us to best structural integrity. Further more while servicing behavior of the defect must be carefully inspected in order to avoid further escalation of the problem and reduce to minimum pollution.

Key words: Structural integrity of pipelines, fatigue, safety factor

METHOD AND PROGRAMMING TOOL FOR AUTOMATIC SEARCH OF DIAGNOSTIC PARAMETERS OF THE SPHYGMOGRAPHY SIGNAL

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For diagnostic goals of the cardiovascular system are apply also mechanographical methods of fluctuation's measurements of blood vessel walls. The diagnostic signs obtain from measurement of coordinate of extremums on the sphygmogram (dependence offset of wall of the vessel from the period time on the graphic). The method of the sliding window was proposed and realized with automation process goal.

The method is based on following algorithm:

1. Received the ssphygmogram signal we shall transform in the array;
2. Choosing the time of analysis of array data for signal - the time window with width T;
3. From array we allocating subarray which is correspond of the window width T;
4. For values subarray we are get approximating function;
5. The array that we got we are researching at a peaks and cavity;
6. We implement shift of the period time window and going to item 3 of algorithm.

The method was realized with area visualization programming LabVIEW version 8.2.

Program (look picture 1) is described in the While Loop structure â€“ that program equivalent: do {program} while {condition}.

The terminal of iteration i and condition (square with pie arrow) are placed in the internal structure. Fragment of the program that is placed in the structure is carry out before connecting on terminal the condition of set the Boolean variable True (1) or False (0). Option Selection stop is set using the string of menu Stop If True or Continue If True. If terminal of the condition is not connecting to some kind of output, then program works one time in the structure.

1. We create a subarray (1) and on the input of it are going data from input file (2). This Function is return a part array. The array begins with the index and contains the number of elements, which it is define on input as length. Function automatically is changing as consistent with the dimension when the array is connected. Index in our program it is output value getting from multiplication of iteration u (3) at installed length of an array (4). On the output we have the plotter (5).

Method of realization using the program LabVIEW

The program (look picture 1) we write in the While Loop structure â€“ it equivalent: do {program} while {condition}. The iteration terminal i and the condition terminal are setting in inside of structure. Fragment of program arranged in structure, runs before delivery to the condition terminal with defined Boolean variable True (1) or False (0). Choice of stop variant is establishing with strings of menu Stop If True or Continue If True. If the condition terminal is not connecting to some of output, that program performs one time in structure.

DESIGNING AND FABRICATION OF AN IONTOPHORETIC TRANSDERMAL DRUG DELIVERY SYSTEM

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Iontophoresis is a process used to deliver drugs through the skin into the body. To deliver the correct dosage of drug, the current flow through the skin must be actively controlled. This can be performed by means of an automated system. The transdermal drug delivery system that uses this technique is completely non-invasive. The main advantage of a transdermal drug delivery system is providing a controlled release of the drug without serious pain to the patient. In this work, a simple, low-cost and portable iontophoretic system based on skin modeling was designed and fabricated that allows the user to select the level and frequency of the current pulse (varies for each type of drug) and the polarity (depending on the drug). The system consists of a constant current driver circuit, the selection of current level unit, the polarity change unit and a microcontroller-based control. Performance of the system was evaluated by the skin model which was especially designed for iontophoresis system.

ANALYSIS OF VISUAL PARAMETERS VARIANCE UNDER THE INCIDENCE OF RADIATION PRODUCED BY COMPUTER MONITORS AND MEDICAL DEVICES UPON THE OPERATORS WORKING IN SPECIALIZED SURGERIES

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The performances of the human visual system are strongly affected by some parameters reaching the human factor as luminous radiation. The amount of perceived and processed information by human visual system is estimated at approximately 98% of the entire information amount received by the human factor. This fact requires the maximum protection of the human visual system according to various luminous radiation levels originated from the medical equipment monitors or computers or other type of electromagnetic radiation from the specialized medical wards.

By means of this research we try to create a fast and flexible mechanism of the influence degree for the performances of the human visual system of a subjects' sample by the optical radiations originated from the medical equipment and computer monitors from a medical ward.

The modular construction of the analysis methodology allows obtaining some complex and complementary evaluations, also allows the accomplishment of analyses correlated to the anthropometric parameters of the subjects' sample, to the environmental parameters and last but not least to the analyzed devices parameters.

In the final part of this research a methodology and evaluation procedure is structured in order to assess the influence of the radiations originated from the specific equipment on a subjects' sample and by specific ANOVA type methods the variance coefficients of the visual parameters are established in order to accomplish the optimization of use for these equipments and the human factor protection.

SYSTEM FOR DATA ACQUISITION AND CONTROL OF ANKLE FOOT ORTHOSIS

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In the cases of neurological disorders (cerebral palsy, insult, spinal cord injury), muscular-skeletal disorders (traumas, age changes) and pathologies of the ankle-foot complex can result in abnormal gaits and commonly treated with orthoses to partially compensate functional loss. For increasing stability and mobility of the ankle different type of orthoses are used. These technical assisting devices are served for improvement of the gait and reduced the high-energy cost as well as preserved of the dynamic walking balance.

Particular interest to biomechanics and orthotics is the analysis of human motion. With the development of sensors technologies and gait data analyzing techniques are investigates kinematics, kinetics and dynamics of lower limbs, improves the locomotion and makes a comparison in normal and clinical conditions. The different types of motion sensors and systems are used for various gait analysis applications.

There is a need for a system that can provide a wireless connection in real-time and reliable result to measure ankle foot movements. In this article is present a system based on Brushless Direct Current (BLDC) motor attached to Ankle Foot Orthosis (AFO) with wireless communication XBee for data acquisition and control in complex movements of more than one joint. Considering the advantages of BLDC motor (better speed versus torque characteristics, high dynamic response, high efficiency, long operating life, noiseless operation, higher speed ranges) we choose it as the best option for data acquisition system and control in orthotics.

The method use high precision quadrant encoder in addition to Hall sensors built in the BLDC motor to increase precision of measurement of angles and creates corrective moments if necessary. In same time the system allows measurement and data acquisition for ankle joint movement and then transfers collected data by wireless connectivity to the analyzing software. We designed a controller board meets the block diagram requirement with possibility to connect wireless module directly via built in RS-485 interface. As a result of the work are shown software and hardware realizations. Brushless motor application is useful in highly compact spaces with small motors. The proposed method estimation can improve measurement accuracy and commutation smoothness.

Key words: Ankle foot orthosis, human gait, BLDC motor, data acquisition system

THE SIGNAL CONTENT ANALYSIS SPECTRA INDUCED MAGNETIZATION OF BIOLOGICAL MATTER SAMPLES

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On former Geomagnetic Institute (Geomagnetic observatory Grocka – GCK and Paleomagnetic Laboratory), on Mechanical Faculty on Department for Biomedical Engineering, on Military-Medical Academy in Belgrade, (VMA), and on Institute for Biological Researching "Sinisa Stankovic", Belgrade, in period 2005-2009, are done experimental magnetic measurements of gradient of total intensity vector of magnetic field of different samples of biological matter (changes of total vector of induced magnetization).

In this study we will present some results of the experimental magnetic measurements of the vector total magnetic field intensity of different biomaterials (the intensity of the vector induced magnetization. Changes in the magnetization vector were measured on samples of water, tissue, blood, skin, insect and other samples of biological matter. In this work we will present some few groups results of the signal induced magnetization of spectrum analysis of water, tissue, blood, skin, insect and other biological samples.

Magnetic measurement's results indicate that physical processes in biomaterials related with diamagnetic properties and there transition to paramagnetic properties.

Key words: Spectrum, the content of spectra, the content analysis of signal, induced magnetization, biological sample

APPLICATION OF FAILURE MODE AND EFFECTS ANALYSIS TO EVALUATE THE RADIOSURGERY PROCESS IN RIO DE JANEIRO

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Brazil has at least 25 radiotherapy centers that perform radiosurgery, between these 4 are located in Rio de Janeiro. Several accidents have happened around the world and many patients have received significant unplanned doses. Aiming at preventing accidental exposures to the patient who is undergoing radiosurgery, this work was started to study and evaluating the radiosurgery process in two radiotherapy centers in Rio de Janeiro applying the Process Mapping and Failure Modes and Effects Analysis(FMEA) tools. This work is still in developing, in a first moment it is expected compare the current radiosurgery processes in these two centers.

After the Process Mapping had been developed, the FMEA is being applied for all major process in each one of the radiotherapy centers. FMEA is a risk analysis tool which has been used in medical field and it consists in three steps: i) identifying the sub-process, failure modes and the causes of failure for each sub-process, ii) determining the Risk Priority Number (RPN) using a scoring system to ranking the failure modes, iii) identifying safety measures to be proposed in order to improve the process quality, safety and patient care. The scoring system involves the probability that a specific cause will result in a failure mode, the severity of the effects resulting from a specific failure mode and the probability that the failure mode will be detected.

Twelve major processes were identified in both Process Mapping. However it is observed that the fourth sub-process identified for the center 1 does not occur in the center 2 and the fifth sub-process identified for the center 2 does not occur in the center 1. All the sub-processes have been identified for the first 7 major processes of both centers, the center 1 has 24 sub-processes followed by 41 failure modes and the center 2 has 25 sub-processes followed by 36 failure modes. Although the identification of sub-processes for all major processes is not still finished, it is possible to assert that the major process with greater complexity is the Treatment Planning to both centers presenting more than 15 sub-processes and more than 40 failure modes. The Process Mapping and FMEA are important tools to identify in a easy and clear way how occur the process in a radiotherapy center, allowing a quality management using the prospective risk analysis. The preliminary results showed that the process to the same practice, in this case radiosurgery, is different in the radiotherapy centers and these differences are based on structure, on equipment and technologies available in each one of them. This has an affect on the amount of failure modes, causes of failure and consequently in RPN showing that the priority adopted to the safety measures should be different also.

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POLYMORPHISM OF SOD1 GENE AND SPONTANEOUS CHROMOSOMAL INSTABILITY RELATED TO AGEING

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SOD1 gene encodes an enzyme responsible for destroying free superoxide radicals. It is speculated that this gene could be involved in the process of ageing. On the other side according to the literature available, spontaneous chromosomal instability measured by micronucleus (MN) frequency in human peripheral blood lymphocytes increases during ageing.

The aim of our study was to test if polymorphism of SOD1 gene is related to spontaneous chromosomal instability that is related to ageing.

One hundred and thirty two healthy persons (75 female and 57 male) of varying age (from newborns to 92 years of age) participated in the study. The participants were divided into five categories: newborns (28), from 20 to 40 years of age (30), from 41-60 years of age (29), from 61 to 80 years of age (26) over 81 years of age (19).

For evaluation of spontaneous chromosomal instability, MN frequency citokinesis-blok method – Fenech and Morley modification was used.

We discussed polymorphism of SOD1 gene and its relation with MN frequency, age and gender.

Key words: SOD1 polymorphism, micronucleus frequency, ageing, gender

COMBINED PHARMACOLOGICAL THERAPY OF THE ACUTE RADIATION DISEASE USING A CYCLOOXYGENASE-2 INHIBITOR AND AN ADENOSINE A$_3$ RECEPTOR AGONIST

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Combined approaches to the treatment of the acute radiation disease are preferred to single-agent therapies due to proved or anticipated better outcomes including increased therapeutical efficacy and decreased incidence and intensity of undesirable side effects. Our studies on possibilities how to improve the results of a post-exposure treatment of a mammalian organism irradiated by sublethal or lethal doses of ionizing radiation included testing the effectiveness of meloxicam, a cyclooxygenase-2 inhibitor, and IB-MECA, an adenosine A3 receptor agonist. We have shown that both the drugs, which are currently in use or in clinical studies for other indications, stimulated hematopoiesis and increased survival in sublethally or lethally irradiated mice.

In the studies reported here, the efficacy of meloxicam and IB-MECA to positively influence the progress of the acute radiation disease has been tested in situations of their combined administration with granulocyte colony-stimulating factor (G-CSF), a drug usually nowadays used for the treatment of radiation-induced myelosuppression, or with each other. In experiments on mice, a complex hematological analysis and post-irradiation survival were used for evaluation of the effectiveness of the therapies tested.

The results of our studies have revealed a statistically significantly improved regeneration of hematopoietic cell populations ranging from the bone marrow progenitor cells to mature blood cells after combined administration of meloxicam + G-CSF, IB-MECA + G-CSF, or meloxicam + IB-MECA. Often the values of the parameters studied have been found to be signficantly higher in the combination-treated groups in comparison not only with the controls but also when compared with the mice treated with only one of the agents. Also survival of mice exposed to lethal radiation doses was highest in the animals treated with the combination of two drugs.

It can be inferred from the results of the experiments reported here that if the drug combinations employed were used in humans, e.g. in the treatment of victims of radiation accidents, a better therapeutical outcome could be expected. The desirable effects of the drugs administered in combinations can be generally anticipated and were proved in the cases shown here to be mutually potentiating. Undesirable effects can be weakened by the possibility to use lower doses of the individual compounds in the combined therapy in comparison with the doses which would have to be used if the drugs were used as single therapy agents. Therefore, further studies directed at clinical applications of meloxicam and IB-MECA in radiation victims are recommended.

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OPTICAL AND MECHANICAL PROPERTIES OF THE NANOSTRUCTURED MATERIALS MODIFIED WITH LASER-DEPOSITED ORIENTED CARBON NANOTUBES

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Modified surface and photorefractive properties of the inorganic and organic materials of the UV and near IR spectral range are discussed according the previous [1-5] and recent results.

Some accent are given to show the advantage of the nanostructurization process to decrease the resistivity of the conducting inorganic structures and increase the wetting angle of some different inorganic materials operated in the optoelectronic and biomedicine systems. Different semi-conducting and metallic matrixes such as zing sulfide, silicon, alumina, etc. have been treated to obtain and support the evidence of the transmission increase and refraction decrease. Additionally the substantial reflected optical second harmonic generation signal has been found. The signal has shown substantial anisotropy of the reflected features. Both surface as well as bulk component has been contributed.

Special role of the dipole moment as a macroscopic parameter of an organic medium accounts for a relationship between the photorefraction and the photoconductivity characteristics and it can be considered as an indicator of following dynamic parameters change that can be responsible for the high speed display elements, laser switchers, medicine instruments improvements, etc. Basic polymer, namely, polyimide and pyridine compounds as well as the liquid crystal matrixes from cyanobiphenylgroups are chosen as the good model to increase the local volume polarizability via intermolecular charge transfer complex formation.

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EFFECTS ELECTROMAGNETIC FIELDS HIGH FREQUENCY ON BETA CELLS ENDOCRINE PANCREAS IN RATS

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Since the data about the effects of high frequency electromagnetic field (HF EMF) on both human and animal pancreas are poor and contradictory, especially with reference to the endocrine parts, this paper aimed at testing both morphological features of endocrine pancreas treated by high frequency electromagnetic field (1.9 GHz, 4.79 V/m, 0.24 A/m and 2.0 W/m^2) on an animal model over a 30-day period. Under our experimental conditions, the HF EMF caused the increase of number, volumetric density, and nucleocytoplasmic ratio and resulted in the decrease of beta cell surface in comparison with the control group, which reflected their boosted activity. To sum up the thesis results in this paper, caused both morphological and morphometric alterations of the endocrine component of pancreas, Langerhans islets and beta cells. Since insuline, the hormone they excrete, had the effect opposite to glucagone and decreased the level of blood glucose, the results of the study indicated a possible diabetogenic effect of HF EMF with rats.

Key words: Endocrine pancreas, beta cells, electromagnetic fields

CHRONIC EXPOSURE TO COBALT COMPOUNDS – AN *IN VIVO* STUDY

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An *in vivo* experimental model for testing the effects of long-term chronic treatment with cobalt(II) compounds – cobalt chloride ($CoCl_2$) and cobalt-EDTA (Co-EDTA) on hematopoiesis and hematopoietic organs in mice from different stages of development was optimized. Pregnant mice were treated with daily doses of 75 or 125 mg/kg body weight until day 90 of the newborn pups. The compounds were dissolved in regular tap water. Mice were sacrificed on days 18, 25, 30, 45, 60 and 90 after birth which correspond to different stages of their development. The exposed animals showed reduced body weight compared to untreated control mice. Altered weight indices (calculated as a ratio of organ weight to body weight) of the organs studied – spleen, liver and kidneys, were found depending on the type of compound used, dose, duration of treatment and the age of the experimental animals. The results also showed significant accumulation of cobalt ions in blood plasma, spleen, liver and kidneys of the exposed mice. Co(II) content was higher in blood plasma of mice treated with $CoCl_2$, while in the organs more cobalt was measured in animals exposed to Co-EDTA. High correlation between plasma cobalt and iron concentration were determined. An inverse correlation was found between the metal ion concentration and hemoglobin content in the erythrocytes of the treated mice. Results indicated that immature mice were more sensitive to treatment.

SOME BLOOD PROTEIN IN PATIENTS WITH BREAST CANCER ON THE STAGES OF TREATMENT, INCLUDING RADIATION THERAPY

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Besides the appearance of cancer markers in tumors may increase the synthesis of serum proteins associated with inflammation and immunoreactivity. To estimate the reactions of the organism to treatment, we studied the levels of CRP and pregnancy associated alpha2-glycoprotein (α2-PAG). In the previous study, we obtained data on level changes of these proteins in biological fluids of cancer patients (in different malignant tumors). CRP is a classic marker of acute-phase response. α2-PAG has a strong immunosuppressive effect, but also has properties of steroid-linked. Therefore once been investigated sex hormone binding globulin (SHBG).

Aims: Investigate the dependence of the level of CRP, α2-PAG and SHBG on the condition of patients with breast cancer before and after treatment including gamma radiation therapy.

Methods: Proteins were determined by immunochemical methods (ELISA, IDA) in samples of blood serum of 223 women with breast cancer. Monitoring the level of CRP, α2-PAG and SHBG in the blood of women was made from diagnosis until the end of combined treatment: on the day of admission, for 4-10 days after surgery, followed by background radiation therapy and chemotherapy.

Results: Level of CRP, α2-PAG and SHBG is directly dependent on the stage of the disease, SBAG on the age, but lowered after menopause. Found an inverse correlation between levels of SHBG and age of patients. CRP before treatment detected in 23.8% of patients (8.5 mg / l). After surgery, the frequency of detection increased to 56% (10.7 ± 0.54), and after radiation and chemotherapy has declined to 33% (13.3 ± 0.67) and 27% (8.8 ± 0.44) respectively. Expressed changes of the level of α2-PAG and SHBG there are in the follicular phase of the menstrual cycle in young patients with breast cancer. α2-PAG before treatment detected in 70% (max 14 ± 0.7 mg / L) after the operation - to 50% (7.5 ± 0.37), after radiation - 44% (7.2 ± 0.36) after chemotherapy, 33% (5 ± 0.25). SHBG before treatment significantly increased (up to 15.1 ± 0.755 mg / l) after operation is reduced to normal levels, and background radiation therapy reaches 37.7 ± 1.885 mg / l. The highest SHBG levels detected by gamma therapy in postmenopausal women. With chemotherapy and hormone therapy, these figures are in the range of reference values and did not differ from the level of the donors.

Conclusions: The identified changes in three proteins may indicate the degree of associated with treatment processes. α2-PAG and SHBG have higher activity at radiotherapy than chemotherapy.

HEALTH RISK SENSITIVITY ANALYSIS DUE TO PROBABILITY DENSITY DISTRIBUTION VARIABILITY OF EXPOSURE PARAMETERS

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A primary objective of the sensitivity analysis is to determine which variables the most strongly influence the risk estimate. Apart from the common procedures for uncertainty estimation due to overall uncertainties of input variables (Monte Carlo procedure and GUM framework), it was made attempt to extract influence of the specific distributions on the risk uncertainty estimation.

In this paper, cancer mortality risks were calculated due to direct soil ingestion exposure using Monte Carlo simulations. Ten soil samples were taken from the alluvial horizon of the Djetina River. Gamma spectroscopic measurement was performed for determination of the radionuclide ^{238}U activity concentration in soil samples. Four hypothetical exposure cases were considered with different combinations of input parameter distributions. In each case, same probability density distributions were assigned to the input quantities like activity concentration (characterized by the uniform distribution), cancer mortality risk coefficient (characterized by the lognormal distribution) and exposure frequency (characterized by the triangular distribution). Two probability density distributions were assigned to the quantities considering daily soil ingestion rate (lognormal and triangular distribution) and exposure duration (triangular and uniform distribution). The choice of input parameter distributions can affect uncertainty. Variability of exposure parameters and risk uncertainty were considered separately and influence of the input parameters variability on the risk uncertainty estimation was quantified.

Results of cancer mortality risks were presented as mean value for each case, associated with 95 % uncertainty. Also 5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th} quantiles were presented. For all cases, median is in the range of $(15.7 - 31.8) \times 10^{-9}$. Uncertainty due to variability of exposure factors distributions is presented as 95^{th}quantile range $(108 - 194) \times 10^{-9}$. Analysis like this is recommended for the risk assessors and decision makers having in mind that variability of exposure parameters cannot be reduced and it can only be better characterized.

WHICH PART OF RASPBERRY FRUIT EXHIBITS ANTIMICROBIAL ACTIVITY?

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Introduction: Raspberry fruit has rich chemical composition that provides it with many beneficial effects used in medicine. One of those effects is its antimicrobial activity. Many of raspberry substances are described as bioactive. Some of those substances have polar characteristics and dissolve in polar solvents and some are non-polar and dissolve in non-polar solvent. We wanted to know which of them are responsible for killing pathogens.

The aim of this study was to determine antimicrobial properties of raspberry juice, pomace matter extracted with polar and pomace matter extracted with non-polar solvent.

Materials and methods: Juice, ethanol and ether extract were made of fresh raspberry fruit. Juice was obtained by squeezing fresh fruits, ethanol and ether extracts were obtained by pomace extractions. Their effects on eight Gram positive, six Gram negative bacteria, fungus and alga were examined. Agar well diffusion method was used in this study. It was conducted by Clinical and Laboratory Standards Institute (CLSI) recommendations. Samples were examined in triplicates. Zones of growth inhibition were measured by ruler. Statistical method of results obtaining was arithmetic mean calculated by Microsoft Office Excel 2007 program.

Resultants and discussion: Antibacterial and slight antifungal action are shown in this study. Effect on alga is none. Juice and ethanol extract showed antimicrobial effects. Ether extract had no antimicrobial properties. These resultants are in line with many studies that show antimicrobial activity of raspberry fruits polar components.

Conclusion: Polar matters of raspberry fruit are responsible for its antimicrobial properties. In concentration that was examined and by the method that was used there was no antimicrobial activity of ether extract of raspberry.

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HYPERSPECTRAL REMOTE SENSING APPLICATIONS FOR ENVIRONMENTAL PROTECTION

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The latest developments in spectroscopic instruments, hyperspectral sensors with high spectral resolution along with a high signal to noise ratio, are now able to generate exceptionally high-quality digital hyperspectral information far beyond the capabilities of multispectral remote sensing data. Hyperspectral sensors are providing high spectral resolution across a wide range of the electromagnetic spectrum, enabling the identification of the surface composition of the imaged target (vegetation, soils, rocks, etc). Hyperspectral remote sensing offers unique opportunities for environmental monitoring. The measurements and representations of earth surface characteristics support the information requirements for effective environmental management and decision making. Recent remote sensing systems due to regular, synoptic, hyperspectral and multi-temporal coverage of an area provide accurate database on spectral behaviour of the objects, in particular vegetation and its growing environment.

This paper aimed to outline the applications of two hyperspectral remote sensing techniques, leaf reflectance and chlorophyll fluorescence, for monitoring and assessment the effects of adverse environmental conditions on vegetation ecosystems and the opportunities for making decisions before the occurrence of injuries. The hyperspectral reflectance and fluorescence data were obtained in the visible and near infrared ranges, 450÷850 nm and 600-900 nm, respectively using a portable fiber-optics spectrometer. The spectral behaviour of the vegetation depends on its nature and interactions with solar radiation and other climate factors, also by the content of chemical nutrients and water. Spectral reflectance analyses were performed in four most informative for the investigated species regions: green (520-580 nm), red (640-680 nm), red edge (680-720 nm) and near infrared (720-780 nm). Fluorescence spectra were analyzed at five characteristic wavelengths located at the maximums of the emitted radiation and at the forefronts and rear slopes. Statistical and first derivative analyses were applied to assess the differences between the spectral data of healthy and injured (stressed) plants. Strong relationship was found between the results from the two remote sensing techniques and some biochemical analyses which indicate the efficiency and sensitivity of these techniques for easily and without damage, rapid assessments of vegetation health condition.

Key words: Hyperspectral remote sensing, leaf reflectance, fluorescence, environmental protection

THE USE OF MARINE LUMINOUS BACTERIA FOR ASSESSING RADIATION HORMESIS AND TOXICITY

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Bioluminescence (BL) is glowing of living organisms; it is based on chemiluminescent enzymatic reactions. Marine luminous bacteria are widely used as bioassays for monitoring the environmental toxicity. The main tested physiological parameter here is the BL intensity.

In this work, the BL intensity was monitored in solutions of the alpha-emitting radionuclide Am-241 ($Am(NO_3)_3$, 0.4–6.7 kBq/L) and the beta-emitting radionuclide H-3 (HTO, 10–10^5 kBq/L) under the conditions of chronic irradiation. Three BL assay systems were used to study the effects of the radionuclides: the marine bacteria *Photobacterium phosphoreum* (intact and lyophilized) and coupled enzymatic reactions.

Three stages of the bacterial BL response to the radionuclides were found in the BL kinetics: (1) the absence of any effect, (2) activation, and (3) inhibition. The bacterial response was interpreted in terms of the standard reaction of organisms to a stress factor; it includes the following successive stages: (1) stress recognition, (2) adaptive response/syndrome, and (3) suppression of the physiological function. Stage (1) demonstrates the "threshold effect" of ionizing radiation, stage (2) – radiation hormesis, and stage (3) – radiation toxicity.

The duration of stages (1) and (2) were compared in solutions of Am-241 and HTO for the lyophilized and intact bacteria. It was found that damage of the bacterial cells by the lyophilization procedure reduced the stages. Additionally, stages (1) and (2) were shorter in Am-241 solutions than in those of HTO. Variations in the radioactivity of the solutions virtually did not affect the duration of the stages and the BL intensity.

In the enzyme system, in contrast to the bacterial culture, the kinetic stages mentioned above were not revealed, but a dependence of the BL intensity on the HTO specific radioactivity was found. The role of peroxides in hormesis and in toxic effects of the radionuclides was studied using the chemiluminescent luminol method. Peroxides were found in Am-241 solutions and were not found in those of HTO.

An increase in the content of beta-structured proteins in bacterial cells exposed to HTO was demonstrated by diffuse reflectance FTIR spectroscopic studies. The changes involving the secondary structure components of cellular proteins were interpreted in terms of a stress response of the bacterial cells to the low-dose chronic radioactivity. Accumulation of Am-241 and H-3 in bacterial cells and in DNA was determined. The mutagenic effect of H-3 was investigated using restriction analysis of marker amplicons.

INAA STUDY OF SYNTHETIC AND NATURAL IRON BACTERIA PRODUCTS

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The remarkable feature of some Fe-oxidizing bacteria (FeOB) are the unique morphology structures they produce, such as powders, sheaths or stalks, that act as organic matrices upon which the deposition of hydrous ferric oxides can occur. The biogenic products obtained under different environmental conditions find important applications as pigments, catalysts, absorbents etc. Our attention attracted the bacteria of genera *Sphaerotilus – Leptothrix* which as a result of their metabolism form biogenic iron oxides/(oxy)hydroxides, accumulated in their sheaths.

In the present work we give details of the neutron activation analysis (NAA) technique and discuss the results from the simultaneous determination of the elements and radionuclides in the products of Leptothrix (sheaths mostly empty of cells). The NAA helped in revealing an optimized scheme for isolation and enrichment of bacteria in laboratory. Short or long-term irradiations were performed in the vertical channels of the research reactor at the Budapest Neutron Centre depending on the required isotopes half-life.

From the several elective media been studied the best results were obtained after cultivation of bacteria on two different elective media (Adler's medium and Isolation medium) under static or dynamical (flow of nutrient solution) conditions. Higher enrichment level of iron was found in all six samples of products of cultivated bacteria as compared with the reference sample taken from a natural source in high mountain locality. The enrichment rate varied between 3.8 and 7.4. The results showed that in the two media used the iron (II) from the media has been transformed into iron (III) in the form of different (oxy) hydroxides. Three types of iron oxide compounds were established after cultivation in Adler's medium: lepidocrocite (γ-FeOOH), magnetite (Fe_3O_4) and goethite (α-FeOOH). The cultivation in the Isolation medium under static experimental conditions showed the presence of a single phase, namely, goethite. XRD and SEM investigations show that the biogenic oxides are nanosized and could be used in appropriate nano- and biotechnologies.

Additional interest comes from the registered highly selective increase of several essential elements which supports the ability of the NAA technique to reveal and quantify the presence of specific trace elements in the biosphere. Thus, the traces of Th, U and Sb found in the reference material raise possible ecological issues.

QA DOSIMETRY FOR THE BIOMEDICAL IMAGING AND THERAPY FACILITY AT CLSI

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The BioMedical Imaging and Therapy (BMIT) facility provides synchrotron-specific imaging and radiation therapy capabilities [1-4]. In 2013 a commissioning program on the Insertion Device beamline 05ID-2 with the beam terminated in SOE-1 experimental hutch started. The source for the ID beamline is a multi-pole superconductive 4.3 T wiggler [5] that gives a critical energy over 20 keV. High critical energy presents shielding challenges and great care must be taken to assess shielding requirements [6-8]. The optics in POE-1 and POE-3 hutches prepare monochromatic beam [9-10] that is used in the last experimental hutch SOE-1. The double crystal bent Laue or Bragg, or single crystal KES monochromators prepare a beam 22 cm wide, with energy range appropriate for imaging studies in animals (20-100+ keV).

SOE-1 (excluding the basement structure) is 6 m wide, 5 m tall and 10 m long and accommodates (LAPS) [11] and MRT Lift [12] animal positioning systems. This endstation also includes a unique camera positioner with a vertical travel range of 4.9 m and moveable shielding integrated with the safety shutters, which are required for the KES imaging angle range of +12.3° to –7.3°.

Microbeam radiation therapy (MRT) is an experimental form of synchrotron radiation (SR) treatment for some types of cancer. Accurate measurement of dose distribution in MRT experiments is a very challenging task due to the presence of a very high maximum dose (few kGy) and large dose gradients over a very fine spatial scale (a few microns). In this work we report results from our work towards the development of a specialized detector for MRT. The radiation detection is based on the change of the oxidation state of Samarium ions in a suitable detector medium under X-ray exposure. The recorded dose distribution is measured using confocal photoluminescence microscopy technique.

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THE ROLE OF MUCOCILIARY CLEARANCE IN THE MICRODOSIMETRY OF THE INHALED RADON DAUGHTERS

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Mucociliary clearance is one of the main clearance mechanisms of the particles deposited in the large bronchial airways. The cilia propelled mucus which covers the conductive airways moves the deposited particles towards the pharynx. If particle retention time is comparable to the half life of the deposited isotopes, then spatial distribution of the deposited activity can significantly be modified by mucociliary clearance.

In this work a numerical model of mucociliary clearance in the central airways has been developed and the local burden of radon progenies was quantified. The model simulates the dynamics of the inhaled particles both before and after deposition. According to the model the presence of particles in the studied airway segment is due to primary deposition in this airway and clearance of particles from deeper airways. Activity in the studied airways is influenced by the deposited radionuclides, primary clearance and the activity of particles cleared up from the deeper airways. The isotopes can decay any time during their transport in the airways.

Our computations revealed the existence of a slow clearance zone around the peak of airway bifurcations. Particles deposited here clear up more slowly. However, particles originating downstream this region usually avoid it. Trajectories of particles with diameter higher than 1 micrometer are independent of particle size. The degree of inhomogeneity due to the nonuniform deposition is lowered by mucociliary clearance by a factor of 4-7 in case of micrometer particles and to a smaller extent for nanoparticles. In airway generations 4-5, the contribution of primarily deposited particles to the activity roughly equals the contribution of particles deposited in deeper airways and upcleared to this level.

EFFECT OF GAMMA-RAY IRRADIATION ON THE SWIMMING SPEED OF *ESCHERICHIA COLI*

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The effects of ionizing radiation on bacteria are generally evaluated using a dose-dependent survival ratio based on the colony-forming ability and mutation rate of the cells. To date, the mutagenic damage to cellular DNA induced by radiation has been extensively investigated, primarily by using methodologies that estimate the degree of DNA damage in specimens following bulk irradiation. However, the effects of irradiation on cellular machinery *in situ* remain unclear. Recently, we observed an unexpected robustness of the bacterial flagellar motor against irradiation from a high-energy (2 MeV) proton beam; the average ion fluence required to stop the flagellar motor of the tethered cells was 2.0×10^{12} protons/cm^2 (approximately 60 kGy) [Kato et al. Applied Physics Letters 100: 193702; DOI, 10.1063/1.4714911]. In the present study, we applied gamma rays from ^{60}Co (up to 8 kGy) to *E. Coli* cells in liquid media, and measured their swimming speed using a microscope. The results indicated that the swimming speed remained unaltered after the lethal gamma ray dose was administered to the cells; however, the ratio of the cells adhering to the glass substrate (not swimming freely) increased by the irradiation. Moreover, the inhibition of protein synthesis by kanamycin did not alter the swimming speed, but increased the ratio of the stuck cells.

EXPERIMENTAL DATA PROCESSING FOR BIOEFFECTS OF ELECTROMAGNETIC RADIATION IN DIFFERENT FREQUENCY INTERVALS

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Experimenters divide the whole region of electromagnetic radiation (22 order of frequency) into 7 parts according to the used equipment for generation and detecting of electromagnetic radiation. At processing of experimental data they are guided by a known paradigm: accuracy of measurements increases, when the number of measurements increases. Microbiologists who study ensembles of living microobjects, know, that for increase of accuracy of result, the number of living objects in ensemble should be big.

In this case the average over the ensemble gives the most exact result. It is the paradigm of the precision of biological measurement. It is used for all bioeffects of visible light and in other experiments. Situation became more complicated in the middle of the 20th century, when physicians began to study bioeffects of microwave radiation. Effects were fixed, but they were controversial. Situation was aggravated after discovery of resonant bioeffects of MM radiation. This discovery was a result of a great project under direction of Acad. N.D. Devyatkov. The reputable scientists have worked in this project, and exact physical experiments were made. International response was controversial and the question: “Is an effect or not?” has appeared.

Data of physical experiments allowed to attract the theoretical physicists to this problem. The answer was given by thermodynamics of irreversible processes for systems under electromagnetic radiation [1]. Some of reasons were revealed. Only one will be considered in my report.

Thermodynamic theory of efficiency of electromagnetic energy conversion into other types of energy revealed different laws of such conversion for the Wien region (visible light, ultraviolet, X-rays and γ-radiation) and for the Rayleigh-Jeans region (radiofrequencies and extremely low frequencies). In the Wien region, efficiency of conversion obeys the Weber-Fechner law, and in the Rayleigh-Jeans region, efficiency obeys the Devyatcov law (“step” on the power coordinate).

The position of beginning of this step (the threshold of effect) is defined by entropy generation rate in the system under irradiation due to irreversibility of processes. This point is boundary of endergonic process (with increase of the Helmholtz free energy) and exergonic process (with decrease of Helmholtz free energy). The use of method of averaging in this case gives not more exact result, but the zero result [2], as endergonic process and exergonic process are opposite ones. For microbiological systems the experimentalists have zero effect more often, than in medicine, as an averaging is absent in medical object (patient). As a result a practical use of MM radiation began in medicine many years ago. The recommendations for successful experiment (researches) can be formulated.

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A NOVEL BRAIN IMAGING AGENT INCLUDING ALZHEIMER'S DISEASE DIAGNOSIS POTENTIAL: ^{99M}TC-BIOQUIN-HMPAO

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Recently, development of novel brain imaging agents for assessing the blood-brain barrier (BBB) has attracted much interest due to the limited number of brain imaging agents and the lack of Alzheimer's disease (AD) diagnosis agents. Despite the fact that this chronic and progressively neurodegenerative disorder affects a wide audience, definitive diagnosis of AD still requires post-mortem examination of the brain through histological staining of amyloid plaques and neurofibrillary tangles, which are two hallmarks of AD pathology. Early recognition of the condition has important benefits in planning treatment strategies and yet, early stage dementia is often unrecognized or misdiagnosed. Scans using conventional imaging techniques and nuclear medicine brain imaging techniques are not specific yet. We sought to elucidate the diagnosis of AD by designing amyloid probes that could be used to measure brain amyloid noninvasively by single photon emission computed tomography (SPECT). An ideal amyloid SPECT probe would incorporate ^{99m}Tc, the optimal radioisotope for SPECT with a half-life of 6.02 h and gamma energy of 140 keV which is widely employed and most commonly used radioisotope in both nuclear medicine clinical applications and pre-clinical studies to determine the pharmacokinetic properties of the new drugs in animals. Additionally, the development of technetium-99m (^{99m}Tc) brain perfusion imaging agents suitable for SPECT has been a subject of great interest in radiopharmaceutical research. These agents have to cross the intact BBB but also must remain in the brain for sufficient time to allow SPECT imaging.

A novel radiolabeled agent, ^{99m}Tc-Bioquin-HMPAO (^{99m}Tc-BH), that overcomes impositions of the BBB was synthesized and characterized. The radiolabeling yield and the radiochemical purity (RCP) of ^{99m}Tc-BH were over 95 %. Stability of the complex was appropriate for imaging period. Bioaffinity of the complex, ^{99m}Tc-BH, was investigated on male Balb/c mice at various time points post-injection. Regions of the brain have uptakes over 4 % ID/g following intravenous (iv) injection. Furthermore, hippocampus has uptake approximately 10 % ID/g. It is suggested that ^{99m}Tc-BH has potential to be used as a novel brain imaging agent including AD diagnosis potential due to its chemical structure and uptake on hippocampus.

INFLUENCE OF SOME RISK FACTORS ON CHEST X-RAY FINDS IN PATIENTS WITH INITIAL PNEUMOCONIOSES

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The aim of the study is to analyze the influences of different risk factors for the appearance of p small round opacities as well as s, t and u irregular opacities on chest radiography in cases of border and initial forms of silicosis, and mixed pneumoconiosis, caused by quartz containing dust.

Materials and Methods: A nestled case control study of the p small round opacities and s, t, u irregular opacities (on chest x-ray, accounted according to ILO'80) found in patients with pneumoconiosis (silicosis, mixed pneumoconiosis) was done. The subject of the study were 480 miners in brown, black, anthracite coal mining, and led - zinc mining, as well as 120 workers exposed to mixed quartz containing dust during the period 1985 y. up to 2003 years. The group of unexposed individuals was composed by 121 persons. The average age of the exposed and the unexposed workers' were respectively 42.6 and 42.3 years. The average duration of the workers' dust exposure was varied between 10.95 and 16.52 years. An anamnesis, pulmonary examination, posterior – anterior chest radiography (red by ILO'80), and spirometry were done. A statistical analysis by SPSS software was performed. Non - parametric analysis (Pearson Chi-Square Test, Fisher's Exact Test etc.), Mean, Std. Deviation, χ^2, and significance (P) were calculated.

Results and Conclusions: A significant trend of appearance of p 0/1, p1/0, p1/1 small round opacities on chest radiographies in workers with initial pneumoconiosis with 11 years dust exposure, was detected. The average quartz exposure duration, related to the appearance of initial p0/1 small round opacities was 12.42 years. A statistical correlation between s, t irregular opacities (ILO'80) and dust exposure duration (Pearson's $R = 0.458$, $P < 0.0001$) were found. The synergistic effects of tobacco smoking, alcohol consumption, and dust exposure duration play an important role for the appearance of s, t, u irregular opacities, and p small round opacities found on chest radiographies in dust exposed individuals.

Conclusions: The occupational dust exposure duration, tobacco smoking, and alcohol intake play an important role on appearance of pneumoconiosis, and they must be taken into account during preventive medical screening

Key words: Chest x-ray, pneumoconiosis, ILO'80, s, t, u, p opacities, dust, alcohol, smoking.

THYROID VOLUME QUANTIFICATION BY SPECT IMAGES

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Purpose: Accurate determination of the thyroid gland volume is of great importance when absorbed patient dose is to be calculated for thyroid treatment, using radioactive substances. Scintigraphy is a necessity for thyroid function diagnosis and a possible way for the thyroid volume to be estimated. The need of an accurate, automated volume estimation method through scintigraphic imaging is of great importance. We propose a new computer-automated MatLab program for thyroid volume determination, using 3D SPECT images. A method, using planar images, proposed by Huang et al, was also incorporated in this study in order to compare the two methods.

Methods and Materials: A set of 14 patients' thyroid examinations were studied. Planar and SPECT imaging were completed by a gamma camera GE SPECT StarCam 4000. The SPECT acquisition was performed for angles of -90 to +90 degrees, in 32 projections. Processing was done using Ramp and Hanning filters with Xeleris-2 processor. The tomographic images were transferred, in a Dicom format, in MATLAB-8 code (R2012b) to be used in our automated algorithm "Thyr-Vol". A series of isocontour surfaces for each thyroid were created to identify the appropriate threshold value. Based on this calculated threshold the gland volume is determined in voxels/ml. The thyroid volumes of the same set of patients were calculated in ml, by the planar images using the program by Huang et al (2013), in order to compare and evaluate the results.

Results: Our SPECT based algorithm Thyr-Vol is sensitive to initialization and insensitive to noise and detects the segmented regions automatically to specify the outer contour. The images are filtered and there are less numerical errors using this method. A comparison of SPECT and Planar techniques has been made and the results were validated through their good correlation with Huang's program (JY. Huang et al, 2013).

Conclusion: For the thyroid volume estimation, our approach showed good agreement with the program designed by Huang et al. From the satisfying results of this approach, we expect that the automated computer-aided Thyr-Vol algorithm could be used to accurately determine thyroid volumes by SPECT.

DESIGN OF THE NEXT GENERATION PROTON COMPUTED TOMOGRAPHY (PCT)

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Proton computed tomography (pCT) offers an alternative to x-ray imaging with potential for three dimensional imaging, reduced radiation exposure, and in-situ imaging. The second generation pCT system being developed at Northern Illinois University in collaboration with Fermilab and Delhi University is comprised of a tracking system, a calorimeter or the range detector, data acquisition system, a computing farm, and software algorithms for image reconstruction. The proton beam encounters the upstream tracking detectors, the patient or phantom, the downstream tracking detectors, and a calorimeter. The tracking detectors are scintillating fibers and calorimeter is made up of stacked scintillator plates.

In this presentation, we will describe the complete specifications of the pCT detector and its implementation in the GEANT4 framework. We will present the simulation results for the energy resolution, postion resolution, etc. which are critical parameters for the image reconstruction. We will also describe the optimization of the pCT detector geometry with the help of MC simulation. Recently, we have put our stacked detector in the 200 MeV proton beam line and the analysis of the data is currently ongoing.

IS IT POSSIBLE THAT GET CLOSER TO GOLDEN RATIO MEANS TO BE MORE HEALTHY? A STUDY OF PROPORTIONS OF THE HUMAN BODY THROUGH MAGNETIC RESONANCE IMAGING

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Background: The Golden Ratio in mathematics and the arts is a geometric proportion based on a specific ratio. Given a segment (AC), you get a golden section when the shorter part of the segment (BC) is to the longest (AB) as the longest (AB) is to the entire segment (AC). Golden Ratio, defined as φ, is about equal to 1.618 and also seems to be the standard for perfection, grace and harmony. We used MRI that allowed us to make many type of measurements and comparisons, finding out that many times, from smaller to bigger measurements, φ is present in human body in a way that made us to hypothesize that get closer to this ratio could mean to be more healthy.

Materials and Methods: We made measurements on singulars MRI of 10 subjects (5 M, 5 F, aged 31-65y) and furthermore we made comparisons on 3 other subjects (3 M, aged 56-67y), evaluated at the beginning and at the end of a training period with a patented device for postural correction. A high-field MR apparatus has been used (AVANTO 1,5T).

Results: Measurements on all the subjects showed that many proportions are really near to φ. Furthermore, on subjects who made a training period, the proportions of the area of the body on which the used device acts, changed, going to be really closer to φ at the end of the training period than at the beginning. All the 3 subjects, at the end of the training period, stated, in subjective evaluation, to feel less pain, probably caused by their altered posture, than the beginning.

Conclusions: These results, although in limited series, suggest that φ could be related to health. Since φ has been studied from centuries, but never in small portions of the human body seen through MRI, as a pilot study, these findings do not want to impose any theory, but could open a chance to new studies in this way to analyze many possibilities. Human body and its functions are like a large set of equilibriums. If one of these equilibrium does not work correctly, the whole system could not work in the right way. As example, we could think to the pain caused by altered posture. A question that could come from the hypothesis of this study could be: is it possible to find a relation between φ and every function, mechanical or physiological, or proportion of the human body, perhaps with advanced MRI techniques or even with functional MRI?

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DESIGN AND FABRICATION OF A NEW NMR SPIRAL PLANAR MICROCOIL

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Radiofrequency planar microcoils are used to increase the resolution, signal to noise ratio (SNR) and the analysis ability of small samples in magnetic resonance imaging (MRI) and NMR systems too. In this research, a new spiral planar microcoil was designed and fabricated. In order to achieve the maximum signal-to- noise ratio and quality factor, the important parameters of microcoils such as internal diameter (D_i), width (w), distance between the rings (G), thickness (Th), and the number of windings (N) were calculated. The mentioned parameters were calculated by using MATLAB and optimized by using COMSOL and ADS software and finite element method. The results showed, setting the mentioned parameters on D_i = 241 µm, W = 233 µm, G = 235 µm, Th = 35 µm, and N = 4 would promise the best performance of microcoil. Then the simulation and theoretical results were compared. The comparison of results showed a very good agreement between them. Furthermore in this new NMR spiral planar microcoil, the signal to noise ratio was ten times higher than the previous published works and the Micro – coil's quality factor was 57.85. The other important parameter to evaluate the performance of microcoils is reflection coefficient (S_{11}). This parameter also was calculated by using network analyzer at frequency of 63.8 MHz. The amount of S_{11} was -48 dB with the accuracy's value of 97 %.

LOW DOSE COMPUTERIZED TOMOGRAPHY EXAMINATIONS OF THE HEART, PREVENTION AND SCREENING OF THE CORONARY OCCLUSIVE DISEASE

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Introduction: Coronary occlusive disease (COD) is the leading cause of mortality in the world. According to WHO it is asymptomatic in more than 50% of the cases and develops independently of risk-factors. CT examination of the heart is a revolutionary diagnostic method, due to 2 main reasons:

a. it is non-invasive, whereas diagnostic sensitivity allows examination of coronary status, further evaluation and follow-up of pathologic changes (level of occlusion), in many cases of atypical stencardic symptoms with reduction of the lumen up to 50%
b. CT enables determination of calcium score index, which is the only certain predictor of atherosclerosis progression and coronary occlusion.

Multidetector CT (MDCT) of the heart has been used in clinical practice since 2006. MDCT examinations are connected to high radiation risk because the patient receives high absorption dose (about 2.5 times higher compared to conventional coronarography). The main reason for high absorption dose is great energy of X-rays generated in the x-ray tube with high heat capacity, very thin slices (0.625mm), powerful generators and different types of detectors.

Aim: The aim of this study is to determine the optimal technologic solution which would enable performing CT exam of the heart using doses acceptable on the screening level.

Methodology: There is a uniform context of the solutions which can be offered in the everyday practice. It is determined by energy of the X-rays, duration of the exam, spatial resolution and the presence of arrhythmia during the exam. Every leading world manufacturer offers their own concept defined through the "cardiac CT", but none of them is definite. This study used different statistic models.

Results: (1) Number of arrays of detectors: Every increase of the number of arrays of detectors over 64 in the case of heart examination is not rational from the aspect of dosimetry. (2) Introduction of the high power pulse generators lowers exponential dose for over 40%. (3) The speed of tube rotation should be as high as possible, certainly not longer of 0.3s for 360 degrees. (4) Technologic solution of the dual source CT unit leads to inaccuracy in definition of the density of explored blood vessels (3-4mm wide) in the sense of mixed plaques. (5) Artifacts due to arrhythmias and non-sinus rhythm of the heart during the exam, dyspneas during 7-8s must be solved specially designed software post-processing. (6) The most important technologic parameter is the level of the sensitivity of detectors.

Conclusion: Modern cardiac CT generations of MDCT units (2012-2013) allow the definition of Ca score index, using the dose of 0.6-0.8 mSv, or 1.2-2mSv for the contrast coronarography. With further decrease of the absorption dose, the definition and development of the screening program for the prevention of coronary occlusive disease should enable clinical control of this leading cause of mortality.

INTERACTION BETWEEN BROCCOLI EXTRACT AND ^{99m}TC-GH ON *IN VIVO* DISTRIBUTION AND LABELINGOF BLOOD COMPONENTS

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Nowadays there is a swift increase in consumption of these natural foods like vegetables and fruits. An interaction between vegetable consumption and cancer prevention is observed[1]. Biological studies have shown that vegetables in Brassica family could reduce risks of the cancers, especially the gastrointestinal tract cancers[2]. A great many of the vegetables in Brassica family have been subject of the chemical and biological studies. Broccoli (Brassica oleracea Italica) is a nutrient source which contains many bioactive components including glucosinolates, flavonoids, minerals and antioxidants[3]. In Nuclear Medicine, interactions between herbal extracts and radiopharmaceuticals are not completely understood. Nevertheless patients consume these vegetables without the knowledge of the side effects of biological and/or chemical contents of these vegetables[4]. These contents may cause different variations on the behavior of radiopharmaceuticals. These variations may arise due to various factors including interactions and competition to binding site between herbal extract and radiotracers. It has been already reported that the biodistribution of radiopharmaceuticals used for imaging in Nuclear Medicine is also altered by herbal extracts[5]. In these studies, it has seen that some of the herbal extracts could alter uptake of the radiopharmaceuticals by organs, accordingly SPECT and PET scanning results could change. It's concluded that drugs such as natural, herbal origin or synthetic drugs, as well as labeling conditions, could be effective on the labeling of blood constituents[6].

Current study aimed to evaluate *in vitro* and *in vivo* effects of broccoli extract on the biodistribution of Tc-99m labeled glucoheptonate (^{99m}Tc-GH), which used for renal imaging and function testing.

Biodistribution studies were performed on male rats which were treated via gavage with either broccoli extract or SF as control group for 15 days. Blood samples were withdrawn and radiolabeling of blood constituents performed. Radiochemical yield of ^{99m}Tc-GH was 98.46±1.48 % (n=8). Biodistribution studies showed that according to the control, the treated group with broccoli was approximately 10 times less uptake in kidney. The percentage of the radioactivity ratios of the blood components was found to be same in both groups. Although there was no considerable effect on the radiolabeling of blood components, there was an outstanding change on the biodistribution studies especially on kidneys.

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EFFECTS OF GREEN TEA EXTRACT ON THE RADIOLABELED BLOOD CELLS AND ON THE BIODISTRIBUTION OF RADIOPHARMACEUTICAL SODIUM PERTECHNETATE

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People drink various types of tea without knowing the side effects of biological and chemical contents and radiopharmaceuticals interactions. In current study, it is aimed to evaluate the effects of green tea extract in different extraction solvents on the radiolabeling of the blood constituents with ^{99m}Tc and on the biodistribution of radiopharmaceutical sodium pertechnetate (Na^{99m}TcO4) in male Wistar Albino rats. The extraction of green tea was performed indifferent solvents. Biodistribution studies were performed on male rats which were treated via gavage with green tea extract in different extraction solvents or saline (0.9 % NaCl) as a control group for 7 days. The radiolabeling of blood constituents performed incubating with $SnCl_2$ and ^{99m}Tc. According to experimental results, radiolabeling blood components with ^{99m}Tc were not modified in the usage of the different extraction solvents for green tea extraction, but a significant alteration ($p<0.05$) of biodistribution of Na^{99m}TcO$_4$ was observed after treatment with green tea extract in distilled water.

Although there is no considerable effect on radiolabeling of blood components, there is an outstanding change on the biodistribution studies especially with green tea extract in distilled water. The identified change monitored in this study may cause to reduce the risk of misdiagnosis and/or avoid the repetition of the examinations in Nuclear Medicine.

EXTRACTION OF HYDROXYTYROSOL FROM OLIVE LEAVES, RADIOLABELING WITH I-131 AND EVALUATION BIOAFFINITY OF THE RADIOIODINATED HYDROXYTYROSOL

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Nowadays; fruits and vegetables are consumed very much and intensity of the traditional use of them are becoming increasingly important. It is known that natural fruits and vegetables having high antioxidant capacity has protective effect on human health [1,2]. One of these fruits is olive because of its phenolic compound contents that show high antioxidant properties. Olive is a dynamic research object because Mediterranean diet has been shown to protect against cardiovascular disease and cancer [3]. The major phenolic compound in olive, olive leaf and olive oil is hydroxytyrosol (HT) [4]. In recent years, there is a significant increase on the production of antioxidant substances from natural plants and purification of them to search the potential use at the treatment and diagnosis of diseases [1,5]. With this purpose in current study; olive leaf, which is known to be rich on HT, is extracted, HT is isolated and labeled with ^{131}I radionuclide utilizing iodogen method. Biodistribution studies on healthy male and female rats and cell culture studies on different cell lines (Hutu-80, Caco-2, PC-3, MCF-7) were performed to evaluate the bioaffinity of the ^{131}I labeled HT (^{131}I-HT) compound. In the experimental studies, it has seen that HT could be radiolabed with ^{131}I in yields 95.62% ± 4.36 (n = 8); *in vivo* studies showed that radiolabeled compound has urinary bladder, stomach, small intestine, large intestine, breast and prostate uptake; and significant binding activities of radiolabeled compound on studied cell lines was observed at *in vitro* studies. This study carried out, as an herbal product extract for the development of new agents for imaging and therapy is thought to contribute to the investigations done in this area.

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AVOIDING OF FALSE POSITIVE FINDING IN SPECT PERFUSION MYOCARDIAL SCINTIGRAPHY WITH ITERATIVE IMAGES RECONSTRUCTION

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Introduction: Spect myocardial perfusion scintigraphy (MPI) is non-invasive technique for detection of myocardial ischemia caused by stenosis of one or more coronary arteries. However, the gold standard for detection of coronary arteries stenosis is coronary angiography (CA). Finding of perfusion defects on SPECT without coronary stenosis on CA is considered like false positive. The aim of this study was to evaluate three different SPECT image reconstructions in order to find the one with the best correlation with CA findings.

Patients and Methodology: We have examined 77 patients with angina pectoris (AP), 54 men and 23 women with standardized two-day protocol for MP with stress study done on the first, and rest study was done on the second day. All studies were done on double-headed Siemens gamma camera. Reconstruction of the heart images was done by Filtered Back Projection (FBP), Maximum Likelihood Expectation Maximization (MLEM), and with **Ordered Subset Expectation Maximization** (OSEM). All patients were undergone CA with standard Seldinger access. Visualization of perfusion defect was considered as pathological finding at SPECT. At CA finding of 50% or more stenosis of coronary artery was considered as pathological. Visualization of perfusion defect on SPECT without stenosis on CA was considered as false positive finding on SPECT. Statistic analysis was done by Spearman Correlation index with significance at 0,01.

Results: On MPI, we have found myocardial perfusion defects with FBP in 26%, with MLEM 11,7% and with OSEM in 9,1% of patients. On CA pathological coronary arterie stenosis was found in 7,6% of patients. With FBP there were 18,4% false positive findings, with MLEM there were 4,1% of false positive, and with OSEM reconstruction there were 1,5% false positive findings. Spearman Correlation between FBP and CA was 0,380 with significance at 0,001, between MLEM and CA correlation was 0,648 with significance <0,001, and between OSEM and CA correlation was 0,751 with significance <0,001.

Conclusion: With OSEM iterative reconstruction, we have achieved the best corelation between MPI and CA, and the smallest number of false positive findings on MPI. Therefore, OSEM reconstruction should be used whenever it is possible for processing of the images on MPI.

Key words: Myocardial perfusion, coronary angiography, filtered back projection, MLEM, OSEM

EVALUATION OF RADIOLABELED AMINOACID COATED MAGNETIC NANOPARTICLES

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In this study, biofunctionalization of Fe (II) and Fe (III) iron particles were provided with L-alanine, which is the standard amino acid. Then structure and size determinations of L-alanine and L-cysteine-coated magnetic nanoparticles were performed by using Scanning Electron Microscope (SEM). The radiolabeling study was carried out through direct labeling with $[^{99m}Tc(CO)_3]^+$ core. The quality control of $[^{99m}Tc(CO)_3]^+$ core was made via Thin Layer Radio Chromatography (TLRC) and the yield of the core in the saline solution was determined as % 99.72. In the serum stability studies it was observed that L-alanine coated radiolabeled magnetic nanoparticles kept its stability for 4 hours. Biodistribution studies were performed on Wistar Albino rats to determine radiopharmaceutical potential of L-alanine coated radiolabeled magnetic nanoparticles.

It is thought that the gained data from this study will make contribution to development and usage as an imaging agent in the medical applications of amino acid coated radiolabeled magnetic nanoparticles complexes.

IMPORTANCE OF ULTRASOUND ELASTOGRAPHY PRIOR TO TESTICULAR SURGERY: CLINICAL EVIDENCE

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Background: In the last years it has been developed an ultrasound software: Ultrasound Elastography, which is an important step in the ability of ultrasound to become a method that in addition to "see" lesions, "recognizes" them for what they are. The Elastography is a validated method in the characterization of thyroid nodules, prostate lesions, breast lesions, muscle and tendon injuries, and pathology of the liver. It is based on the ability of the tissues to deform and undergo the compression of the probe in a different way according to its anatomical and histological composition. For example, benign lesions tend not to present histological upheavals compared to "normal surrounding tissue" thus reserving similar deformability; on the contrary, a malignant lesion presents histological alterations of the composition compared to normal parenchyma that infiltrates, making it more rigid. We used Elastography to assess the nature of a testicular lesion in a patient with Carney Complex.

Materials and Methods: The method is able to characterize in real-time the nodular lesions tissue through an algorithm, which allows to obtain an elastogram in which each color gradient is related to a degree of elasticity of the tissue. The instrument used is an ultrasound Hitachi. The patient (M 63y) is affected by Carney Complex, a rare genetic syndrome. During the follow-up the testicular ultrasound study had detected an intraparenchymal mass of about 5mm with calcified rib on the left and not palpable on physical examination.

Results: Elastography allowed us to define the nodule highlighting the nature of rigid, non-deformable and it was possible to assume a conservative treatment. The removed nodule was confirmed of benign nature, characterized as an hyperplastic area of Leydig cell. It was adopted a conservative surgical approach with saving the testicle.

Conclusions: Today, the incidental ultrasound evidence of testicular nodules is increasing, the nature of which, in 80% of cases, is benign to the histological investigations. The Ultrasonography alone is insufficient to define the nature of lesions. So Elastography can provide valuable support to their diagnosis and allow an approach less demolitive. Elastography can provide an additional aid in the decisions to be taken when undertaking an indication of which other tests to perform.

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HER2 POSITIVE BREAST CANCER PATIENTS: CORRELATION BETWEEN MAMMOGRAPHIC AND PATHOLOGICAL FINDINGS

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Objective: HER2 positive breast cancers represent a highly aggressive breast cancer subtype and are associated with a worse prognosis. This study was designed to investigate the mammography findings of HER2 positive breast cancer and to compare the results with characteristics of HER2-negative breast cancer patients.

Methods: From January 2010 to October 2011, mammography findings of 65 patients with pathologically confirmed HER2 positive breast cancers (n=22) or HER2 negative breast cancers (n=43) were retrospectively reviewed. We also reviewed pathological reports for information on the histological type and differentiation grade.

Results: Among the two types of breast cancer patients, ER-negative/PR-negative/HER2-positive breast cancer patients most commonly had associated calcifications (18/22) on mammography. On mammography, cases with a cluster of calcifications usually were presented as pleomorphic calcifications (12/18) and branching calcifications (4/18). Patients with HER2 positive breast cancers showed a histological grade II. HER2 positive breast cancer patients usually had ductal invasive carcinoma (17/22). Moreover, postmenopausal patients showed a significantly higher frequency of HER2 positive tumors.

Conclusion: Our results suggest that the imaging findings might be useful in diagnosing HER2 positive breast cancer patients.

RADIOLABELING OF A NITROJEN MUSTARD DERIVATIVE

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The purpose of this study; is to radiolabel melphalan (L-PAM) known as a significant analog of nitrogen mustards which belongs to a category of bifunctional alkylating agents, with ^{99m}Tc, and investigation of *in vivo* biological behavior of this new complex.

In order to prepare ^{99m}Tc-L-PAM, designed as a new radiopharmaceutical, primarily melphalan commercially named as ALKERAN (2mg), has been purified from its tablet form, and quality control was checked with HPLC method. After purification process, L-PAM has been reduced in the presence of $SnCl_2$ and labeled with Tc-99m in an acidic environment. The quality control of the radiolabeling procedure has been checked with TLRC method, and the yield has been calculated as % 99.0 ± 1.19.

Biodistribution study performed on female Wistar Albino rats to determine *in vivo* biological activity of ^{99m}Tc-L-PAM complex. It is examined that ovary, breast and uterus have high ^{99m}Tc-L-PAM uptake.

In conclusion, it is thought that melphalan radiolabeled with Tc-99m (^{99m}Tc-L-PAM) would contribute as a selective imaging agent.

A NOVEL METHOD FOR WATER EQUIVALENT PATH LENGTH MEASUREMENT IN PROTON RADIOGRAPHY

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The purpose of this study is to present the experimental evaluation and quantification of proton radiography using scintillation screen coupled to CCD camera and beam energy modulation (BEM) water phantom. Using the BEM water phantom, proton beam energy was modulated by controlling water thickness with two kind of methods. Modulated proton beam which passed through water phantom was measured by imaging system which consists of a plastic scintillation screen, a mirror and a CCD camera in a dark box. A range compensator (RC) was taken using two kind of radiography techniques and each technique was compared analysing water equivalent path length (WEPL) resolution and scatter effect. Proton radiography with BEM water phantom was expected to be used for obtaining accurate dose distribution and calculating range uncertainty.

MEDICAL IMAGES PROCESSING FOR MONTE-CARLO BASED TREATMENT PLANNING SIMULATION

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The new radiation treatment planning system for neutron therapy named NPPlan is now under development at MRRC, Obninsk, Russia. The system contains several modules: medical images delineation and contouring, 3D positioning, treatment simulation and dose evaluation, with patient database and therapeutic neutron facility integration. As one of the core part medical images transformation algorithm has been designed. This algorithm provides functionality for DICOM-images-to-grid and grid-to-dose transformation.

A common way of medical images transformation for Monte-Carlo based calculations is to transform source image once to uniform grid and rotate and transform beam source model with linear conversions. This approach is resulted in significant decreasing of resulted calculation speed. Our approach is to construct an always orthogonal to source beam lattice. Such approach obviously resulted in increasing calculation time for preliminary stage, but it was investigated that overall computing time significantly decreases.

The input data for proposed algorithm is DICOM series, the output data is extrapolated Hounsfield scale for new slices orthogonal to source linear transformation. This data can be later used for voxel aggregation algorithms and final output are input file for MCNP/mcnpx, series of input files for modified Geant4 'dicom' example and, prospectively, input task for FLUKA.

All algorithms listed above were implemented with Python programming language using VTK and numpy libraries and built-in multiprocessing module. Average processing time from DICOM input and source definition to simulation task files is 7 seconds on 8xIntel Xeon 2.13 GHz.

Modern radiation treatment planning system must meet all requirements for quality assurance. There is a common approach to use conformal beams, intensity modulation techniques and so forth. Parallel computing is the most common approach nowadays and there is obvious need to implement such approaches in medical software. The chosen module is the only first step towards accurate parallelization which resulted in decreasing planning time as well as increasing treated patients quantity.

FREQUENCY OF PERIAMPULLARY DUODENAL DIVERTICULA AND ITS ASSOCIATION WITH BILIARY DISORDERS /RETROSPECTIVE ANALYSIS OF THEBULGARIAN POPULATION/

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Introduction: The purpose of this retrospective analysis of the large population was to investigate the frequency of JPDD and its association with disorders of the biliary system in patients undergoing ERCP.

Methods: Patients examined at the Endoscopy section of the Department of Gastroenterology with collaboration of the Department of Radiology between 1989 and 2011 were included in this study. All these patients were examined with respect to evidence and location of PDD and presence of biliary disorders.

Results: 3259 patients were examined by endoscopic retrograde cholangiopancreaticography because of presence of current or previous pancreaticobiliary disease. 775 of those patients had periampullary diverticala and 61 had more than one diverticulum. 48.91% are male, 51.09% are female. In our series the incidence of choledocholithiasis is 48.51% in patients with periampullary diverticula compare to 36.27% in patients without diverticulum. The prevalence of purulent holangitis was more frequent in patients with PDD than in the control patients (4% vs. 3.3%). Gallbladder stones with cholecistitis was found in 26.32% in group with PP vs. 20.28% in controls. The incidence of previous choleciytectomy is 34.96% in patients with PDD, and 30.75% in patients without DD. Papillitis stenosans was found in 58.45 % in patients with PDD, and in 40.37% in patients without PDD.

Discussion / Conclusion: To our knowledge this is the largest study yet published in our country concerning the relationship between periampullary duodenal diverticula and biliary disorders. The incidence of diseases of biliary tract associated with duodenal diverticula is higher than that of non associated. In our retrospective analysis, an association of choledocholithiasis and PDD was shown. A higher frequency of gallbladder stones and cholecistitis was evident. Previous cholecistectomy and papilitis sclerosans were also more frequent in patients with PDD.

CONTRAST VERSUS PATIENT DOSE IN MODERN DIAGNOSTIC RADIOLOGY

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The paper considers and comments different aspects of the correlation between image contrast and patient dose in radiological investigations. The modern systems, with silicon detector and Computed Radiography assure a reduction of dose compared with the film system (1.7 - 2 times), without affecting the image quality. This may be explained by the analysis of all physical processes. The silicon system seems to be the best. The doses are measured usually, with a validated phantom, but K. Bacher et al. used a big set of patients, equipped with TLD detectors. There are papers which study the influence of different voltages and filters. The pediatrics is a special case. The dose reduction by digital systems with or without added filters must be compared. Measurements are ongoing in a pediatric hospital on a phantom. The filters attenuate low energies which are most absorbed in the body (more than 97%). The filters may affect the contrast, but the physician, based on his experience, may choose the adequate compromise. Even a small reduction of effective dose, will represent a huge reduction of the "collective dose" of millions of patients in the world, every year.

SCINTIGRAPHY MEASUREMENT OF SEGMENTAL COLONIC TRANSIT IN CHILDREN WITH BOWEL BLADDER DYSFUNCTION

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Introduction: Children with "bowel bladder dysfunction" (BBD) complain of urinary frequency and incontinence, non-monosymptomatic nocturnal enuresis, voiding dysfunction, recurrent urinary tract infections, chronic constipation and/or encopresis. Two different types of chronic functional constipation have been identified in children based on colonic transit time (CTT) measurement: a more generalized and severe form known as slow-transit (ST) constipation and a segmental type known as functional fecal retention (FFR). Both entities present with similar symptomatology (decreased defecation frequency, fecal incontinence, abdominal pain), but involve different pathophysiological mechanisms and require different treatment strategies. Moreover, ST constipation can be unrecognized, as fecal mass cannot be identified on digital rectal examination, or megarectum on ultrasound examination.

Purpose: To evaluate types of constipation according to CTT in chronically constipated children in BBD group and to compare the results with transit type in children with chronic functional constipation without urinary symptoms (constipation group) and children with normal bowel habits (control group).

Patients and Methods: One hundred and one children were included in the study and their medical histories were obtained. Physical examination including a digital rectal examination was performed, together with the measurement of rectal diameter by transabdominal ultrasound. BBD group kept a voiding diary, and underwent urinalyses and urine culture, ultrasound examination of bladder and kidneys and uroflowmetry with pelvic floor electromyography. Radionuclear transit scintigraphy was performed in all children according to a standardized protocol. The radiopharmaceutical was prepared by adding DTPA labeled with 99m-Tc pertechnetate to granular carbon. Sequential images of the abdomen were taken at 4, 8, 24, and 48 hours. Segmental colonic transit was analyzed visually and semi-quantitatively by calculating the geometric center from the different anatomic regions of the colon. Patients were categorized as having either ST, FFR or normal transit. Results were compared between the groups.

Results: FFR was diagnosed in 31 out of 38 children with BBD and 34 out of 43 children in the constipation group. ST was found in 7 children with BBD, compared to 9 children in the constipation group. The control group children demonstrated normal colonic transit.

In the BBD group, patients with ST had significantly lower GCs at 24 and 48 hours when compared to those with FFR ($P<0.001$, $P<0.01$, respectively). Similar results were found in the constipation group at 24 and 48 hours ($P<0.001$, $P<0.05$, respectively). Significant differences were also found at 24 and 48 hours between children with ST in the BBD group and the control group with normal transit ($P<0.001$), as well as at 24 hours between the children with ST in the constipation group and those with normal transit ($P<0.001$).

Conclusions: FFR is the most common form of chronic constipation in children with BBD. However, some children might suffer from ST constipation. The differentiation between these two types of constipation is clinically significant because they require different treatment strategies.

MEDICAL PHYSICS

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GEANT4 SIMULATION OF A HELICAL TOMOTHERAPY UNIT

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Radiotherapy represents a main treatment option in cancer care (about 52% of oncological patients receive radiotherapy at least once during their cancer treatment) and Monte Carlo is considered the gold-standard method to perform absorbed dose evaluation, because it provides a detailed description of the radiation fields and of their transport in tissues [1]. Helical Tomotherapy (HT) is a 6MeV Linear Accelerator (LINAC) rotating in CT-Scan like gantry, featuring intensity modulated radiation therapy (IMRT) functionality by means of a dynamic binary Multi Leaf Collimator (MLC). A megavoltage computed tomography (MVCT) detector array, which rotates opposite to the LINAC head, is used for 3D patient image acquisition in order to allow Image Guided Radiation Therapy (IGRT) features. High gradient dose distributions are possible allowing treatment of complex tumors [2,3], as well as dose escalation protocols. The delivery is continuous while the treatment couch moves into the gantry and it come out a helical delivery. Consequently, HT presents new challenges in Monte Carlo (MC) simulation because several components must be precisely modeled: LINAC head, jaws collimation system, MLC, treatment couch and MVCT. Besides, simulation of the whole HT structure movements requires a high precision level in components alignments. In this work, a full Geant4-based MC package (TOMOG4) of a full HT treatment unit has been carried out. Geant4 [4] is a MC toolkit that allows modelling and simulation of the interaction of particles with matter. The Geant4 code has been chosen because its free distribution and its flexible combinatorial geometry capability, required for detailed modelling of complex systems.

TOMOG4 has been commissioned by tuning LINAC parameters in order to obtain accordance of simulated dose profiles with the measured ones. A dose deposition sensitive water tank phantom has been simulated to allow commissioning. The dose profiles on which the commissioning is based are Percentage Depth Dose (PDD) and Transversal as well as Longitudinal profiles at several depths in water phantom. The best fit with the experimental values was obtained with 5.7 MeV incident primary electron energy.

The TOMOG4 MVCT geometrical setup has been verified by comparison of detector array signal with experimental MVCT static acquisition. Rotational procedure modality and MLC intra-projection motion have been implemented, in order to perform dosimetric verification of complex IMRT delivery simulations.

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THE MEDICAL PHYSICS PRACTICE IN THE LIGHT OF THE NEW INTERNATIONAL BASIC SAFETY STANDARDS

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In the field of medical radiation physics, significant changes have been introduced in the new Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (the BSS). First, the medical physicist is identified in the new BSS as one of the key professionals, together with the radiological medical practitioner and technologist/radiographer, with responsibilities for quality assurance and patient radiation protection. Training and clinical competence requirements for medical physics practice are identified in the BSS. Medical physicists can practice only if they are specialized in the appropriate area, such as radiotherapy, nuclear medicine, diagnostic radiology or image guided interventional procedures. The details of the specialization have to be defined at the national level by the relevant professional body, health authority or other appropriate organization. According to the BSS, for therapeutic uses of radiation, the requirements for calibration, dosimetry and QA, including the acceptance and commissioning of medical radiological equipment, need to be fulfilled by or under the supervision of a medical physicist. For diagnostic uses and image-guided interventional procedures, the requirements for imaging, calibration, dosimetry and QA, including the acceptance and commissioning of medical radiological equipment, need to be fulfilled by or under the oversight of or with the documented advice of a medical physicist. The degree of involvement of the medical physicist in diagnostic uses and image-guided interventional procedures is determined by the complexity of the radiological procedures and the associated radiation risks. This presentation highlights the main elements of the new BSS as it relates to the field of medical radiation physics and highlights the potential benefits for the professionals working in this field.

EVALUATION OF ABSORBED DOSE IN GADOLINIUM NEUTRON CAPTURE THERAPY

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The neutron irradiation facility for development of neutron capture therapy (NCT) method at the horizontal channel of WWR-SM research reactor of Institute of Nuclear Physics Uz AS has created. Gadolinium Neutron Capture Therapy (GdNCT) derived mainly from the consideration of quite higher neutron capture cross sections of gadolinium (49700 barns in natural composition) vs. boron (3835 barns for ^{10}B) that implies a huge dose delivery in tumour region. The use of gadolinium in vice of boron was proposed in NCT in more recent studies. We used Gd compounds such as Magnevist for experiments on biological objects at specialized reactor horizontal channel. In the preclinical studies on neutron capture therapy for experimental animals the different concentrations of Magnevist was tested. Distributions of Gd in tumors on mice and in muscles on rats were obtained.

The dependence of Magnevist amount in irradiation place depending on time - r(t) was experimentally defined. Mathematical description of experimental dependence - r(t) is presented. Calculations of gadolinium amount in a tumour, of irradiation duration and of absorbed dose are carrying out. These results will be used in experiments on biological objects and in clinical tests of cancer treatments with using epithermal neutron beam.

DOSIMETRY OF ELECTRON BEAM EXTRACTED FROM BETATRON BY POLYMER FILMS GAFCHROMIC EBT 3

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Intraoperative radiotherapy is a treatment modality for a locally advanced tumor of the abdomen, pelvis and breast, which involves the use of large single dose of radiation delivered to the tumor or bed of tumor and areas of potential regional spread during the surgical operation. This treatment modality is mostly based on the electron beams of MeV energies. One chooses the electron beam for such a treatment because of particular dose distribution in the tissue-equivalent environment; namely, a depth dose distribution has a plateau that starts directly at the surface of irradiated volume and a rather steep slope that depends on the electron energy.

Nowadays, most of the clinics worldwide which carry on the IORT procedure use the electron sources based on the compact linear accelerators. However, in Russia historically several clinics have been using the sources based on betatrons that have been manufacturing at Tomsk Polytechnic University. The main advantages of the betatrons are the possibility to change the beam energy in a wide range with small steps (e.g. 2-6 MeV with spacing 0.1 MeV), low energy spread of the beam and the relatively low cost of a device (typically $ 200 000). These days our team develops new generation of betatrons with extracted electron beam for IORT and skin cancer treatment.

For the commissioning of accelerators before operation in a clinic it is necessary to carry out a set of clinical dosimetry procedures, for example, to measure the dose at a reference point or to determine the dose distribution in a reference phantom. One can carry out these procedures using robust 2D dosimeters based on ionization chambers, solid state detectors or polymer films. Due to tissue equivalence and ease of operation the film has become a very attractive option for the dosimetry of the electron beams. This dosimeter type allows to measure at the same time the absolute values and the spatial distribution of the absorbed dose with a high resolution. According to the manufacturer the polymer film Gafchromic EBT 3 can be used both for dosimetry of photon beams and electron ones.

In this report we present the absolute distributions of the absorbed dose of electron beam generated by a prototype of the next-generation betatron for medical purposes. The beam energy varied from 2 to 6 MeV at 500 keV step. All measurements were performed in tissue-equivalent phantom with zero air gap. The results show that obtained distributions of the electron beam in a tissue-equivalent environment for all energies of betatron coincide rather well with theoretical simulations.

MONTE CARLO DOSIMETRIC COMPARISON OF FOUR BETA-EMITTING GLASS SEEDS FOR BRACHYTHERAPY APPLICATIONS

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The aim of this study is to determine the dosimetric characteristics, as suggested in the AAPM TG-60 reports, for the four glass seeds consisting of the beta-emitting radionuclides ^{90}Y, ^{142}Pr, ^{153}Sm and ^{166}Ho which are proposed for potential application in brachytherapy. Monte Carlo codes MCNP5 was used to calculate the absorbed dose distributions at different radial distances around the seeds. A complete set of the dosimetric data for these seeds is tabulated and a detailed dosimetric comparison was carried out. Based on the present calculation and comparison, it can be concluded that the ^{153}Sm seed is dosimetrically different from other seeds.

PHOTOKERATOCONJUNCTIVITIS CAUSED BY DIFFERENT LIGHT SOURCES

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Ultraviolet (UV) light is the most common cause of radiation injury to the eye. The cornea absorbs most UV radiation. Exposure to UV radiation can lead to ocular surface disorder (i.e. keratopathy, pinguecula, pterygium or squamous metaplasia).

The goal of the paper is to present a study on the occurrence of photokeratoconjunctivitis, induced by different light sources. Following this reason, we recruited 102 consecutive cases from January 2010 to September 2013, through emergency department at general hospital in Vrsac. The patients were exposed to UV light. All subjects had visual acuity test, anterior segment examination and macular function examination.

Whereas 90,2% were occasional welders, 9,8% cases were attributable to ultraviolet lamps. The age of the respondents ranged from 17 years to 70 years. There were minor to moderate phototoxic syndromes involving the eye, only 2 sever cases.

The cornea is sensitive to the effects of ultraviolet light and can suffer both acute and chronic toxicity. The clinical syndrome is characterized by the onset of significant ocular pain and decreased acuity between 6 and 12 hours after exposure, usually to a welder arc or a tanning lamp. A superficial punctuate keratitis, typically bilateral, develops early; in severe cases, this is frequently followed by total epithelial desquamation. conjunctival chemosis, lacrimation and blepharospasm are also usually present. The lag time between exposure and symptoms is characteristic and is an indirect evidence that the effect is photochemical rather than thermal.

Key words: Phototoxicity, cornea, ultraviolet keratitis

GEANT4 MONTE CARLO AS A TOOL TO EVALUATE THE EFFECT OF DIFFERENT LUNG DENSITIES ON RADIOTHERAPY DOSE DISTRIBUTION

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Purpose: To evaluate the effects of different lung densities on dose distribution after irradiation at different field size, by comparing experimental measurements, GEANT4 Monte Carlo simulations and three TPS calculation algorithms on ad hoc phantoms.

Methods: The experimental set-up consists of a cubic phantom (30 cm sided) made of a lung equivalent material, with a PMMA (Polymethylmethacrylate) cube (6 cm sided) placed in the center. Different ad hoc phantoms were designed and constructed, reproducing different lung densities that represent the extremes of the density range corresponding to different breathing phases. Irradiations were performed with a Varian Clinac 2100 C/D with a nominal energy of 6 MV with different square field sizes. Dosimetric experimental measurements were obtained with radiochromic films. A software based on GEANT4 Monte Carlo code was developed to simulate both the accelerator and the phantoms. The simulations were run on a specifically designed computing system. Three different calculation algorithms, as implemented in commercial treatment planning systems, were considered. Results were compared. In the lung equivalent regions, the agreement of MC simulations and TPS calculations with experimental data is shown.

Results: Dose distribution evaluation results show an acceptable agreement between MC simulations and experimental measurements, both in the tumor equivalent region and in the lung equivalent ones. On the opposite, results vary among the three TPS algorithms, especially in regions of lung equivalent material at low density, but also at the interface between lung and tumor equivalent materials.

Conclusions: GEANT4 Monte Carlo simulations can be used to evaluate adequately situations such as a very low density in lung tissue surrounding a tumor, whereas deviations of some TPS calculations from the real dose distribution can be significant. Methods and results of this work may also be useful to evaluate the dose distribution in the lungs when other tumor sites are irradiated and to evaluate the dose distribution in presence of small air cavities.

Keywords: Lung cancer, radiotherapy, Monte Carlo, quality assurance, dosimetry, GafChromic EBT, treatment planning systems

CONSIDERATIONS ON THE INFLUENCE OF COLLOIDAL SOLLUTIONS ON THE ENERGY-INFORMATIONAL FIELD OF THE HUMAN BODY. STATISTICALLY RELEVANT STUDY

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The study conducted on a statistically relevant lot of 32 persons aimed to reflect the effects upon the human biofield in the course of several hours after the ingestion of a dose of ionic colloidal silver, through repeated measurements made with a GDV Camera (Gas Discharge Visualisation). The testing conditions and the measuring intervals were established through a prior test study conducted on a group of 3 persons, a study that also allowed drawing some partial conclusions. These partial conclusions were then verified and largely confirmed through statistical methods. The results obtained from the use of the GDV specific programs were taken and converted graphically to allow a most accurate interpretation. The GDV method is non-invasive, as it consists of the stimulation, in the electromagnetic field, and the photographing of the electrophotonic glow produced by the stimulation around the 10 fingers. The photos obtained are then processed with the aid of some special software. All living creatures are surrounded by an energy-informational field – a form of bio-radiation that is directly linked to the physical body. The energy-informational body reacts to certain stimuli much faster than the physical body, which constitutes an ideal condition for GDV-based research. The study was meant to be an attempt to demonstrate the fact that ionic colloidal silver is much more than a mere antiseptic solution.

SUMMARY OF THE METHODS USED TO LOWER THE ANXIETY PARAMETER – STRESS INDEX (T) / ACCORDING TO THE MEASUREMENTS MADE WITH THE GDV CAMERA

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In this article, we have tried to systematize the experiments made with the GDV (Gas Discharge Visualization) Camera and the afferent special software, focusing mainly on the Anxiety parameter – referred to as Stress index (T) as it was defined by Dr. Korotkov, the inventor of this method. The GDV method is a non-invasive method of extracting information from the properties of the biological energy field through a non-linear mathematical analysis of the fractal images obtained by photographing the discharge of the 10 fingers in a high frequency field, followed by the processing of the images with the aid of some special software.

By studying the stress index we are able to estimate the type of interaction between man and environment.

The anxiety or stress parameter (T) is based on the hypothesis that the difference between the mental and physical field represents the level of anxiety. This hypothesis has been confirmed by psychological tests (POMS – Profile of Mood States). The images obtained with the GDV Camera – referred to as GDV beograms – that were taken without a filter represent the sympathetic nervous system, whereas those taken with a filter represent the parasympathetic nervous system. The reduction of this parameter was done through different methods: Art of Living Programme, dance therapy, music, sounds created by specially tuned crystal bowls, states changed by consciousness, the ingestion of colloidal solutions etc. These methods are presented in a number of dissertations from Holos University in the USA (Gibson, Cowan, Haydin), Bucharest – Romania (Mohirta, Manolea), Ljubliana (Dobson), as well as the experiments conducted by the above-mentioned authors.

Each person’s choices create chaos or order into life, and the methods used to decrease anxiety are intended to be such a choice, as a person’s health or cure is not a passive event, but they require action.

MONTE CARLO SIMULATION OF LINAC IRRADIATION WITH DYNAMIC WEDGES

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Introduction: Wedges fields can be delivered by moving the collimator jaws within LINAC during irradiation, termed a virtual or dynamic wedge (DW). The component module (CM) called DYNJAWS has been added to the BEAMnrc code, which is designed to simulate dynamic wedges. The computer-controlled STT (Segmented Treatment Tables) generated by treatment planning system (TPS) are utilized as the input file for the BEAMnrc Monte Carlo (MC) code, which was converted using the Matlab code written. This study aims to assess the dose distribution of the breast irradiated by LINAC with dynamic wedges, which has known inaccuracy issues with TPS.

Experimental: LINAC (Varian, 6MV, SSD =95 cm) was used to irradiate the phantoms. DWs were used to obtain the dose profiles at Z= 5 cm for various wedge angles (15, 30, 45, 60 degree) with the RW3 solid-water phantom (PTW, Germany). The STT data for each angle of the DW, was converted and input for Monte Carlo simulation. The script, AUTODJWAS by Kakahel MB, *et al.* written in Matlab (version 7.8.0.342, MathWorks) automates and generates the BEAMnrc compliant input file for simulating LINAC irradiation with dynamic wedges. The dose profiles were determined with the diode Profiler (Sun Nuclear, 48 diodes).

A water tank (50x50x50 cm^3) was used to simulate the PDD of open field (10x10 cm^2 field size) at various dynamic angles. This was calculated both by TPS and Monte Carlo simulation and compared to the measurements from the ion chamber. In addition, an acrylic cylinder phantom (diameter=15.5 cm, depth 10.5 cm) was used to simulate the breast irradiated by LINAC. The dose distribution simulated by DOSXYZ was compared to the TPS data to further explore the surface (skin) dose distribution.

Results and Discussion: The gradients for each dose profile (Y-axis, Z= 5 cm), using dynamic wedges of LINAC, show good agreement with TPS, MC and diode Profiler measurements for 15, 30, 45, and 60 degrees.

The PDDs of the water tank irradiated by LINAC were found to be in good agreement with TPS and Monte Carlo calculated data, excluding the build-up region. At depths from 0~0.25 cm (epidermis), the depth-dose of TPS is approximately 65%~73% higher than the MC data (26%~63%).

The discrepancies between MC and TPS are more pronounced near the surface. Results from the cylinder phantom were similar to the water tank. Therefore, if the breast cancer is near the surface, the isocenter dose assessed by TPS should be increased by 10~30% in order to achieve sufficient dose.

Conclusions: The dose distribution of LINAC irradiation with DW can be accurately simulated (Monte Carlo simulation) with the DYNJAWS component module and the AUTODJAWS script. The overestimation of skin surface dose by TPS may potentially be as high as 30%.

DOSIMETRIC COMPARISON BETWEEN 3D TPS (TREATMENT PLANNING SYSTEM) AND MONTE CARLO SIMULATION IN NASOPHARYNX PHANTOM FOR ^{192}IR HDR BRACHYTHERAPY SOURCE

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For the treatment of some cancerous tumors such as nasopharnx carcinoma (NPC) using brachytherapy methods and high-energy photon sources, such as ^{192}Ir is usual. In 3D treatment planning that is done in hospitals, CT images are assumed homogeneous. This study presents the results of Monte Carlo calculations for non homogeneous nasopharynx phantom and 3D Treatment Planning System (TPS). Version 5 of the Monte Carlo N-Particle Transport (MCNP5) Code was used to calculate the dosimetry parameters for bench marking and dosimetry parameters in nasopharynx phantom. One reason for these differences could be the difference in homogeneous and non homogeneous environments. In all of TPSs the planning environment is considered homogeneous water; however, in MCNP5 simulation non homogeneity could be considered. If in Treatment Planning System, non homogeneity and photon energy spectrum are considered, these errors will be decrease and accuracy of Treatment Planning will be increase. In conclusion, Monte Carlo simulation performed better simulation due to simulation of non homogeneous and photon energy spectrum.

PRECISION COMPARISON OF DIFFERENT MONITOR UNIT ALGORITHMS USING AN IN-HOUSE DESIGNED PHANTOM

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A phantom for use in radiotherapy treatment planning of human pelvic anatomical region has been designed with si hollows for inserting materials mimicking different biological tissues and ionization chamber. The yellow plaster of paris was used to mimic the bone, Styrofoam for the lung and water for soft tissue. The phantom was scanned with Toshiba-Asteion CT-scanner and the images were transferred to the CMS-Xio treatment planning system for planning using 3 photon algorithms. Measurements of monitor units were conducted using 6 MV photon beams from the Elekta-Precise clinical linear accelerator with iso-centric set up. The test of the phantom was done using Fast superposition (FSS), the Superposition (S) and the Convolution (C) algorithms. Results with FSS algorithm showed better accuracy than S and C. The standard deviation of measurements with bone heterogeneity for all plans varied between +2 % and -3 %. FSS has faster computation speed than other algorithms; however C has a good balance of speed versus accuracy in homogeneous medium. Choice of algorithm for use should not be based on the speed of computation alone but also on the accuracy especially for applications with modern radiotherapy techniques such as intensity modulated radiotion therapy (IMRT) and Arc-therapy.

Key words: Phantoms, treatment planning system, fast superposition, superposition and convolution

CLINICAL NARROW PHOTON BEAM PROFILE RECONSTRUCTION FROM MEASUREMENT DATA WITH IONIZATION CHAMBER

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Purpose: Small field dosimetry is a challenging area due to difficulties arising during measurements and interpretation of its' results. Profile measurement results are affected by detector characteristics and in case of ionization chamber that means averaging effect due to its non-zero sensitive volume. There is a computational approach of true profile reconstruction which utilizes Wiener deconvolution of measured profile and detector dose kernel. Dose kernels can be obtained in different ways but one of the most accurate is Monte-Carlo modeling of the dose absorption process. In this work results of such reconstruction are presented and a comparison of reconstructed and simulated profiles is done.

Materials and Methods: Experimental results were obtained using PTW 31010 ionization chamber by measurement of Varian Clinac iX 6MV photon beam shaped with Millennium 120 MLC. Monte-Carlo modeling was performed using EGSnrc system with BEAMnrc package for linac head simulation and egs_chamber package for ionization chamber response calculation. Dose kernel was calculated by Wiener inverse convolution of measured profiles and simulated "true" profiles.

Results: It was found that calculated detector dose kernels can be fitted by Gaussian curve with σ depending on chamber radius. True profiles reconstructed with the use of obtained kernels can be filtered and smoothed to match a simulated true profiles which means possibility of future application of the presented technique to mathematically process measurement data before its use.

Conclusion: Results of small field profile ionization chamber measurements can be effectively processed to exclude averaging effect.

EFFECTIVE AND EQUIVALENT DOSE EVALUATION FOR BREAST CANCER RADIATION TREATMENT ON NG-24 NEUTRON GENERATOR

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Assessment of risk of radiation-induced cancer as a result of whole body radiation scattered radiation during radiation therapy is one of the factors for choosing the strategy of cancer treatment and an important parameter while ensuring the quality assurance of radiation therapy. This step is essential in the planning of radiation therapy on facilities with new features or a new combination of radiation exposure. As a part of pre-clinical studies of physical, dosimetry and radio-biological characteristics of new therapeutic beams of fast neutrons in the NG-24 (VNIIA, Moscow) to evaluate the equivalent and effective doses was conducted, which are formed in the patient's body by scattered radiation during neutron therapy with an energy of about 14 MeV . To estimate the effective doses an anthropomorphic human phantom ADAM was used. The phantom was modified with addition geometric cells describing mammary gland and ovaries. The simulations were performed with Monte Carlo method implemented in MCNP-5 program on a machine with 8 processors Intel Xeon 2.13 GHz, using the parallel computing technology MPI (MPICH library).

In mammary tumor irradiation case the collimator was positioned that another breast emplacement was geometrically outside neutron field. In the first series of simulations medical room's walls affection on the absorbed dose, critical organs and human tissues was assessed. Little impact of the wall starts to affect organs at distances greater than 50 cm from the irradiated volume (7-10%) The greatest value of additional radiation due to the scattering of neutrons in the room reaches the most distant organs: the ovaries (20%), bladder (30 %), and testis (35 %). The rest organs additional dose received dose does not exceed 5%.

The main series of simulations was performed with radiation and tissue weighting factors described in ICRP recommendation 1990 that allowed us to compare the results with published data. To estimate an impact of changes of W_R W_T, introduced by the ICRP in late 2007, we performed several additional simulations with new values of the weighting factors.

The collation of the simulations results of equivalent and effective doses shows that the effective dose is increased by 20%, mainly due to increase of tissue weighting factors for breast and other organs by 2.4 times, e.g. from 0.05 to 0.12. The data obtained are comparable to the doses during the course of proton therapy with passive retarders and point to the need for careful selection of schemes of combined gamma-neutron therapy based on the forecast life expectancy and the possible long-term post-radiation complications.

NEUTRON DOSIMETRY FOR AN 18MV MEDICAL LINEAR ACCELERATOR USING SILICON PIN DIDOES

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Electron Linear Accelerators (LINAC's) used in Radiotherapy treatments produce undesired photo-neutrons when they are operated at energies above 8 MV. These photo-neutrons contaminate the therapeutic beam and increase both in an out of treatment field dose to patients. As a consequence healthy tissues will receive a non-negligible dose and the patient risk of developing secondary cancer is increased. As radiation therapies are increasingly using higher energy beams as standard treatment procedure in Prostate therapy and IMRT, the production of photo-neutrons is becoming a prevailing issue. Dosimetric characterisations of these high energy beams, as well as investigations about neutron contamination are key interests. Primarily the need is to detect these photo-neutrons and be able to relate their presence to the total absorbed dose in the patient. At present there have many studies conducted to investigate neutrons in air but there has been little research focused on the presence of neutrons at depths within the patient, where radiosensitive organs are located. Recently a novel approach using silicon PIN diodes has been investigated at the Centre of Medical and Radiation Physics in Australia. Bulk and Planar type silicon PIN diodes have been developed and their sensitivity to photo-neutrons and gamma photons investigated using an 18MV Varian 2100 clinical LINAC. In this study we used silicon pin diodes to determine the absorbed tissue dose, at positions both on the surface and as a function of depth in a solid water phantom. The neutron absorbed dose across the surface, for a variety of field sizes was observed to be non-uniform due to the positioning of the LINAC head components. The absorbed neutron dose was observed to decrease gradually with increasing depth in the phantom, however at a depth of 5cm; it was observed that the absorbed neutron dose was slightly higher than expected. The diode response at this depth could be possibly due to the presence of fast neutrons for this particular spectrum. This is due to diode sensitivity to thermal neutron being ~50 times less than for fast neutrons. This result emphasises the importance of considering an appropriate depth in tissue and the proximity to radiosensitive organs to this position. As treatment planning procedures in hospitals still do not account for photo-neutrons, this is a need to improve the current methodologies. The advantage of these diodes, when used in high energy mixed radiation fields, is their passive operation, small size and good reproducibility. It is possible with further investigations and improvements; they might have potential application in hospitals as part of a routine Quality assurance procedure.

FEASIBILITY STUDY OF FLUKA MONTE CARLO SIMULATION FOR A BETA-EMITTING BRACHYTHERAPY SOURCE: DOSIMETRIC PARAMETERS OF ^{142}PR GLASS SEED

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Beta-particle emitter praseodymium-142 could be a prospering radioisotope for brachytherapy. Previously, a *^{142}Pr glass seed* for brachytherapy with a simple structure was introduced and the dosimetric calculations were performed using the experimental measurements and Monte Carlo N-Particle Transport (MCNP) code simulations. Frequently, the dosimetric calculations by modeling brachytherapy sources in the water phantom using MCNP code as a well-established Monte Carlo simulation code has been performed to fulfill the requirements according to American Association of Physicists in Medicine (AAPM) recommendations before the clinical use of new brachytherapy sources. In this work, the capability of the FLUKA Monte Carlo code to simulate ^{142}Pr glass seed as a beta-emitting brachytherapy source was extensively evaluated. The reference dose rate, target dose rate, radial dose function and the anisotropy function were estimated. A good agreement between the reported experimental measurements and the FLUKA code results was observed. FLAIR as a user friendly graphical user interface facilitated the editing of the input files, execution of the code and visualization of the output files such as isodose profiles without the need for command-line interactions. In conclusion, the observed agreement between the reported radiochromic film measurements and the FLUKA code results indicated that FLUKA can predict the recommended AAPM dosimetric parameters reasonably well.

MONTE CARLO CALCULATIONS OF DOSIMETRIC PARAMETERS FOR A NEW DESIGN ^{125}I SOURCE

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^{125}I brachytherapy sources are being used for interstitial implants in tumor sites such as the prostate. Recently, a new brachytherapy source, IR04-^{125}I, has been developed at Iranian Agricultural, Medical and Industrial Research School and is design for temporary implant. Monte Carlo radiation transport code version MCNP 5 was used to calculate the dosimetry parameters around the source in accordance with the update American Association of Physicists in Medicine (AAPM) Task Group No. 43 report (TG-43U1). For this source, the dose rate constant Λ, the radial dose function $g(r)$, and the anisotropy function $F(r,\theta)$, were obtained. The results indicated the dose rate constant of 0.934±0.1% cGy h^{-1} U^{-1} for the IR04-^{125}I source. Brachytherapy seeds model, 6711-^{125}I, BT-^{125}I and MED3631-A/M ^{125}I, carrying ^{125}I radio nuclides, was modelled and benchmarked against previously published values. Finally the calculated results were compared with published results for those of other source manufacturers.

A COMPARATIVE TREATMENT PLANNING STUDY OF INTENSITY MODULATED RADIOTHERAPY AND 3-D CONFORMAL RADIOTHERAPY FOR HEAD & NECK CANCER

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Radiotherapy is a treatment method having an important value in the treatment of patients presenting with head and neck tumours. Radiotherapy is preferred using with suitable techniques in head and neck tumours in terms of being reduced at least the damage to vicinity tissues. It is significant to be investigated the differences, advantages and disadvantages of the different methods and treatment planning techniques which are in progress.

The purpose of this study was to investigate the main differences and the advantages of Intensity Modulated Radiation Therapy (IMRT) in comparison to 3D Conformal Radiotherapy (3DCRT) for head&neck (h&n) patients. In this work, treatment plans of 20 h&n patients treated between 01.01.2011 - 01.01.2012 in Radiation Oncology Department at Cukurova University were prepared for both two treatment techniques and compared statistically. Target volumes described by radiation oncologists were classified according to the taken doses and the defined area as PTV1, PTV2 and PTV3. Dose values of minimum, maximum and V95% of the target volumes were determined as percentage for each specific definitions and the dose values of organ at risk (OAR) were determined as Gray (Gy). Each results for these two techniques were compared in Eclipse Treatment Planning System (TPS) and the results were discussed according to the p values with using Student's t test. Additionally, factor of Compatibility Index (Conformity Index, CI) was used to determine the extent which high dose region was compatible with PTV. Radiotherapy compatibility index is a very useful method to quantitatively determine the quality of radiotherapy treatment plans and to show the relationship between isodose distributions and the target volume.

COMBINED ACTION OF ELECTRICAL FIELD AND ERUFOSINE ON BREAST CANCER CELLS

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Electrochemotherapy (ECT) is now in routine clinical practice to treat tumors of different histology. The alkylphosphocholines (APC) are new group antitumor agents which show cytotoxic activity against different tumor cell lines. APC show a new and different way of action as they work on membrane level and modulate the signal transduction pathways originating from the membrane. They induce apoptosis in many tumor models and cancer cells without affecting the normal cells. Erufosine is the first intravenously injectable APC agent with reduced hemolytic activity and increased therapeutic ratio in vivo. The aim of the study was to examine how ECT with erufosine could act on cell survival, organization of cell cytoskeleton, apoptosis and cell cycle.

Materials and Methods: Erufosinewas synthesized and provided by Prof. H. Eibl (Max Planck Institute for Biophysical Chemistry, Göttingen, Germany). The cells were treated with 5μM, 10μM, 15μM and 50 μM solutions of erufosine. MDA-MB-231 and MCF-7 cell lines (ATCC) were used. Cells were plated at density of 1.5 x10^5 cells/ml on the bottom of 24 well plates or on slides placed on 6 well plates. For cell electroporation the Chemipulse III electroporator was used, which was produced at the Institute of Biophysics and Biomedical Engineering, Bulgarian Academy of Sciences, Sofia, Bulgaria. Eight biphasic pulses were used with an intensity of500V/cm and 1000V/cm.

Methods: Proliferation MTS assay, double staining for actin and cell nucleus and FACS analysis was used.

Results: MCF-7 cells did not show high sensitivity to the action of electrical field and erufosine. The invasivecelllineMDA-MB-231 revealed a concentration-dependent decrease of cell survival. The most sensitive reduction of cell survival (50 %-IC_{50}) was detected with combined treatment of 15μMerufosine and electrical field (500V/cm and 1000V/cm). Destruction of the actin filaments was visible together with appearance of round-shaped cells and nuclei destruction (apoptosis). FACS analysis showed an increased SubGphase (apoptotic phase) when cells were treated by the combination of erufosine and EF. For MDA-MB-231 cells was found a considerable increase in GM phase with treatment with M erufosine and electrical field (500VcmorVcm).

Conclusion: The combined treatmentof breast cancer cells with electrical field erufosine showed an increased effect on cell cytotoxicity, actin destruction, apoptosis and cell cycle arrest which might show a positive effect on cancer treatment in vivo.

MEDICAL USE OF RADIATION

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ANORECTAL MALIGNANT MELANOMAIN A HAEMORRHOIDAL NODULE

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Anorectal malignant melanoma (ARMM) is an extremely rare condition, often misdiagnosed and mistreated until development of metastatic disease. Clinical presentation mimicking haemorrhoids is a well know pitfall. We present a male patient with hemorrhoidal nodules who was referred to the Policlinic of Dermatology for management of anal pruritus. A dark macule was detected over one of the haemorrhoidal nodes histologically verified as melanoma. Subsequent CT and PET/CT showed lymph nodes involvement and the patient underwent wide local excision (WSE) followed by abdominoperineal resection (APR). The rarity of ARMM does not allow for establishment of a validated staging system, placebo-controlled treatment trials and management guidelines adoption. The current treatment for the condition is surgical excision, using different techniques according to the stage of the disease and depth of invasion. The prognosis and overall survival are poor, but recent genetic studies give promising results for molecular targeting. Awareness for this disease is indispensable, as early recognition could result in improved survival and quality of life.

Key words: Anorectal malignant melanoma, wide local excision, abdominoperineal resection

SUPERFICIAL SPREADING MALIGNANT MELANOMA – COMPLETE REMISSION AFTER SURGICAL EXCISION

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Superficial spreading type of malignant melanoma is usually characterized as the most common form of cutaneous melanomain Caucasians. The average age at diagnosis is in the fifth decade, and it tends to occur on sun-exposed skin, especially on the backs of males.

As the risk of spread varies with the tumourthickness, early SSM is more frequently cured than late nodular type of melanoma. Melanoma is a malignant tumor of melanocytes. Melanocytes are cells that produce the dark pigment, melanin, which is responsible for the dark color of the skin. They predominantly occur in the skin, but are also found in other parts of the body, including the bowel and the eye. Although melanoma makes up only 4% of skin cancers, it causes 77% of skin cancer deaths. Surgery to remove melanoma is the standard initial treatment. It is necessary to remove not only the tumor but also some additional normal tissue around it, with the purpose to reduce the risk that any cancer remains. The width and depth of surrounding skin to be removed depends on the thickness of the primary melanoma and how deeply it has invaded the skin. When the tumor tissue is very thin, the biopsy may remove all the cancerous tissue and no additional surgery may be necessary. In some other clinical cases, following the initial biopsy, every melanoma undergoes possible re-excision to remove the skin around the original site of the tumor in order to ensure complete removal and to reduce the risk of recurrence of the tumor at that site. The re-excision margin depends on the thickness of the primary melanoma, with increasing margins for increasing categories of thickness, from five till 9 millimeters on either side of the scar for melanoma in situ to potentially two centimeters on either side for melanoma over two millimeters tumourthickness.

However, it is important to note that the surgical approach to every melanoma should be customized based on the specific details of the patient and the melanoma, location of the primary tumour, and how the resultant wound could be finally closed. A simple excision of a melanoma can usually be accomplished by sewing the skin together, resulting in a linear scar, as in our patient. In most instances, wide excision alone can be performed under local anesthesia in the physician's office. We present a 72 year old patient with SSM on his back. Eliptical excision with 2 cm margins and very good cosmetic results was performed. The examination of the slides revealed clear margins. The patient remains disease-free at 6 months follow-up.

Key words: SSM, surgery, sun exposure, Melan A, S-100

HEMATOMA OR MELANOMA?

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An 18 year old patient presented with a dark tumour-like hyperpigmentation with peri –and subungual localization at digitum II of his right foot. The lesion exists since 4 months. There were no data for mechanic irritation or a trauma in the area of appearance. The patient attended the Department of Dermatology to exclude an acrolentiginous melanoma. Clinically the brown to black colored lesion showed a sharp demarked border. Dermatoscopically there were no signs of benignant melanocytic lesion, but a permanent black color among the entire lesion with a small area of a brown pigmentation in the lower area. Differential diagnoses were a hematoma following possible traumatic injury of the toe and an acrolentiginous melanoma. A punch biopsy was designed to exclude a malignant melanoma. Two days later the patient attended the Dept. of Dermatology again. Surprisingly, the lesion has been removed by the patient itself using mechanical pressure. A biopsy was not necessary. A subungual and periungual hematoma is a collection of blood in the space between the nailbed and fingernail. Subungual, but also periungual located hematomas result in most of the cases from a direct injury of the toenail or fingernail. Small sub- and periungual hematomas usually do not require any specific treatment. However, if the hyperpigmentation does not change within one month, it would be better to clarify, if there is possibility for another differential diagnosis such as acrolentiginous malignant melanoma. A cutaneous biopsy is strongly recommended.

PENILE PIGMENTED TUMOUR – UNCOMMON CLINICAL PRESENTATION: A CASE REPORT

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HPV infection is involved in the etiology of a number of nonmalignant, premalignant and malignant cutaneous lesions. One of them is the so-called giant condylomata of Buschke Löwenstein type (BLT), which sometimes can imitate clinically other tumors or tumor-like conditions. Clinicians face a particular challenge in cases of (BLT) where, clinically, the lesions demonstrate a permanent brown hyperpigmentation in parallel with the dermatoscopic lack of the characteristic melanocytic network, globules or regression zones. There are uncommon clinical presentations with solitary, sharply demarcated pirgmented lesions. In that cases the histopathological verification of the lesion is obligat and the most efficient treatment method in the early period of the disease is the complete surgical excision.

We report a patient who was admitted to the University Hospital "Lozenetz" in connection with profuse varicous bleeding of the esophagus associated with liver cirrhosis of unknown etiology. He underwent a consultative examination at the department of dermatology because of suspected, advanced stage melanoma of the prepuce. Computed tomographic analysis indicated diffusely located bone metastases in the small pelvis and femur as well as metastatic disease in the left inguinal lymph nodes.

However, the following histopathologic examination of the lesion, rather than showing melanoma, has confirmed the presence of HPV-associated giant condyloma of Buschke and Löwenstein in initial stage, without histopathological evidence for invasive and destructive tumor growth.

In some cases the clinical picture of the malignant and premalignant cutaneous lesions in the genital area could be problematic. The complete surgical excision and following histopathological verification is the best way to find out the exactly diagnosis.

Key words: HPV, papillomatosis, malignant melanoma, differential diagnosis, koilocytosis

DUAL ENERGY X-RAY ABSORPTIOMETRY GOLD STANDARD FOR BONE HEALTH AND BODY COMPOSITION ASSESSMENT

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Dual energy x-ray absorptiometry (DXA) is considered the gold standard to assess bone health and body composition because of its reliability, precision, and the fact that it is based on a three-compartment model. DXA uses two X-ray beams with different energy levels to measure body fat, muscle, and bone mineral density. The differential attenuation of the 2 energy x-rays is used to estimate the bone mineral content and the soft tissue composition. DXA method determines total body fat mass and fat mass %, bone mass and lean mass, and separately their regional values for the arms, legs, head and trunk (which includes ribs, pelvis, thoracic spine, and lumbar spine). Total Body bone mineral density (BMD) and body composition are valuable tools in the management of clinical disorders.

DXA determines total and regional body composition. Body composition measurement is a valuable clinical tool in the management of long-term health and fitness. DXA is a sensitive technique of body composition assessment, which measures whole and segmental body fat and lean body mass and determines the proportion of lean body mass (muscle) versus total body fat. A scan of the entire body is performed for measuring the body composition.

DXA scans are now the best method of diagnosing and monitoring osteopenia and osteoporosis. A DEXA scan is considered to be the gold standard for diagnosing and monitoring bone loss. It uses two low energy x-rays. A machine sends x-rays from two different sources through the bone being tested. The bone blocks certain amount of the x-rays. The more dense the bone is, the fewer x-rays get through the detector. For bone density measurements, scans of the lumbar (lower) spine, the hip, and the wrist are usually made. DXA is the best way to diagnose and evaluate the degree of osteoporosis. DXA scan evaluates bone mineral density, which is typically expressed in T-scores. A T-score greater than minus one is considered to be within the range of normal bone density. The diagnosis of osteoporosis in postmenopausal women means that the bone density has fallen below the range expected in premenopausal women (often called a T-score below -2.5).

Bone densitometry is very safe, and it does involve a very small amount of radiation. The amount is so small that the technologist remains in the room with the patient during the entire exam. The DXA scan calculates bone density based on the amount of radiation absorbed by the bone, and compares patient’s bone strength, bone density to that of young adults with normal bone density and to other persons at the same age. This DXA scan is a safe, painless and quick test that can measure bone strength and predict fracture risk before patient develops osteoporosis and hence effective preventive therapy can be started. Bone density tests are also used to monitor the response to particular medications. Our experiences in body composition and osteoporosis DXA assessment are evaluated in this study.

SKIN CANCER ASSESSMENT IN UROLITHIASIS PATIENTS DURING URETEROSCOPIC TREATMENT

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Urolithiasis patients have urinary stones, located anywhere in the urinary system. Ureteroscopy is an effective intracorporeal treatment method for urolithiasis in which an endoscope under the guidance of fluoroscopy is inserted through the ureter to retrieve or obliterate the stone. In addition to fluoroscopic radiation, urolithiasis patients are radiated by some other diagnostic imaging systems, such as kidney, ureter and bladder X-ray (KUB), intravenous urograms (IVU) and CT too. However, the used fluoroscopy in ureteroscopy is responsible for overall radiation exposure of urolithiasis patients. So, because of this fluoroscopy, the skin receives a major of radiation exposure. By considering the high incidence rate of urolithiasis and 50 percent risk of developing the second stone in one person life, a large number of people are at risk of skin cancer. So assessment of radiation absorbed dose during ureteroscopy treatment is very important. The main purpose of this study is assessment of skin radiation absorbed dose during ureteroscopy through simulation by Monte Carlo method (MCNPX) in the layers of skin to estimate the cancer risk.

To achieve this goal, a cylindrical phantom with two surface layers of plexi-glass as skin layers of whole body was simulated. Absorbed doses in these layers were measured in normal settings of X-rays machine means, 80 kVp and 900 mAs. The results were compared to the experimental measurement of skin entrance dose in an anthropomorphic male phantom by using MOSFET dosimeters. Then skin layers absorbed doses in cylindrical phantom were calculated at the worst conditions of fluoroscopy during ureteroscopy, means 91 kVp and 1800 mAs of X-rays machine.

In the simulation study, the skin absorbed doses in epidermis and dermis layers were 48.9536 and 49.6261 mGy respectively, while experimental measurement which was used to validate the study, showed the skin absorbed dose about 98.58 mGy. Also in the worst conditions of fluoroscopy during ureteroscopy, skin absorbed doses in epidermis and dermis layers were 106.393 and 106.455 mGy, respectively. By considering 10 percent skin cancer risk per 1 Sv absorbed dose according to the ICRP103 report, the skin cancer risk in urolithiasis patients should be about 1.06 percent for the patient who had only one ureteroscopy in a year.

Whereas urolithiasis patients are exposed by x-rays through other diagnostic or therapeutic devices and high probability of developing second stone, the estimated skin cancer risk may be increased significantly. So fine calibration of ureteroscopy is very important to reduce the cancer risk. Furthermore it should be done by using expert physician, limited radiation field of view, using fine calibrated fluoroscopy units and decreasing the fluoroscopy time as much as possible.

DOSE DISTRIBUTION AND RELATIVE BIOLOGICAL EFFECT FOR INTRAOPERATIVE RADIOTHERAPY

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The purpose of this study is to calculate the relative biological effectiveness (RBE) according to the dose distribution of the transmitted X-ray generator (INTRABEAM, Carl Zeiss Surgical, Oberkochen, Germany), which is used for further breast cancer treatment in auxiliary during breast surgery, as known Intraoperative Radiotherapy (IORT). The generator utilizes a 50-keV electron beam to hit the gold target to generate a forward bremsstrahlung radiation. The electron beam incidents the target from different beam angles that may cause various dose distribution to breast tissue compared with the distribution from the treatment plan. It is important to verify the dose distribution and understand the treatment plan uncertainty. The dose profile, provided by the vender in the treatment planning system, was verified by EBT2-film to record the dose around the surface of the spherical applicator. In addition, we apply a PENELOPE Monte Carlo tool in simulating the X-ray generator's dose distribution. The PENELOPE simulation algorithm for electrons reproduces the actual transport process to a high degree of accuracy and is stable even at low energies in our cases. The dose distributions for several applicators were simulated and compared with the measured results. Moreover, we use the dose distribution to calculate RBE and evaluate the risk of IORT in breast cancer.

RADIOLOGY INTERVENTIONS IN CARDIOVASCULAR DISEASES DURING PREGNANCY – IGNORE TABOOS TO SAVE LIVES

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Cardiovascular diseases during pregnancy are increasing due to the rise in prevalence of hypertension, diabetes and obesity, and older maternal age. Physiological alterations during pregnancy are **haemodynamic**, **hemostatic** (hypercoagulable state that increases the risk of thrombo-embolic events enhanced by venous stasis) and **metabolic**: impaired glucose homeostasis, hypercholesterolemia, *altered drug pharmacokinetics* requiring dose adjustments and monitoring. Therefore, it is reasonable to expect cardiovascular complications such as myocardial infarction (coronary dissection being the most common mechanism), pulmonary embolism and aortic dissection which are life threatening but are associated with the X-ray exposure during diagnosis and treatment. So why are we always surprised when we meet them in practice?

Pre-pregnancy risk assessment and counselling is indicated in women with known or suspected congenital or acquired cardiovascular and aortic disease according to widely accepted CARPREG risk score. Patients on predictable risk are usually managed jointly by a multidisciplinary team with a clear plan of follow-up during pregnancy and hospital delivery. It is a "safe zone" where we know that we can expect complications and we are focused on prevention but we are ready to intervene whenever necessary.

Transthoracic echocardiography is the cornerstone of cardiac evaluation in pregnancy. Excellent imaging of the fetal heart can usually be obtained by 20 weeks' gestation with fetal echocardiography. The biggest fear of cardiologist is a foetal exposure to radiation in diagnostic and therapeutic purposes (e.g. in myocardial infarction a coronary angiography with the possibility of percutaneous coronary intervention is preferred over thrombolysis).

Radiation is harmful to all living tissue and particularly to the foetus. Increasing radiation exposure is associated with a range of tissue defects, beginning with isolated cellular damage and progressing to growth impairment, structural deformity, neoplasia, and gonadal damage. It should be emphasised that the upper limit with regard to danger of injury for the foetus is considered to be 50 mSv (50 000 µGy). Therefore, all diagnostic modalities in acute cardiovascular pathology may be used without a significant risk to the fetus.

The amount of radiation absorbed by the foetus for different diagnostic tests is: for chest radiography < 10µGy or 0.01 mSv, perfusion lung scan with Technetium-99m labelled albumin (1–2 mCi): 60 - 120 µGy or 0.06 - 0.12 mSv, ventilation lung scan 200 µGy or 0.2mSv, CT angiography (1st trimester 3 - 20 µGy or 0.003 - 0.02 mSv, 2nd trimester 8 – 77 µGy or 0.008 - 0.08 mSv, 3rd trimester 51 - 130 µGy or 0.051 - 0.13 mSv), pulmonary angiography by femoral access 2210 – 3740 µGy or 2.2 - 3.7mSv, pulmonary angiography by brachial access < 500 µGy or < 0.5 mSv.

Conclusion: Cardiovascular diseases frequently complicate pregnancy, all diagnostic and therapeutic modalities that involve X-ray exposure are considered to be not only safe but lifesaving.

COMPARISON OF RADIATION DOSE AND IMAGE QUALITY IN SCREEN-FILM AND DIGITAL RADIOGRAPHY

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Digital radiography systems are rapidly replacing units with screen-film image receptors in diagnostic radiology departments as digital detectors have many outstanding advantages as possibility of image post-processing for disease specific-condition, display flexibility and easy access, transfer and storage. However, transfer from analogue to digital imaging systems requires caution, understanding of digital technologies and specific training of the operators. Although transfer from screen-film to digital system eliminates technical reasons for poor image quality and image rejection, the reasons related to non-technical reasons as skills of the operators remain. Whereas in screen-film systems there is a need to irradiate the detector to a certain level needed to obtain adequate optical density on the film, any over- or under- exposures in digital systems can be easily rectified by adjusting the image signal. Thus, if not adequately used digital imaging systems could cause patient over-exposure without knowledge of operator or artefactual appearance of anatomy of post-processing in inappropriately applied. The purpose of this paper is to evaluate image quality and dose to patients in the radiography of sacroiliac joints and to perform clinical comparative study of digital and conventional screen-film radiography. Routine radiography of sacroiliac joint was performed for 60 patients using digital and screen-film radiography. The visibility of five anatomical regions and overall image quality was rated by experienced radiologists. Patient dose assessment in terms of entrance surface air kerma (ESAK) was performed. The digital system showed improved, but not significant, visualisation of specific anatomical structures. Overall image quality was significantly better in digital when compared with screen-film imaging system. The average ESAK was 2.4 mGy in screen-film and 3.6 mGy in digital radiography. The digital radiography provided equal or better visibility of anatomical details and overall image quality. However, the system must be optimised in order to keep adequate image quality with dose level as low as reasonably achievable.

ENTRANCE RADIATION DOSE DETERMINATION FOR SELECTED CANCER PATIENTS AT THE LAGOS UNIVERSITY TEACHING HOSPITAL, NIGERIA

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Aim: To asses the precision of radiation dose delivery to Radiotherapy cancer patients at the Lagos University Teaching Hospital (LUTH), Nigeria.

Method and Materials: Entrance dose for 30 patients of diverse cancer presentations were determined using in-vivo Thermoluminescence dosimetry (TLD) technique. The TLD system which had earlier been calibrated was from the Rados technology, Turku, Finland. The ELEKTA clinical Linear Accelerator (LINAC) available at the LINAC Center of the Radiotherapy Department served as the source of the 6 MeV photon beam. A cylindrical ionization chamber (Type/ser: TM31010-1338) and electrometer (Type/Ser: T100001-11478) were used for pre-calibration of the LINAC. The patient were treated under the normal conditions with TLD detectors placed at suitable points in the beam on the patient skin.

Results: The results obtained shows that 90% of the patients studied received doses that were within the recommended precision $\pm$ 5 % limits compared with prescribed dose.

Conclusions: The slightly high deviations between the prescribed and delivered doses in 10% of studied cases are ascribed to obliquity factors. The results demonstrate reasonably good practice within the prevalent technical limitations.

Keywords: In-vivo dosimetry, Quality assurance, Entrance dose, Radiotherapy, TLD

VALIDATION OF GATE SIMULATION CODE FOR DOSIMETRY IN GYNECOLOGICAL BRACHYTHERAPY BY CÉSIUM-137: INTERCOMPARISON SYSTEM MANCHESTER AND ICRU-38

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The aim of our study is to determine the most appropriate method for dose distribution in the treatment of brachytherapy for cervical cancer by cesium – 137. Also to validate the GATE simulation code in brachytherapy. We used clinical and dosimetric aspects in the treatment of brachytherapy for cervical cancer , especially in the distribution of doses when using the method of Manchester (prescription at point A) and the method recommended by the ICRU 38 (International Commission on radiation Units and Measurements, Report No. 38) give the prescription dose in terms of volume treated.

We used the GATE simulation code and experimental results for these methods of dose prescription for the choice of the reference isodose , and also to estimate doses in organs at risk.

The results obtained with the GATE simulation code by comparing the expirimentaux results show that the two methods have significant differences in the selection of the reference isodose for three centers. However, the method recommended by the ICRU 38 is the best approximate clinical reality for the choice of the reference isodose.

Both methods show that doses in the organs at risk are within tolerance.

Despite this, the role of the radiation therapist for this type of treatment is important.

Keywords: Brachytherapy, Cesium-137, GATE, Manchester System, ICRU.

QUALITY CONTROL IN INTERVENTIONAL CARDIOLOGY AND RADIOLOGY

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The Directive 97/43 Euratom lays down the general principles of the radiation protection of individuals undergoing medical examinations with the use of ionizing radiation. Quality Assurance (QA) programmes including quality control (QC) measures are among requirements of this document. The goal of a QA programme in interventional radiology and cardiology department is to ensure that an x-ray system provides adequate image quality at minimum dose. The QA program in interventional procedures covers the following aspects of the imaging process: image quality and procedure protocol, equipment specification and performance, patient dosimetry, dose quantities, reference levels and procedure complexity, skin injuries prevention, dosimetry and follow up protocol, staff dosimetry and operator training. Complicated procedures performed in interventional radiology and cardiology may involve long fluoroscopy times and a large number of images. There is a potential for high radiation doses which in some cases may exceed the threshold of tissue reactions. Digital units are increasingly used in interventional radiology and cardiology. Detectors in digital systems have a large dynamic range and thus, too low and too high doses are hardly noticeable in images. For digital equipment QC is therefore essential to avoid unnecessarily high doses and to maintain good image quality. Consequently, there is a need for development of a dedicated QC protocol according to the actual clinical needs. The objective of this work is to describe and outline the QC activities of the interventional centers in Serbia in terms of physical and technical aspect of QC and scattered dose levels indicating the magnitude of the occupational radiation exposure. Key parameters reflecting quality in interventional procedures are related to the patient entrance dose rate, detector dose, limiting spatial resolution, low contrast resolution and accuracy of relevant patient exposure indicators are cumulative dose in interventional reference point and kerma-area product (KAP). These parameters were tested for all clinically used protocols in ten interventional and craniological and radiological unite used in Serbia. In addition, scattered dose levels in terms of t ambiental dose equivalent were measured in the relevant positions in the international ward. The survey on the cardiac and radiological interventional units in a sample of Serbian centers demonstrated a large variability in entrance dose rates for both, fluoroscopy and image acquisition modes, image quality performance and KAP calibration. As an outcome of this study, a preliminary set of reference levels for the patient entrance dose quantity is proposed. It can be adopted by centers and maintenance engineers to set up the equipment at an acceptable dose performance level. The developed protocol and results of its implementation could contribute to the assessment and optimization of patient and staff dose levels in interventional procedures in cardiology and radiology, while preserving the image quality.

CENTRAL OBESITY INDEX DETERMINED WITH DXA

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Obesity and body fat distribution are known risk factors for cardiovascular disease. Individuals with an "apple," or abdominal fat distribution pattern (upper body) are at a substantially higher risk for developing cardiovascular and metabolic diseases compared with those with a "pear," or lower body fat distribution pattern (hips, thighs and buttocks). Because of that, effective methods for assessing visceral fat are important to investigate its role for the increased health risks in obesity. DXA measurements of fat distribution may be useful in studies related to obesity-associated disease risk.

DXA investigates the normal and pathological topography of fat distribution to reveal the possible correlation with metabolic disorders. DXA enables determination of body fat distribution as well as central obesity index (COI) values. Body fat distribution is simply determined with DXA by the relationship of the regional (segmental) fat compartments.

COI is an indicator of central, abdominal obesity, which is the main characteristic of the metabolic syndrome. COI indicates android to gynoid fat mass percentage ratio, which is in a positive relation with the abdominal (central) obesity, and the metabolic syndrome.

DXA assessment in this study was performed with Lunar DPX-NT system. For body composition measurements, a scan of the entire body was performed in postmenopausal women. Total and regional fat mass (FM) and FM% were determined, truncal FM (TFM), android FM (AFM), gynoid FM (GFM) and COI as a ratio of the AFM% to GFM%, automatically determined with DXA machine. Central abdominal fat was measured from the upper border of L2 to the lower border of L4. Also, fat mass % was determined in a spine and hip scans as well as their ratio as an estimated COI (eCOI) value. Correlation and the difference of eCOI values in the spine and hip scans with automatically determined COI values in total body scans were compared. Mean values of COI are 0.9 ± 0.18 and those of eCOI are 0.92 ± 0.14. They were not significantly different ($p > 0.05$). COI and eCOI values correlated highly significantly ($p < 0.0001$). Higher significance of the COI correlation with android FM and TM was detected in comparison with the correspondent gynoid values, confirming COI positive association with central, abdominal fat and tissue mass, and abdominal fat distribution. eCOI measurements were reliable and comparable to automatically measured COI.

It can be concluded that body composition should not be performed for COI determination because it could be determined during regular spine and hip DXA measurements. Determination of eCOI is more practical, faster, with lower radiation and is more acceptable; moreover spine and hip bone mineral content is determined at the same time.

INFLUENCE OF LITHIUM CARBONATE ON EFFICACY OF RADIOIODINE THERAPY IN PATIENTS WITH GRAVES' HYPERTHYROIDISM – OUR PRELIMINARY RESULTS

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Introduction and Aim: Crucial influence on the outcome of radioiodine therapy (RIT) in Graves' hyperthyroidism (GH) has the effective half-life of ^{131}I in the thyroid gland, which can be extended by Lithium carbonate ($LiCO_3$) treatment. Till now, information on the usage of $LiCO_3$ to increase the effectiveness of ^{131}I is limited. For this reason, we aimed this study to assess the possible influence of $LiCO_3$ on efficacy of RIT in patients with GH.

Patients and Methods: It is planned that this prospective study includes 60 patients, but so far, 15 patients (12 female, age 36-69 years) were fully overviewed by the end of the study period of 12 months. Seven patients were treated with $LiCO_3$ in combination with ^{131}I-NaI (Li-RIT group), and 7 patients only with ^{131}I-NaI (RIT group). Treatment with $LiCO_3$ (daily dose of 900 mg) was started one day before RIT and continued six days thereafter. All patients were subjected to the same conditions of preparation (antithyroid drugs were discontinued 7 days before RIT) and application of ^{131}I-NaI dose activity. Therapy outcome was assessed by serum thyroid-stimulating hormone (TSH) and thyroid hormones levels, and clinical evaluation. A successful response to RIT (cured patients) was defined as euthyroidism and subclinical or clinical hypothyroidism.

Results: Comparison of gender (85.7 vs. 75.0% females, P=0.605), age (54.7±10.3 vs. 50.6±12.1 years, P=0.497), values of free thyroxine (15.8±4.97 vs. 13.7±5.20 nmol/l, P=0.540), free triiodothyronine (6.77±1.47 vs. 5.22±0.89 pmol/l, P=0.070), TSH (3.26±6.97 vs. 1.43±2.01 mU/l, P=0.490), TRAb (P=0.165), and duration of antithyroid drugs therapy (16.2±25.2 vs. 12.1±10.6 months, P=0.681) before RIT showed no significant difference between Li-RIT and RIT group. Also, there wasn't significant difference in administered activity of ^{131}I-NaI (392±50.0 vs. 388±64.0 MBq, P=0.891) between two groups. In Li-RIT group the serum level of Li was 0.56±0.16 μmol/l (normal range 0.3-1.3 μmol/l) at the moment of ^{131}I-NaI application. The cumulative incidence of successful response in Li-RIT and RIT group was 100 vs. 37.5% after 3 months, and 100 vs. 62.5% after 6, 9 and 12 months. All cured patients from Li-RIT group become hypothyroid after 3 months, while among cured patients from RIT group 12.5%, 50.0%, 50.0% and 62.5% become hypothyroid after 3, 6, 9 and 12 months, respectively.

Conclusion: Our preliminary results showed that radioiodine combined with short-term treatment with $LiCO_3$ resulted in cure of hyperthyroidism in all patients after three months. Cure of hyperthyroidism was achieved only in less than one-third of patients treated with radioiodine as monotherapy after three and in 62.5% of patients after 12 months. Although examination is needed on a larger number of patients, our preliminary results point out that lithium in connection with RIT in Graves' hyperthyroidism may have an influence on therapeutic success, especially in earlier elimination of hyperthyroidism.

Key words: Graves' hyperthyroidism, radioiodine therapy outcome, Lithium carbonate

THE INFLUENCE OF PROLIFERATION INDEX ON SOMATOSTATIN RECEPTOR SCAN IN PATIENTS WITH CARCINOID TUMORS

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Aim of the Study: Since somatostatin receptors tend to be overexpressed in patients with carcinoid tumors, the purpose of this study was to assess the role of the somatostatin analogue ^{99m}Tc-EDDA-HYNIC-TOC (^{99m}Tc-Tektrotyd) scintigraphy in carcinoid tumor diagnosing and staging. The scan results obtained in this study were compared with the principal diagnosis, taking into consideration the value of proliferation index of the tumor.

Material and Methods: Sixty-one patients (31 female, 30 male; age range: 33-76 years) were examined: 13 patients highly suspected of having a carcinoid and 48 patients who had undergone the surgical removal of the tumor. Whole body scintigrams at 4h postinjection, spot scintigrams, and SPECT of the selected regions were obtained for all patients. After the reconstruction of the radiopharmaceutical according to the manufacturer's instruction manual, the patients were administered 740 MBq activities and 8μg of octreotide.

Results: Fifty-eight out of 61 patients were diagnosed with carcinoid tumor, 39 of which were well differentiated (Ki67<2%), 14 were found to have well-differentiated neuroendocrine carcinoma (Ki67 2-15%), and 6 patients were diagnosed with poorly differentiated neuroendocirine carcinoma with proliferation index above 15%. Positive scan results, defined as detection of either primary tumor or/and metastatic spreading were found in 30 patients, and negative scan results in 31. On a per patient basis, overall sensitivity was 79%, specificity 86%, and positive and negative predictive value 87% and 77%, respectively. In 24 patients, the negative scan findings correlated with results obtained by means of other methods, and 26 patients with positive scintigraphy findings had their results confirmed. Seven patients had false negative scan results, and 4 false positive results. The greatest incidence of positive scan results (69%) was found in patients with low proliferation index (below 2%), whereas 4 out of 7 false negative patients had proliferation index above 15 %.

Conclusion: The results of this study point to the fact that somatostatin receptor schintigraphy with ^{99m}Tc-Tektrotyd represents a sensitive and specific method for diagnosing and staging patients with well-differentiated carcinoid tumors. However, in poorly differentiated tumors with high Ki67 proliferation index, additional analyses are necessary for precise staging.

Key words: Carcinoid tumor, somatostatin receptor scintigraphy, proliferation index Ki67

EVALUATION OF THE SCATTERED DOSE BY BLANKETS FOR HELICAL TOMOTHERAPY

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We employ a blanket to keep patients' body warm in a too cold room for Tomotherapy Hi-ART system. This study estimated skin dose elevation due to scattered radiation by blanket. We designed to perform comparison of superficial dose of a phantom, considering two plans with and without a blanket. We considered two types of blanket, thin and thick, which are usually used in our institution. After acquiring three sets of CT simulation data of a bare phantom, a phantom with the thin and the thick blanket, we registered all of three images as a phantom for DQA plan of Tomotherapy planning system. For the identical plan of clinical mode for the model patient, three DQA plans were created with three phantoms. With the dose statistics data of planning system, superficial doses were compared with each others. In addition, the phantoms with three setups were irradiated with DQA plans and the superficial doses were measured with the ion chamber at the depth of 0.5cm and 1.5cm. The results obtained from DQA plans showed that the surface dose was 25Gy, 36Gy, and 30Gy in the case of a bare phantom, and the thin and the thick blanket, respectively. The experiment for dose measurement using an ion chamber showed that the dose at the depth of 0.5cm was 2.323Gy when a fractional dose, 5 y, was delivered to the bare phantom. In the same setup with the thick blanket, the 0.5 cm depth dose was increased to 2.351Gy. At the depth of 1.5cm, the dose to bare phantom was 1.946Gy and that to the thick blanket was increased by 1.986Gy. It is concluded that skin dose elevation should be carefully examined, when we consider employment of any blanket for keeping warmth in a Tomotherapy room.

APPLICATION OF RESPIRATION DATA TO EVALUATE THE RADIATION DOSE FOR 4-DIMENSIONAL RADIOTHERAPY

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Respiratory motion of thoracic and abdominal region of human body may decrease the target irradiation in radiotherapy for cancer treatment and increase dose to healthy tissues. In the field of clinic, the accurate evaluation of dose distribution delivered to a patient gets more important in the case of lung cancer. In this study, we examined an applicability of respiratory signal of an individual patient for each fraction in 4-dmensional radiotherapy for cancer treatment. Using the commercial moving phantom, we developed a dosimetry system to evaluate quantitatively a dose delivered to an individual patient. When the 4-D planned treatment was executed by the respiratory gating system, data for respiration signals were saved in to the own database for each fraction. The extracted data were transferred as an input to program a respiration with the moving phantom. The moving phantom was located in the couch, irradiated with the treatment plan for the realistic patient. During irradiation with the gating program planned initially with the obtained 4-dimensional CT, the moving phantom was operated according the program with the respiration data for each fraction of an individual patient. By inserting the radiochromic film, we measured the dose distribution to the phantom and compared with that intended by the treatment planning system. The results showed that an application of data for respiration signal to program a motion of phantom might be effective tool for evaluating dose distribution to an individual patient for each fraction in the field of clinic.

OFF-CENTER EFFECTS ON RADIATION DOSE REDUCTION TO SUPERFICIAL ORGANS IN CT EXAMINATIONS: COMPARISON OF ORGAN-BASED TUBE CURRENT MODULATION (OBTCM), IN-PLANE BISMUTH SHIELD, AND COPPER FOIL BEAM FILTRATION

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Purpose: The aim of this study was to assess the off-center effects on radiation dose reduction to superficial organs in CT examinations using three methods of organ-based tube current modulation (OBTCM) technique, in-plane bismuth shield, and copper foil beam filtration.

Materials and Methods: A 16-cm diameter cylindrical phantom and an oval phantom were scanned with a dual-source and dual energy CT scanner (SOMATOM Definition Flash, Siemens, Germany). The cylinder and the oval phantom refer to patient's head and chest region. Radiation dose distributions of (1) OBTCM technique, (2) in-plane bismuth shield, and (3) copper foil beam filtration scans were measured with routine head and chest scanning protocols. A 10-cm length pencil-type ionization chamber (RTI, Electronic AB, Sweden) inserted into those phantoms was used to measure the real-time dose distribution under three scanning conditions. The dose distributions of three methods were compared with that of reference scan. Furthermore, the off-center effects of dose distribution were also compared with those at iso-center.

Results: OBTCM is an advanced application of tube current modulation. The intensity of an X-ray beam can be reduced when the X-ray tube moves in front of a patient's superficial organs, such as eye lens, thyroid, and breast. Then the tube current has to be increased when the X-ray tube is on the opposite side. Thus, the radiosensitive organs can be protected without loss of image quality. Bismuth shield can be used to protect eye lens, thyroid, and breast of adults and pediatrics as well. The streak artifact and increase of image noise can be observed from CT images when using a bismuth shield during CT scans. Copper foil beam filtration can be used to separate the streak artifact from CT images. The radiation dose reduction to superficial organs can be achieved with minimal increase in image noise. When a patient is not scanned at iso-center, the dose distribution of three scanning conditions was changed and asymmetric.

Conclusion: We assessed three strategies of radiation dose reduction to superficial organs in head and chest CT examinations. Organ-based tube current modulation is recommended for protect eye lens, thyroid, and breast in head and chest CT scans. For other CT brands without OBTCM application, in-plane bismuth shield or copper foil beam filtration can be alternative methods. Copper foil beam filtration can be used to reduce radian dose without streak artifact.

CORRECTION OF SPLITTED RADIOTHERAPY COURSE FOR CANCER PATIENTS

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The aim of this study was correct the splitted radiotherapy course for cancer patients. It has been carried out in 50 patients presented with common types of cancers in RICK hospital, the data collected including diagnosis, total dose, daily dose fraction, number of fraction, number of given fraction, total bio-effect, given bio-effect, decay factor, final bio-effect, missing bio-effect and rest period. The collected data has been analyzed by using Exile software and it reveals that: radiation bio-effect increases as the tumor dose increases according to $y=0.0153x + 19.203$ with significance at $R2 = 0.6$. And the decay factor decrease as the rest period increase according to $y=0.018x+0.8372$. at $R2 =0.9$. The radiation bio-effect% increases with tumor dose increment for total biological effect and the final biological effects according to $y=0.0153x+19.203$ and significance at $R2 =0.6$ and 0.7 respectively. The final radiation bio-effect due to splitted radiotherapy course was 75.1% and the missing biological effect was 40.8%. Also the analysis showed that missing biological effect was so significant in affecting tumor control at $t=0.5$ (t-test).

THE ROLE OF FORENSIC RADIOLOGY IN THE PROCESS OF FORENSIC EXPERTISE AND INVESTIGATION

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Forensic Radiology is a science which takes an important place among the medical and forensic sciences. Based on this fact, the focus of this paper is to show where and how forensic radiology helps in solving, processing and analysis of the cases.

The materials used for the analysis were the autopsy cases at the Institute of Forensic Medicine and Criminology in Skopje where the X-ray investigations were carried out with Shimadzu's mobile X-ray equipment in order to determine the mechanism of injury in car accidents, fall from heights, distinguish missiles and other foreign objects in firearm injuries, verify the identity of unidentified persons by comparing the ante-mortem with post-mortem facts, as well as identification of living individuals by ossification of the bones.

The X-ray investigation significantly improved and simplified the analysis of mechanism of death, because it allows the analysis to be repeated even after the forensic autopsy is finalized and provides permanent evidence in further court proceedings.

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PHOTONUCLEAR CROSS SECTION AND ISOMER RATIO IN PHOTONEUTRON REACTIONS ON NATURAL SN

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Nowadays the studies of the isomeric states of nuclei became once again of great interest due to the considerably development of experimental devices in the last decades. These experimental progresses give the possibility to verify and improve old experimental data and to obtain new ones on the isomeric states productions.

Photoneutron cross section reactions on natural Sn were evaluated using Talys code for incident neutrons energy up to some tens of MeVs. For each Sn isotope the contribution of compound, direct and preequilibrium mechanism were extracted. The isomer cross sections and isomer ratios were calculated. The results are compared with existing experimental data obtained by bremsstrahlung source and activation methods.

MEASUREMENTS AT NEUTRON BEAMS OF LVR-15 RESEARCH REACTOR WITH FRICKE GEL AND THERMOLUMINESCENCE DOSIMETERS

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Dosimetry in thermal or epithermal neutron fields with very high neutron fluxes requires development of suitable methods. It is necessary to determine the spatial distribution of the different dose contributions due to the various secondary radiations generated by neutron interactions with the traversed medium. Therefore, to perform reliable dose measurements, it is necessary to utilize suitable dosimeters, capable of measuring such different dose contributions, with good spatial resolution and without affecting the radiation field.

The dosimetry method based on layers of Ficke-Xylenol-Orange-infused gel has shown noticeable potentiality for in-phantom or in-free-beam dose distribution measurements in the high fluxes of thermal or epithermal neutrons characteristic of columns of research reactors. The discrimination of the various dose contributions is achieved by means of pixel-to-pixel manipulations, with suitable algorithms, of pairs of dose images obtained with gel-dosimeters having different isotopic composition. It is possible to arrange large dosimeters, detecting in such a way large dose images, because the layer geometry of dosimeters avoids sensitive variation of neutron transport due to variationof gel isotopic composition.

In order to have the possibility of verifying the correctness of the separation of dose contributions achieved with Fricke gel dosimeters, a method for measuring gamma dose and thermal neutron fluence with thermoluminescence detectors (TLDs) has been developed. Gamma and thermal neutron contribution are separated by means of algorithms based on the shape of the termoluminescence emission curve.

Various measurements, both in phantom and in free-beam, have been carried out at the collimator of two columns of the LVR-15 research reactor in Řež (CZ): the epithermal column suitably designed for boron neutron capture therapy (BNCT) treatments, with a moderator consisting of a disc of polythene with a thickness of 2 mm inserted into the collimator mouth, and the thermal column HK1 aimed at experiments of neutronography. Very good consistency was found between the values obtained with Fricke gel and thermoluminescence dosimeters.

NEUTRON ACTIVATION ANALYSIS ON DETERMINATION OF ARSENIC IN BIOLOGICAL MATRIXES GIVING SUPPORT TO THE WORKER'S HEALTH AWARENESS PROGRAM

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Aiming at giving support to the Worker's Health Awareness Program of the Municipal Department of Health of Belo Horizonte, capital of the Brasilian State of Minas Gerais, an assessment related arsenic was carried out in three galvanising factories by means of hair and toenail samples analysis as biomonitors. The arsenic was determined in the matrixes from factories where gold electrodeposition process was applied. This is because arsenic salts are usually added to gold bath to improve the metal covering. The high concentration results surprised the health surveillance professionals, and alerted for the need of assessing the influence of a long-term exposure. This project was the first action in order to assess the elemental concentration level in this kind of industry determining several elements not considered essential for human being such as arsenic.

Studies concerning this galvanising industrial process have usually been developed broaching many aspects including chromium contamination consequences, but so far none has pointed out the detection and measurement of arsenic. The k_0-Instrumental Neutron Activation method applying the TRIGA MARK I IPR-R1 research reactor was used and the nuclear analytical technique confirmed to be a suitable method on determination of arsenic in biological matrixes.

ANALYSIS OF NEUTRON RESPONSE OF BEO-OSL PERSONAL DOSIMETERS

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The personal dosimetric system “iBeOx” using optically stimulated luminescence (OSL) of beryllium oxide (BeO) has been developed by Hemholtz Zentrum Muenchen and Dosimetrics GmbH. In this study, fast and thermal neutron responses of the BeO OSL personal dosimeter located on an ISO slab phantom are investigated. Am-Be neutron source and thermalized neutron spectrums are used to study neutron energy response of the BeO detector.

MONTE CARLO CALCULATIONS OF THE NEUTRON DOSE EQUIVALENT IN THE ICRU SLAB

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Monte Carlo simulations are performed to evaluate the neutron dose equivalent for irradiation on the ICRU slab by Am-Be source. To simulate the neutron transport and neutron interaction with the atoms of the ICRU slab, the MCNP5/X code was used coupled to a home-made code to calculate the neutron dose equivalent. Previously developed home-made code, Neutron_CR-39.F90 written in the Fortran 90 programming language for irradiation CR-39 detector with neutrons, was rearranged for the ICRU slab. Comparison of results of MCNP and home-made codes for different distances the ICRU slab from neutron source was presented in this paper.

NEUTRON CAPTURE CROSS SECTIONS AND STRENGTH FUNCTIONS IN NEUTRON REACTIONS ON ^{147}SM NUCLEUS

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Cross sections and strength functions were evaluated from slow neutrons resonance neutrons up to some hundred of keVs. For their descriptions the neutron resonance parameters, transmission coefficients for exit channels and the Hauser – Feshbach formalism were included. The theoretical evaluations are performed by using Talys free software and author's computer programs. The obtained cross sections and strength functions are compared with experimental data in order to explain possible non statistical effects reported previously by some authors on the distributions of alpha widths.

MONTE CARLO SIMULATION OF THE NEUTRON SHIELDING FOR ^{99}MO PHOTONEUTRON SOURCE

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Photoneutron reactions are an important source of radioisotope production with application in medicine and other domains of human activity. Nowadays the necessity of ^{99}Tc is increasing constantly for medical applications. This isotope is obtained from ^{99}Mo by β decay and the ^{99}Mo isotope can be obtained in the fission of ^{235}U induced by thermal neutrons in nuclear reactor. The fission method is not a clean one and therefore a new nuclear analytical method is searched. Such an alternative method is through the ^{100}Mo(γ,n)^{99}Mo photoneutron reaction. This reaction is analyzed in the Giant Dipole Resonance Region and a comparison of different reactions mechanism is done. The neutron spectra and the yields of different isotopes in this reaction are extracted and these data are used in the neutron shielding ^{99}Tc isotope production. The present evaluation is compared with experimental data obtained by other JINR groups as well as from literature.

NUMERICAL CALCULATION OF THE DOUBLE DIFFERENTIAL NEUTRON PRODUCTION CROSS-SECTION IN REACTIONS INDUCED BY HIGH ENERGY IONS

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In the present study the double differential cross-section of the reactions induced by proton and carbon ions of energies above hundred MeV/nucleon on carbon target were evaluated. At such high incident energy a lot of channels are open and a model of direct interaction with coupled channels was used. The number of neutrons produced by incident protons per particle is not higher then 2 and about 8 - 10 neutrons per particle for incident carbon ions.

The results of this investigation are intended to improve the research in cancer radiotherapy.

EMPLOYMENT OF BAYESIAN AND MONTE CARLO METHODS FOR BIOLOGICAL DOSE ASSESSMENT FOLLOWING ACCIDENTAL OVEREXPOSURES OF PEOPLE TO NUCLEAR REACTOR RADIATION

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Occupational accidents or overexposures of people to ionizing radiation usually involve X or gamma-ray sources. An accidental overexposure to nuclear reactor radiation is less frequent but more complex in its evaluation, because the body is irradiated by both neutrons and gamma rays. Moreover, these two ionizing radiations are never monoenergetic and their biological effectiveness is markedly different and strongly dependent on the energy spectrum. So, there is a need to estimate not only the total dose but also its neutron and gamma components.

The analysis of dicentric chromosomes in peripheral blood lymphocytes of the exposed person is an internationally established method for early biological dose assessment in cases of accidental or suspected radiation exposures. The observed frequency of dicentrics is converted into the absorbed dose with the use of the fitted coefficients of the particular in vitro dose-response relationship. Since peripheral blood lymphocytes are circulating cells, the dicentric frequency reflects the average total-body dose, independent of specific regions of the body that have been exposed.

From the observed dicentric frequency in lymphocytes irradiated to neutron radiation it is not possible to discriminate between those dicentrics due to gamma rays and those due to neutrons. However, if the contribution of neutron and gamma doses to the total dose is known from physical measurements, it is possible to estimate the both dicentric frequencies by applying an iteration process and assuming that both radiation qualities are additive in the production of dicentrics and the observed distribution of dicentrics is Poissonian. In the case where physical estimate of neutron and photon components of the absorbed dose is not precisely available, the above method is rather impossible.

The objective of our poster is to present results of the use of Bayesian and Monte Carlo methods to dose estimations from the dicentric frequencies in human lymphocytes irradiated in a horizontal channel of the nuclear reactor Maria in the National Centre for Nuclear Research.

The main point of the Bayesian method is to propose the best form of the prior function for gamma to neutron doses ratio. The prior is a probability distribution function for such a doses ratio, which can be used with the likelihood function for dicentrics. The results are a probability distributions for the separate neutron and gamma doses.

In the case of the Monte Carlo method, the virtual group of cells is virtually irradiated according to the input data using also the prior function for the ratio of neutron to gamma ray doses. Thus the information about the dose and dicentrics frequency distributions is received.

THE K_0_IAEA SOFTWARE VALIDATION AT THE CDTN/CNEN, BRAZIL, USING CERTIFIED REFERENCE MATERIALS

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Aiming at harmonizing the results produced by the k_0-method of Instrumental Neutron Activation Analysis using "in-house" software, the International Atomic Energy Agency (IAEA), Vienna, Austria, made a new program, called k_0_IAEA software package. The IAEA freely distributed this software to more than 50 laboratories in 36 countries during a few training courses. The Laboratory for Neutron Activation Analysis, at CDTN/CNEN, Belo Horizonte, Brazil, has acquired the k_0_IAEA software package during the Workshop on Nuclear Data for Activation Analysis, 2005, held at the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

This paper is about the validation procedure carried out at aiming at local laboratory validation of the k_0_IAEA software package. The procedure followed at CDTN/CNEN to validate the k_0_IAEA software, version 3.1, was to analyze several certified reference materials with different matrix, for instance, soil (GXR-6 and IAEA/Soil-7), sediment (BCR-320) and a vegetable matrix (GBW 07602). The overall results pointed out that the k_0_IAEA software is working properly.

POSSIBILITY OF THE NEUTRON DOSE ENHANCEMENT IN THE CELL VIA BORON CARBIDE PARTICLES USING PUBE NEUTRON SOURCE

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Boron neutron capture therapy (BNCT) is based on the selective uptake of non-radioactive boron by the tumor cells and subsequent irradiation with low energy (<0.025 eV) thermal neutron flux of high intensity (10^{11} n/s).^{10}B isotope comprises about 20% in the natural boron and has high thermal neutron capture cross-section (3538 b). Irradiation results nuclear reactions ($^{10}B(n,\alpha)^{7}Li$) with 2.31 MeV energy transferred to recoils yielding high linear energy transfer (LET) alpha particles (^{4}He) and recoiling lithium (^{7}Li) nuclei, which have path lengths of ~ 9 and 5 μm, respectively. For the successful BNCT the sufficient amount of ^{10}B (20–35 μg/g or ~ 10^{9} atoms/cell) must be selectively delivered to the tumor tissue and enough thermal neutrons must be absorbed.

However, selective accumulation of commonly used drugs such as borocaptate (BSH) and boronophenylalanine (BPA) in the tumors is not ideal. As a result of innovative techniques of synthesis and increased understanding of biophysical and biochemical mechanisms of BNCT, many new boron containing agents modified with various functional groups have been emerged, including borane-attached porphyrin, borate-lipid liposomes, boron-containing nanoparticles, etc. It has been shown that after neutron irradiation in the presence of such compounds the proliferation capability of various malignant cell lines was significantly inhibited. However, additional information regarding strategies to optimize BNCT is required.

In the present study we investigated the damage induced by neutron radiation in the cells via boron carbide (B_4C) particles. The irradiation experiments were performed at the Center for Physical Sciences and Technology using the PuBe (a, n) neutron source. The application of intermediate neutron flux would be an advantage due to low cost and accessibility, but higher concentration of ^{10}B would be needed. The Monte Carlo N-Particle Code MCNPX has been used for neutron transport calculation, irradiation parameters optimization and energy deposition in the cell calculation. Makrofol (Bayer MaterialScience AG, Germany) plastic detectors were applied for neutron dose evaluation. After irradiation the clonogenic assay was carried out. Cell surviving curves were obtained after neutron irradiation according to the linear quadratic model. The intracellular production of superoxide ($O_2^{\bullet-}$), which is one of the major reactive oxygen species (ROS) and a common marker for oxidative stress, was evaluated as well. The flow cytometric measurements of intracellular $O_2^{\bullet-}$ were carried out using membrane-permeable fluorogenic dye dihydroethidium (DHE).

RECENT IMPROVEMENTS OF THE NEUTRON CALIBRATION FACILITY WITH OLD RADIONUCLIDE NEUTRON SOURCES

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Radiation Protection Measurements Laboratory (LPD) in the National Centre for Nuclear Research (NCBJ) is the only one calibration laboratory in Poland with reference neutron fields. The history of LPD has started in the mid-1980, when for the calibration and testing of dosimetric equipment, the reference neutron fields were established. The well-specified radioactive neutron sources of bare ^{252}Cf, ^{241}Am-Be and ^{239}Pu-Be, with their well known emission rate and anisotropy, were installed in the centre (1 meter above the floor) in the dedicated neutron irradiation room, which is 4×4×16 m^3 in size. Since that time, the fields were periodically examined and inspected in case of long term changes of their physical and dosimetric parameters. As a result, LPD is able to show their continued usefulness as reference sources.

Many years of careful measurements led to an efficient method describing the effective decay scheme for the radionuclide neutron sources. The growth of neutron emission of ^{239}Pu-Be (0.2% per year), as well as slower than predicted from the low of radioactive decay of ^{252}Cf isotope, the disappearance activity of Californium source, has been demonstrated. Explanation for the phenomenon is based on the assumption of occurring isotope impurities (here crucial role plays ^{250}Cf which starts to influence after few years from production the source and become very significant after ten).

Lately, to characterize the neutron fields in LPD, detailed calculations were performed with the MCNP-code with a realistic geometry and materials of the source and the irradiation room. Those results show the differentiation of components of the neutron radiation in the reference points (i.e. direct neutrons, scattered and backscattered) when sources are placed at different heights. Additionally, numbers of measurements were evaluated in describing the real reference neutron sources. The contribution from neutrons scattered from the walls to the total ambient dose equivalent is desired.

The calculations and measurements were found to be in good agreement, showing that the neutron calibration fields in LPD-NCBJ is well established.

A NEUTRON DETECTOR FOR THE "GAMMA-400" SPACE OBSERVATORY

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Neutron detectors could be effectively applied to gamma astronomy as an instrument for increasing a factor of proton rejection in orbital gamma-telescopes.

This article talks about the neutron detector which is designed as an additional instrument for separation between electromagnetic and nuclear cascades in "GAMMA-400" orbital gamma-observatory. This is a necessary procedure to eliminate a proton background during space measurements.

The detector operates in counting mode. It contains four layers of $ZnS(Tl)+^{6}LiF$ scintillator and, in particular, the reaction on lithium is used to capture neutrons.

Calculated efficiency for ^{252}Cf neutron spectrum (average energy 2.3 MeV) is 10%. Positional sensitivity is achieved by using multilayer structure and by collecting signal from 40 isolated neutron-counting volumes. Identification of each cascade is a result of a combination of time, spatial and quantitative analysis of a useful signal.

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MECHANISMS OF DNA SINGLE-STRAND BREAKS AND ALKALI-LABILE SITES FORMATION IN HUMAN BLOOD LYMPHOCYTES EXPOSED TO 365 NM UVA RADIATION

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The potency of UVA radiation, representing 90% of solar UV light reaching the Earth's surface, to induce human skin cancer is the subject of continuing controversy. This study was undertaken to investigate the nature and the origin of initial DNA lesions produced by the exposure to UVA radiation. This knowledge is important for better understanding of the UV-induced carcinogenesis. We measured DNA single strand breaks and alkali-labile sites in human lymphocytes exposed *ex vivo* to various doses of 365 nm UV photons using the comet assay. We demonstrated that the UVA-induced DNA damage increased in a liner dose-dependent manner. The rate of DNA single strand breaks and alkali-labile sites after the exposure to 10 kJ/m^2 was similar to the rate induced by the exposure to 1 Gy of X-rays. It is, therefore, expected that 1 kJ/m^2 UVA irradiation induces around 100 DNA single strand breaks per cell. The presence of the $^{\bullet}$OH radical scavenger, DMSO, in the culture media resulted in the reduction of the UVA-induced DNA damage by a factor of 3. We also showed that chromatin relaxation due to hypertonic conditions resulted in the increased damage in both untreated and UVA-treated cells. The effect was the most significant in the presence of 0.5 M NaCl, implying the role of histone H1. Our data suggest that the majority of DNA single strand breaks and alkali-labile sites after the exposure of human lymphocytes to UVA are produced by reactive oxygen species and that the state of chromatin may substantially contribute to the outcome of such exposures.

EFFECTS OF RADIOFREQUENCY ELECTROMAGNETIC FIELD AND FUNGICIDAL ANTIBIOTIC ON THE *SACCHAROMYCES CEREVISIAE* FATTY ACID COMPOSITION

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Microbial antibiotic resistance is a puzzled problem that makes ineffective clinical treatment of various diseases in the last several decades. Among different physical, chemical and biological factors affecting fungi and resulting in the origin of resistance the effects of unionizing electromagnetic field were observed recently (Stansell *et al.*, 2001). The aim of the current study was to evaluate the effects of the radiofrequency electromagnetic field (RF-EMF, 40.68 MHz, 15W) and fungicidal antibiotic nystatin on the fatty acid (FA) composition of yeast *Saccharomyces cerevisiae*. Two saturated fatty acids (palmitic, stearic) and two monounsaturated fatty acids (palmitoleic, oleic) were obtained from the yeast cells after acid methanolysis. About 75% of the total fatty acids in the cells belonged to the monounsaturated ones and their portion increased on average 8% during 60 min of cells keeping under hypotonic environment. FA pool multiplied in time in both control and treated with RF-EMF or nystatin samples; common tendencies were marked during the first 30 min and disappeared under long-term treatment. Synergistic effects of the combination of RF-EMF, nystatin and temperature were observed. The FA pool as well as quantities of each FA depended on the nystatin concentration ($p<0.012$). Effects of nystatin were nonlinear. RF-EMF and temperature possess no significant influences on the studied indexes. Combined treatment let to achieve more than 50% increase of the FA pool. This work contributes to the knowledge of the mechanism of microbial adaptation and stress resistance.

EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELD (ELF EMF) EXPOSURE INFLUENCES MORPHOMETRIC CHARACTERISTICS OF NEUROSECRETORY NEURONS AND ALTERS SALINITY STRESS RESPONSE IN EARTHWORM *EISENIA FOETIDA* (LUMBRICIDAE)

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An *in vivo* model was set up to establish morphometric characteristics of A_1 protocerebral neurosecretory neurons (measured as cell size in the earthworm *Eisenia foetida* (L.)) exposed to extremely low frequency electromagnetic field (ELF EMF)-(50 Hz, 50 mT, 17 V/m and 50 Hz, 150 mT, 17 V/m, respectively) and to the synergistic effect of ELF EMF and increased substratum salinity (salinity stress). For this experiment, 175 animals were divided in to 25 groups. Groups 1-8 were exposed to homogenous, vertical orientated ELF EMF (50 Hz, 50 mT, 17 V/m and 50 Hz, 150 mT, 17 V/m, respectively). For acute treatment, the exposure time was 2 and 4 hours, while 24 hours and 4 h/day during 7 days was the exposure time for chronic treatment to each specified field strength. The ninth group was the negative control (exposed only to natural magnetic field). Groups 10-17, in addition to the ELF EMF treatments listed above, were subjected to increased substratum salinity. Groups 18-25 was exposed to salinity stress and natural magnetic field according to the same protocol as ELF EMF exposure animals. Serial protocerebral ganglion brain cross-sections were stained using the Alcian blue-Periodic-Acid-Schiff-Orange G technique. Surface area of A_1 neurosecretory neurons were analyzed using the image processing and analysis system AxioVision Rel. 4.8.1. (Carl Zeiss MicroImaging GmbH, Germany) linked to Axio Imager 1 light microscope. Measurements were performed using Digimizer 4.0.0.0. (MedCalc Software, Belgium) image analysis software. A total of 20 A_1 cells per animal were analyzed. The values of the surface area of A_1 neurosecretory neurons were significantly changed in animals exposed to ELF EMF in comparison to the negative control group of animals. Also, exposure to ELF EMF altered, depending on the field strength and duration of exposure, surface area of these cells induced by salinity stress. Our results indicate that the extremely low frequency electromagnetic field (ELF EMF) induce morphological and morphometrical changes of protocerebral ganglion A_1 neurosecretory neurons in the earthworm *Eisenia foetida* (L) independently as well as synergistically with salinity stress. Intensity of these changes are primarily due to length of exposure to the fields, but those effects were recorded only in certain “windows” of field intensity.

Key words: Extremely low frequency electromagnetic field (ELF EMF), *Eisenia foetida*, Lumbricidae, neurosecretory cells, salinity stress

TESTING OF ULTRASOUND TRASDUCERS BY USE OF THERMOCROMIC TILE

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Propagation of ultrasound through biological structures produces thermal and nonthermal (mechanical) effects. Those effects can be used in medical application of low intensity ultrasound for physiotherapy [1]. The therapeutic ultrasound administration implies into a variety of energy and time dosage to achieve clinical results, which are associated to the increase of tissue temperature to healing rates. Tissue temperature increases due the intensity levels irradiated through the patient's body. However, high intensity levels can generate excessive heat what can be dangerous to biological tissue. Thus quality control of physiotherapy ultrasound equipment performance plays a very important role. Acceptability of ultrasound beam for clinical use can be verified measuring uniformity of its acoustic intensity. Beam homogeneity can be quantified by the parameter called beam non-uniformity ratio (BNR), which represent the ratio of the highest intensity in the field to the average intensity. Value of the area over which ultrasonic power is emitted denotes the parameter effective radiating area (ERA). These parameters of ultrasound transducer could change during time and as such should be part of quality assurance program and checked on regular basis. The standardised method for beam uniformity verification is based on the scanning of the acoustic field in water tanks using miniature hydrophones. Unfortunately this method is not very convenient for use in hospital environment. An alternative method based on the use of thermochromic materials was proposed by Butterworth *et al.* [2]. Method consists in placing an acoustic absorber tile containing a thermochromic pigment in cross-section of the ultrasonic beam, forming an image of the temperature distribution. This method gives information about whole thermal pattern, which is related to the intensity of ultrasound, offering a qualitative measurement.

While the thermochromic materials can provide rapid qualitative data to the naked eye, the quality of this data can be improved through image capture and post processing.

In this paper the evaluation of this method in clinical conditions was presented.

Seven physiotherapy ultrasound transducers clinically used in University Hospital Rijeka were tested by using thermochromic material. A systematic image capture protocol has been applied. Images are taken before and after ultrasonic exposure. All thermochromic images were postprocessed in order to calculate beam parameters ERA and BNR. The ERA and BNR were determined for transducers with frequency in range from 1 MHz to 3.3 MHz, and intensity range of $1W/cm^2$ to $3W/cm^2$. Experimental results and the comparisons with specified transducers performance will be presented.

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STUDY ON CELL OXIDATION-REDUCTION EQUILIBRIUM AFTER MODULATED RADIOFREQUENCY RADIATION

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There has been a tremendous increase in the use of mobile phones in the past few decades and concerns are growing about possible hazardous effect of radiofrequency electromagnetic waves emitted by these devices on living organisms. The exact mechanism that could explain effects at non-thermal level is still unknown and under observation. One of the plausible explanations could be associated with oxidation-reduction imbalance which leads to the oxidative stress. Aim of this initial study was to evaluate the proposed mechanism. Modulated radiofrequency field of 1800 MHz, strength of 30 V/m was generated within Gigahertz Transversal Electromagnetic Mode cell (GTEM-cell) equipped by signal generator, modulator and amplifier. Continuous cell line V79, Chinese hamster lung fibroblasts, was irradiated with selected radiation for 10, 30 and 60 minutes. SAR was calculated to be 1.6 W/kg. We determined cell metabolic activity and viability by 3-(4, 5-dimethylthiazole-2-yl)-2, 5-diphenyltetrazolium bromide assay (MTT). Total protein content was determined by commonly used colorimetric method. Concentration of oxidised proteins was evaluated with an enzyme-linked immunosorbent assay (ELISA) which measures the protein carbonyl derivatives formed from protein oxidation. Reactive oxygen species (ROS) were marked with fluorescent probe 2′, 7′-dichlorofluorescin diacetate (DCFH-DA) and measured by means of plate reader device. In comparison to control cell samples metabolic activity and total protein content in exposed cells did not differ significantly. Concentrations of protein carbonyl in exposed cells insignificantly but continuously increase with duration of exposure. In exposed cell samples ROS level significantly increased after 10 min exposure. Decrease in ROS level was observed after 30 min treatment which indicates to the antioxidant defence mechanism activation. In conclusion under the given laboratory conditions, modulated radiofrequency radiation might cause impairment in cell oxidation-reduction equilibrium within the cells in culture.

RADIATION PROTECTIVE EFFECTS OF MODULATED EXTREMELY-HIGH FREQUENCY ELECTROMAGNETIC RADIATION

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Nowadays, biological systems are simultaneously exposed to the large number of environmental factors, including chemical agents, ionizing and non-ionizing electromagnetic radiation (EMR). The question on the role of non-ionizing EMR in changes of nonspecific resistance and realization of radiobiological effects are poor investigated. The purpose of the study was to define features of combined effects of different environmental factors at the cellular level.

The experiments were conducted with the use of mouse whole blood leukocytes and a comet assay technique. Leukocytes in the whole blood immobilized in microscopic agarose slides were exposed to extremely-high frequency EMR (EHF EMR, carrier frequency of 42.2 GHz, incident power flux density of 0.1 mW/cm2, SAR of about 1.5 W/kg, exposure duration of 20 min) and/or to X-rays at a dose of 4 Gy (dose rate of 1 Gy/min), or treated with hydrogen peroxide for 10 min at 37oC. DNA damage was assessed on percentage of DNA in a comet tail (tail DNA). The production of hydrogen peroxide in phosphate buffered saline exposed to EHF EMR was measured using a sensitive assay based on enhanced chemiluminescence in a peroxidase–luminol–p-iodophenol system. All experiments were conducted utilizing the “blind” experimental protocol. The statistical analysis of data was made using one-way ANOVA followed by the Dunnett’s multiple comparison test ($p < 0.01$) or Mann-Whitney U-test ($p < 0.05$).

It was shown for the first time that the exposure of whole blood leukocytes to low-intensity pulse-modulated EHF EMR with modulation frequency of 1 Hz before treatment with X-rays at a dose of 4 Gy induced the expressed radiation protective effect, reducing the level of DNA damage on the average by $21.3 \pm 3.5\%$ ($p < 0.01$). Continuous wave EHF EMR was uneffective. We have supposed that the mechanisms of radiation protective effect of pulse-modulated EHF EMR can be connected with an induction of adaptive response by low concentrations of reactive oxygen species. We have revealed that the exposure of phosphate buffered saline to pulse-modulated EHF EMR (42.2 GHz, 0.1 mW/cm2, 20 min, modulation frequency of 1 Hz) leads to production of hydrogen peroxide in concentration of 4.6 ± 0.3 nM; continuous EHF EMR was ineffective again. In a separate series of experiments it was found that exogenous hydrogen peroxide in nanomolar concentrations (50 – 1000 nM) are capable to induce the adaptive response in mouse whole blood leukocytes, protecting the cells from the subsequent action of hydrogen peroxide in high concentration (20 muM). The revealed mechanism can underlie radiation protective effects of non-radiation factors, including low intensity EHF EMR.

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EFFECTS OF EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS ON THE ANTIOXIDATIVE ENZYME ACTIVITIES IN HUMAN CANCER CELL LINE AND MICRONUCLEI IN HUMAN LYMPHOCYTES

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Current public concern focuses on possible long-term health effects caused by exposure to electromagnetic fields at levels below those required to trigger acute biological responses. Different *in vivo* and *in vitro* studies have shown a possible co-promoter influence of extremely low frequency electromagnetic fields (ELF-EMF) on tumor growth and various biological functions, including redox-related cellular changes. However, in terms of genotoxic potential of ELF-EMF, the results are still confusing. Therefore a possible hypothesis is that ELF-EMF can interfere with chemical reactions involving free radical production and induce DNA damage.

The aim of this study was to determine the effect of ELF-EMF on the antioxidative enzyme activities in cancer cell line and the possible genotoxic potential of ELF-EMF on primary cultures of human lymphocytes.

K562 human leukemia cell line was exposed to 50 Hz ELF-EMF at two field intensities (40 µT and 100 µT) for 3h and 24h. After the exposure, spectrophotometric determination of lipid peroxidation and activities of superoxide dismutase, catalase, glutathione - reductase, and - transferase was conducted. Genotoxicity of ELF-EMF (50 Hz, 100 µT) was investigated by cytokinesis-block micronucleus CBMN assay in human lymphocytes obtained from 10 volunteers during 24h and 48h treatment.

Results of this study demonstrated that ELF-EMF did not initiate the process of lipid peroxidation in any exposed group. Similar results were obtained for the measurement of superoxide dismutase activity. Activity of catalase was significantly increased only after application of 100 µT EMF for 24h. All exposed cells had increased activity of glutathione-S-transferase. Glutathione reductase activity was also increased, except for the group exposed to 40 µT EMF for 3h. CBMN assay revealed that exposure to 100µT ELF-EMF after 24h reduced micronuclei incidence, whereas after 48h treatment, the incidence of micronuclei significantly increased compared to 24h ($p<0.05$), but still remained below the level in control group.

Results of this study indicate that 50 Hz ELF - EMF of particular intensity (40 µT and 100 µT) are week stressors which alone cannot generate enough ROS to induce process of lipid peroxidation in cancer cell line but strong enough to induce response of antioxidative defense system. Furthermore, 100µT ELF-EMF in human lymphocytes did not exhibit a genotoxic potential during 24h and 48h treatment. Anyhow, impact of ELF - EMF on the antioxidative enzymes and DNA damage during chronic treatment should not be ignored in further investigations of their molecular mechanism.

Key words: Extremely low frequency electromagnetic fields (ELF-EMF), K562 cell line, oxidative stress, lymphocytes, micronuclei, genotoxicity

OCCUPATIONAL HEALTH RISK STUDY: POSSIBLE INTERPLAY OF BIOLOGICAL EFFECTS OF RF EMF AND SMOKING HABITS

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The aim of present study is to assess the biological /health effects in occupational EMF exposure in broadcasting radio-communication. Dosimetric characterization of electromagnetic work environment was made with EMR 200 Wandel&Goltermann Analyzer. We used the described methodology for radiofrequency fields and microwaves.

The group taken into study consists of 90 workers exposed to EMF in radio TV broadcasting stations. The results were compared to a control group, with similar mean age. It was applied a special questionnaire to appreciate the possible biological effects related to EMF exposure. We made clinical and parclinical examination and, in dynamics, urinary thioethers assay.

The measured values of radiofrequency and microwaves levels in the work places were below the current international safety standards.

At exposed group our results revealed asthenia, nervous and cardiovascular syndrome. The calculation using a logistic regression model highlighted dose-response relationships between exposure values and presented symptoms. Urinary thioethers excretion in the occupationally EMF exposed workers was increased in comparison with control group. Increased values were found in smokers, comparing to control group.

The symptoms presented by exposed group are shaped in the concept of "microwave syndrome" presence. Dose-response relationships are suggesting the existence of a possible health risk at low levels of RF and MW EMF exposure. The increased levels of urinary thioethers in EMF exposure are suggesting that thioethers could represent a possible marker of chronic exposure to EMF .Increased values found in EMF exposed smokers could mean that chronic electromagnetic exposure combined with noxious components of smoking cigarettes could enhance health impairments or biological effects.

Key words: dosimetric, EMF exposure, health effects, occupational, thioethers, smoking habit

THE DELAYED ACTIVATION OF TISSUE MACROPHAGES IS AN UNTARGETED EFFECT OF EXPOSURE TO IONIZING AND NON-IONIZING RADIATION

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Objectives: Epidemiological, pharmacological and genetic evidences provide a solid support that exposure to ionizing radiation (IR) correlates with increased risks of cancer and non-cancer diseases in post exposure period. Same association for exposure to non-ionizing radiation (non-IR) is still controversial due to absence of proved mechanisms which link biological effects to health consequences. The elevated level of clastogenic factors production by tissue resident macrophages usual for inflammatory conditions could underlies delayed effects of exposure to low doses of IR and, possibly, non-IR. The main goal of our studying was to characterize dynamics of spontaneous free radical production in macrophages after IR and non-IR exposure.

Methods: All experiments were conducted under approval of local ethics committee in concordance with international guidance of animal handling. To study effects of IR Wistar rats were exposed to total body irradiation with gamma-rays at dose 1 Gy (0.92 Gy/min, ^{137}Cs) and sacrificed after 3, 10, 30, 90 days. To study effects of non-IR the male Wistar rats were exposed 14 days to fractionated (4+4 hr*day^{-1}) electromagnetic field imitating signal of GSM-900 mobile phone (0.2-0.3 uW/cm^2, Tx mode, Ch 35, 897.2 MHz) and sacrificed on 1, 7, 15, 21, 28, 34 days after last fraction. The resident peritoneal macrophages were isolated and reactive oxygen spices (ROS) production was estimated by luminol-enchanced luminescence. Cells were subcultured 24 hr in DMEM (10 % FBS) and nitrite level was used as surrogate marker of reactive nitrogen spices (RNS) production.

Results: The resident peritoneal macrophage activation was found in both experimental models. More than 2-fold increasing of RNS productin was identified on 3 and 30 day after total body irradiation, as well as 1.5-fold increasing in ROS production on 30 and 90 day. The production of ROS and RNS has trend to increase slowly after canceletion of exposure to non-IR and reached maximum (2-fold of control) on 14 day last fraction of treatment with following decay to 34 day. Obtained experimental data demonstrate partial similarity in increasing of spontaneous RNS and ROS production in tissue phagocytes in a late post exposure period both after action of IR and non-IR.

Conclusions: Found changes of free radical production in resident macrophages could be recognized as a signature of para-inflammation both after action of IR and non-IR. These alterations via oxidative stress could account to modulating cellular microevironment, epigenomic regulation, mutation rate, cell signalling and thus could provide "missing" pathogenetic link between biological effects and health consequences of exposure to non-IR. Since ascertained increase in reactive oxygen and nitrogen spices production involved in pathogenesis of radiation effects, hence monitoring and management of these parameters could provide tool for amelioration of consequences of exposure to IR and non-IR.

THE PECULIARITIES OF HUMAN KERATINOCYTE (HACAT) RESPONSES TO EXPOSURE TO UV RADIATION *IN VITRO*

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Objectives: The UV exposure is the main natural risk factor of such pathological skin conditions as erythema, preliminary aging and cancer. The human keratinocytes (HaCaT) were routinely used as a model cell culture for *in vitro* studies of mechanisms of cellular responses to exposure and for testing of protective substances for decades. Some genetic features of these cells rise question about adequacy of this model for evaluating of cellular response to toxic treatment. Our aim was to estimate potential and applicability of evaluation of common metabolic activity and oxidative metabolism to characterize cellular response to exposure.

Methods: The spontaneously immortalized human kerotinocytes HaCaT were routinely cultivated in DMEM/F-12 with 10 % FBS and 1% of antibiotic/antimicotic mix. Cells were passaged then reached 70 % confluency. The 250000 cells were seeded in 60 mm Petri dishes 24 hr prior to experiment. Cultures were washed with HBSS twice before exposure to UV on filter surface of gel-documentation system (Chemidoc, Biorad). The estimated exposition dose was 689.13 uW/cm^2 or 59.78 % of total for range of 316-400 nm (UV-A), 463.71 uW/cm^2 or 40.22 % of total for range of 281-315 nm (UV-B) and 0,022 uW/cm^2 (0,002 %) for range of 200-280 nm (UV-C). The cell death was studied by flow cytometry using Anexin-V FITC kit (Invitrogen) 6, 8 and 24 hr after treatment. The common metabolic activity was evaluated with Presto Blue ™ (Invitrogen) and reactive oxygen spices (ROS) production by XTT reduction. The 24-hr nitrite accumulation in culture media was used as marker of reactive nitrogen spices (RNS) production.

Results: The dose-dependent non-monotonic elevation of ROS production in HaCaT was identified during 2 hr after exposure to UV (0-300 sec). No differences in RNS production were found for same exposure period.

The cell death identified as 2-fold increasing in level of cell in early and completed apoptosis on 6 and 8 hr after UV exposure. No differences in level of apoptotic cells were identified in groups of 30 sec and 60 sec exposure. The level of cells with morphologic aberrations showed dose-dependent rising to 8 and 35 % correspondingly (4 % in intact cells). This parameter reached 56 % in 30 sec group 24 hr after treatment with UV (12 % in intact cells). At the same time the level of early apoptotic cells was 4 % (1.6 % in control) and cells with completed apoptosis 13 % (2.3 % in control).

The dose-dependent decreasing in common metabolic activity was identified in HaCaT cultures 24 hr after exposure and made it possible to conditionally differentiate dose range. First, the number of deviding cells decreases showing cytostatic effect (<30 sec), then plato effect was reached plato (30-120 sec) and later (>120 sec) the number of metabolically active cells dramatically dropped as a sign of cytotoxic effects.

Conclusions: The decreasing in metabolic activity of cells exposed to UV is dose-dependent and happened due to decreasing of dividing cell number. The dose which induces 50% of cytostatic plato effect could be used for screening of UV-protective activity of substances.

The obtained results demonstrate what apoptosis in HaCaT cells after exposure to UV was not dose-dependent and keratinocytes died via mitotic catastrophe by p53-independent mechanism. Probably HaCaT cells are not adequate model for studing molecular signaling during response to toxic conditions.

INFLUENCE OF ULTRA-HIGH FREQUENCY IRRADIATION ON *PHOTOBACTERIUM PHOSPHOREUM LUXB* GENE EXPRESSION

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The ever increasing number and diversity of sources of non-ionizing electromagnetic radiation (EMR), and distribution of their operating frequencies in the microwave region (mobile communications, wireless networks) has been accompanied an increased interest in studying the effects of electromagnetic radiation of ultra-high frequency (UHF EMR) on living organisms.

As a useful biological indicator for description of EMR status *Photobacterium phosphoreum*, luminescent bacteria, isolated from sea was used in our research. High sensitivity and response speed, simplicity and efficiency of bioassays based on luminescent bacteria cause their application in our research for rapid monitoring of UHF EMR effects. Bacteria were growing on solid agar medium at 22°C. Bacterial cells from a log-phase culture were exposed to EMR with a “Ray -11”, a centimeter wave therapy apparatus at an EMR wavelength of 12.5 cm (corresponding to a frequency of 2.45 GHz) and power of 15 W, in the regime of continuous generation, for 5 and 15 min. Since EMR of ultra-high frequency is accompanied by heating of object we performed also incubation of bacterial cells at 42°C instead of irradiation. Treated bacteria were cultivated on solid medium for two weeks. Samples for genetic analysis were taken immediately after exposure, in a week and in two weeks after treatment. Evaluation of *luxb* gene expression was carried out with qRT-PCR using SybrGreendye and qTOWER 2.2 (Analytik Jena AG, Germany). Relative gene expression level was calculated with $2^{-\Delta\Delta Ct}$ method.

In our study we evaluated transcriptional activity of *luxb* gene encoding β-subunit of luciferase enzyme that, in turns, causes bioluminescence. Results of analysis showed that irradiation of bacterial colonies by ultra-high frequency irradiation affected expression of *luxb* gene. Level of gene expression depended on and correlated with duration of irradiation: value of transcriptional activity increased with increasing treatment duration. Quantitation of *luxb* mRNA level in bacterial cells immediately after irradiation by power of 15 W with a frequency of 2.45 GHz at 5 and 15 min showed 8- and 12-fold enlargement of this index, respectively, in comparison with non-treated bacterial cells. The further increasing of gene expression level in bacterial cells were detected in a week after exposure both in exposed and unexposed to UHF EMR cells. After 2-weeks growing on solid medium *luxb* expression has decreased up to non-irradiated value. Comparative analysis *luxb* gene expression between pre-heated cells and affected by ultra-high frequency exposure revealed similar peculiarities of gene expression changes. Besides, the longer irradiation led to more similar values of *luxb* gene expression.

Thus, results obtained in our study suggest that irradiation of ultra-high frequency comprises of both specific electromagnetic and thermal components, and the participation of the latter one increases with increasing duration of irradiation.

NON-IONIZING RADIATION IMPACT ON CELLULOLYTIC FUNGUS ENZIMES

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Microwaves at 970 MHz frequency delivered within a TEM cell were used to irradiate cellulolytic fungus cultures for the study of electromagnetic radiation influence on some enzymes. Low power exposures were arranged to get 2.3 and 8.6 W/kg SAR values for exposure durations from 1-4 hours. Phanerochaete crysosporium fungus was considered for investigation due to the practical interest in cellulose biotechnology. Negative influence on protein synthesis was revealed in all exposed samples containing fungi inoculated in Sabouraud agarized culture medium. Cellulase as well as lignin peroxidase activity were assayed, the corresponding results being related to the total protein content. It was emphasized the coherent diminution of lignin peroxidase activity – the enzyme that best describes the fungus ability of decomposing wood processing industrial residues. Electrophoretic proteic fractions were also studied, the results being additionally discussed in comparison to the total protein changes in microwave exposed samples. The results might be of interest for environmental issues involving electromagnetic pollution. It appeared that the fungus function underlying its main biotechnological utilization, i.e. decomposing lignin ability has been inhibited by means of lignin peroxidase inactivation. The main physical phenomenon involved in this experimental finding is supposed to be the enzyme inactivation or/and enzyme synthesis inhibition following microwave energy absorption.

THE IMPACT OF UHF EMR ON YEAST COLONY DEVELOPMENT AND SPATIO-TEMPORAL *FLO*-GENES EXPRESSION

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Electromagnetic radiation of ultrahigh frequency (UHF) is widely used in world-wide for mobile radio systems. UHF irradiation uses high frequencies of > 3000 MHz with a wavelength of <10cm. This radiation is strongly absorbed by biological objects, so it penetrates to a depth of the order of the wavelength. Such exposure causes drastic effects on the processes of growth and development.

Growing on solid surface yeast colony undergo cell specialization and form multicellular organism. It is suggested that Ato proteins have influence on various aspects of colony biology, metabolic reprogramming and differentiation in particular.

The aim of our research was studying the UHF irradiation effect on *Saccharomyces cerevisiae* colony development and *flo*-genes transcriptional activity in yeast cells localized in central and outer colony layers.

24-hours yeast culture were exposed to UHF EMR with a "Ray -11", a centimeter wave therapy apparatus (2,45 GHz and 15 W), in the regime of continuous generation, for 5 and 15 min. Irradiated yeast cells were grown on solid YPED medium for four weeks. For performing gene expression analysis samples were taken immediately after exposure, in 15 days and in 28 days after treatment. Assessment of *ato1*, *flo1* and *flo11* gene expression was carried out with qRT-PCR using Sybr Green dye and qTOWER 2.2 (Analytik Jena AG, Germany). Relative gene expression level was calculated with $2^{-\Delta\Delta Ct}$ method.

Quantitation of *ato1* gene expression level after UHF irradiation showed increasing of *ato1* mRNA amount in comparison with unexposed yeast colonies. The most significant increasing was detected after 15 min of treatment. Differences of *ato1* transcriptional activity between central and outer cell layers were the most defined in non-irradiated samples after 15 days growing on solid medium and in *S. cerevisiae* colony exposed for 5 min after 28 days of cultivation. Change of *ato1* gene expression in the same cell layer during cultivation period was observed only in outer cell groups, whereas insignificant difference in central regions was noticed only in irradiated colonies. Increasing of *flo1* and *flo11* gene expression level in yeast was displayed as a result of UHF exposure. Differences of *flo*-genes transcriptional activity between central and outer cell groups during cultivation period were the most remarkable in irradiated yeast colonies.

Thus, analysis of *ato1* and *flo*-genes expression in yeast colonies revealed that UHF irradiation causes increasing of mRNA level of these genes and can evoke changes in yeast colony development, in particular cell differentiation.

INTERLABORATORY COMPARISON OF MEASURING AND CALCULATION RESULTS OF ELECTRIC FIELD STRENGTH NEAR 35 KV OVERHEAD POWER LINE

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The paper presents interlaboratory comparison of measuring and calculation results of electric field strength near 35 kV overhead power line, in which participated three testing laboratories. This interlaboratory comparison was performed for the purpose of ensuring confidence in the quality of testing results. Measuring and calculation results are analyzed with standard method, based on which the valuation of the laboratories was performed.

EXPERIMENTAL ELECTROMAGNET FOR *IN VIVO* EXPOSURE OF SMALL ANIMALS TO ELF ELECTROMAGNETIC FIELDS

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The ubiquitous presence of electromagnetic (EM) fields in living environment motivates investigation of their influence on biological systems. Existing research data shows a high degree of inconsistency, often due to the poorly described electromagnetic fields that were used. Additionally, large part of the electromagnetic spectrum has not been properly investigated.

Exposure systems for the evaluation of electromagnetic influence on biological systems offer the possibility to control with the high level of consistency the desired exposure fields. Predefined range of frequencies and field intensities is completely covered, allowing for the systematic investigation to be carried out. Finally, highly accurate calculations and measurements of the exposure field levels and energy absorbed by the exposed living cells, tissues or organisms can be performed.

Experimental electromagnet for in vivo exposure of small animals is a novel product aimed at the investigations of influence of static magnetic and extra-low-frequency (ELF) electromagnetic fields. Experiments previously conducted in our group show that inhomogeneous static magnetic field characterized by the 2 mT mean magnetic flux density as well as the homogeneous static magnetic field whose mean magnetic flux density is 128 mT result in statistically significant effects on experimental animals (mice). Maximal electromagnetic field intensity is therefore chosen equal to 130 mT. Having in mind other research showing significant effects of the ELF electromagnetic fields, frequency range of 0 Hz to 100 Hz is chosen. This range covers both the static and the time-varying ELF magnetic field, including the frequency of power lines. Special care is taken for this custom-made device to avoid any specific power utility requirements – it is designed to use the regular three-phase power network.

Prototype design is carried out using preliminary analytical calculations and highly accurate electromagnetic modeling using various advanced computer aided modeling (CAM) software tools. Calculated results of the electromagnetic field distribution and its mean parameters of interest to the experimenters are presented and discussed. Advices for the device utilization and guidelines for performing the experiments are given.

SUN'S UV RADIATION AND OZONE LAYER THICKNESS OVER THE REGION OF NOVI SAD, SERBIA

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The paper presents results of monitoring of UV radiation covering the period of ten years and monitoring of ozone layer thickness over the period of six years. The measurements were made at the site at the University of Novi Sad (45.33° N, 19.85° E and 84 m a.s.l.). Annual results for UV radiation are compared mutually as well as to the results of UV radiation intensity modeling obtained by model NEOPLANTA. Annual results for stratospheric ozone layer thickness are also compared mutually. Obtained results and this considerations are valid not only for Novi Sad region, but also for wider region of Province of Vojvodina.

EPR STUDIES OF UV-VIS AND GAMMA RADIATION EFFECT ON CALCIUM CARBONATE NANO- AND MICROPARTICLES

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This study is based on investigation of calcium carbonate powders with different grain size exposed to UV-Vis light and gamma radiation. Calcium carbonate is widely used in many branches of industry, e.g. as a filler for polymer materials; therefore knowing its properties, among them also its reaction to ionising radiation and UV-Vis light, is essential. Samples of powdered calcium carbonate with average grain size from 15 nm to 25 μm were used in this investigation. Measurements, performed at room temperature using EPR X-band spectrometer, shown the additional signals induced by gamma radiation and the light from Hg lamp. The EPR spectra differ depending on the source of radiation. Signals connected presumably with CO_2^- and CO_3^- species can be observed after irradiation, however there are considerable differences in the spectra of investigated samples, which could be related to the different kinds of impurities and their content, as well as the size of $CaCO_3$ grains. In addition, UV-Vis spectroscopy measurements were performed for all the samples. Further studies based on these preliminary results may prove useful in research of photodegradation of $CaCO_3$-filled materials, as well as helpful in increasing the accuracy of dating of archaeological and geological objects.

CHARACTERISTICS OF SOLAR RADIATION IN REGION CLOSE TO TIMISOARA

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Insolation of a place and its meteorological factors are uncontrollable variables to which knowledge are necessary detailed measurements carried out over long period of time, usually tens of years. For long periods of time (a month, a year), the amount of useful energy of the solar installation depends on the total radiation and also on the solar potential level because for intensities lower than the limit of the intensity, the facility or power plant is inefficient. The total irradiation that exceeds the critical limit, global irradiance depends explicitly and implicitly fraction of insolation.

At the Department of Physical Foundations of Engineeringfrom Politehnica University of Timisoara,actinometrical activities related to research on the use of solar energy have been developed since 1976.

This paper presents a comparative study of the solar potential in the south-west part of Romania based on measurements made and published by the Department of Physical Foundations of Engineering from Politehnica University of Timisoara, Fraunhofer-Institute for Solar Energy Systems ISE in a grant with Timis Prefecture and values from the database of solar radiation monitoring station of the Faculty of Physics –West University of Timisoara.

For the 45° parallel the ratio between the average solar energy on the collection surfaceinclined underthe optimum angle and the average solar energy in the horizontal plane is *r*= 1.17. For Timisoara the optimal angle of the plan solar collector is 50°. So the solar potential for optimum inclination angle is $Q_{optim} = r \cdot Q$.

The average optical efficiency of the thermal collectorsis $\eta_{optic} = 0.75$. So the maximum amount of heat (solar thermal potential) that is produced in one year by the collecting area of 1m², tilted at the optimum angle is $Q_{thermal} = \eta_{optim} \cdot r \cdot Q_{optim}$.

For Timisoara, the average sunshine period is 2154 hours and the days with clear blue sky or clear and cloudy is N = 274. Insolation fraction is *f* = 0.481.

Fraunhofer Institute determined the solar potential of Timis County under a research grant for the benefit of Timis Prefecture in 2009. Solar thermal potential in their determination is $Q_{T, Fra}$ = 1121 kWh / (m² year).

In theDepartment of Physical Foundations of Engineeringdetermination, the global solar flux density in the horizontal plan was determined with the apparatus Solaris 1 and Solaris 2, during years 1985-1995. Multiannual averages have been computed and the conclusionis that the thermal solar potential is $Q_{T\ BFI}$ = 1094 kWh / m².

At West University of Timisoara, solar radiation is measured with Kipp & Zonen pyranometersfrom the Monitoring Station of solar radiation and the conclusion over the solar thermal potential is $Q_{T, UVT}$ = 1074 kWh / (m²year).

ELECTROMAGNETIC MODELING OF TOOTH WITH DENTAL AMALGAM FILLINGS EXPOSED TO MOBILE PHONE

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Excessive use of wireless communication systems has caused a growing public concern about possible health effects of electromagnetic fields, particularly because the mobile phones operate in close proximity to head. In addition, there has been a lot of research on toxic effects of amalgams fillings that are believed to be the main source of human total mercury body burden. New studies suggest that mercury from dental amalgam may lead to nephrotoxicity, neurobehavioural changes, oxidative stress, autism, skin and mucosa alterations or non-specific symptoms and complaints. It has recently been reported that higher mercury concentrations were found in brain regions and blood of some patients with Alzheimer's disease who were exposed to elevated occupational exposure to magnetic fields.

The aim of the research was to determine whether there was synergism between mobile phone exposure and higher release and accumulation of mercury in tissues of the individuals with amalgam fillings. Thus, effects of mobile phone electromagnetic radiation on tooth with amalgam fillings should be investigated.

The hypothesis of this paper is that the effect of electromagnetic radiation could cause galvanic action, electrical currents, and much higher mercury vapor levels.

In this paper the numerical method, Finite integration technique – FIT, was used to compute electrical field and Specific Absorbtion Rate - SAR in the tooth model with dental amalgam fillings exposed to electromagnetic radiation from mobile phone.

Frequency dependent electromagnetic characteristics of tooth tissue and amalgams fillings consisting of mercury (50%), silver (28%), tin (14%) and copper (8%) were used in simulation procedure.

Simulation for monoblock phone model with helicoide antenna was used and electromagnetic field components were calculated, reference power of phone being P=1W (according to the Standard IEEE C.95.3) on frequency f = 900 MHz and port impedance Z = 50Ω. The distance from the tooth to the port of the mobile phone was 1 cm. Radiated energy distributions and averaged SARvalues in 0,1 g of tissue were computedinside the models of tooth.

Numerical result of absorption electromagnetic energy show increased value of SAR in teeth with fillings. Surface currents were observed in fillings and they might cause chemical processes and thermic effects that in turn could lead to increased evaporation of mercury and other metals and further toxication of the surrounding tissue. These effects might cause potential organism disorders and represent secondary harmful effects of electromagnetic radiation on health of individuals. Such research approach enables association of electromagnetic radiation and toxic effects of amalgam fillings as well as investigation of effects of different mobile phones and their usage position on people's health.

NEW ASPECTS OF LEGISLATION CONCERNINGEMF EXPOSURE TO MEDICAL PERSONNEL IN MRI

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In recent years, magnetic resonance imaging (MRI) is one of the most powerful diagnostic methods in medical practice. At the same time there is a concern that the medical staff involved in these diagnostic procedures is at high risk of overexposure to static magnetic fields, mainly due to their non homogeneity. Serious concerns were expressed by medical community to the potential impact of the implementation of EMF Directive on the use of medical procedures based on medical imaging. That is one of the reasons for postponing transposition deadline of Directive 2004/40/EC into national law of the EU Member States and reconsidering the text of the document. Last year the European Commission published new EMF Directive 2013/35/EU repealing Directive 2004/40/EC.The paper presents new aspects in legislation concerning EMF exposure to medical personnel in MRI units.

The paper presents data of EMF measurements in the working environment around magnetic resonance imaging (MRI) devices as well. Several MRI systems are considered mainly 1.5 T devices.

Measurements are performed in two premises – procedure chamber with MRI where incidental stay of the personnel is possible (on procedures of children, patients with claustrophobia; disabled, on giving anesthesia or in case of sedated patients) and personnel/command hall – outside the chamber – where the process is viewed and controlled and a permanent work place for the personnel.

Data are compared to the limit values according to the existing national legislation and the new Directive for the different frequency EMF emitted by the devices.

UV EXPOSURE TO PERSONNEL IN MEDICINE, SCIENCE AND INDUSTRY

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In recent years, sources of ultraviolet (UV) radiation are widely used in various areas of life: in medicine, science, household, industry, for cosmetic purposes. Some specific UV applications, for example, are: in physiotherapy and dermatology for phototherapy; in hygiene and anti-epidemic control - for bactericidal effect; in industry - for drying inks and plastics, for verification the authenticity of documents, and many others. In some working environments workers are exposed to UV radiation as side factor of the production process – e.g. welding.

By 2010 there was no legal basis for the control of optical radiation in working environment in our country. In 2010 Directive 2006/25/EC was transposed in the national legislation introducing exposure limit values for coherent and non-coherent optical radiation and obligations of employers, training requirements and health surveillance of workers. The paper presents results of measurement and exposure assessment of UV sources used in medicine, science and industry in accordance to transposed Directive (Ordinance No. 5/2010). The results show high values of irradiance for most of presented work places in the entire space of working premises, where the working tasks are performed, excluding those with encapsulated/shielded sources. Depending on the location of the source, respectively, on the way of conducting a procedure, the maximum power density is established at different levels: the level of the neck or arms, in the case of higher-mounted source, the maximum values are at eye level. Calculated permissible exposure time is as low as seconds up to several minutes. Compliance within the working day is virtually impossible, so particular safety measures should be taken in order to protect workers' health.

MEASUREMENTS OF WAVEGUIDES PARAMETERS

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The behaviour of a transmission circuit device with two gates, in different conditions of frequency and load is determined by measuring the voltage and current. Since the measurement of voltage and current at high frequencies and very high transmission line is very difficult, instead of measuring them is performed the measurement of their main parameters. In case of waveguides the parameters are: wave resistance, remission in waveguide line, the constant of phase, the power, wavelength and spead of phase in waveguide, frequency and wavelength λ_v. Very high frequency electronic circuits, present some changes in their behavior towards circuits that work in low frequencies. At higher frequencies the wave length becomes comparable to the physical dimensions of circuit elements. These changes in circuit behavior are conditioned by the nature of distributed parameters. Thus the very HF circuit cannot be described through voltage and current at a given node of the transmission lines, but as waves transmitted in a given environment. At frequencies above 1 GHz, geometrical dimensions of components become comparable with the wave length in which they work and this intensifies the changes in the behavior of circuits. Analysis of system transmission and reception in the microwave is limited to linear networks. Because of the limitations of these networks, the network (the circuit with 2-doors) is excited with an incoming sinusoidal signal. The measurements are performed using the standing wave mode (stationary mode) in waveguides. In this case the waveguide was left open-ended, in which we decided reflective sheet metal in contact with the line (to cover it). It was decided the waveguide regime or staying stationary waves. In this paper, for each frequency, we defined two consecutive positions where minimums are detected.

Key words: waveguide, measurement, network, circuit behavior

NOKIA WINDOWS MOBILE'S POWER CONSUMPTION MEASUREMENTS AND ANALYSIS

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Recent mobile Smartphone devices have a very rich set of components and can handle multiple general purpose programs that many times are not UE friendly, meaning about UE internal resources, power drain, generated signaling. Understanding the use of them and impact on UE, mobile network and end user perception, will help to better optimize "frustrating" situation. Actually reducing power consumption looks to be a crucial design for both mobile and other small computing devices that are not always connected to any power source. Good energy management requires a good understanding of where and how the energy is used. To this end we present a detailed analysis of the power consumption of a recent mobile phone, Nokia Lumia 625 model. We measure and discuss the significance of the power drawn by various components, apps and identify the most promising areas to focus on for further improvements of power management. We would like to present this power breakdown for benchmarks as well as for a number of realistic usage scenarios. These results would be good to be validated by overall power measurements of other ex-Nokia Symbian OS. Being able to generate a device-specific scalable power consumption model is therefore crucial for understanding, designing, and implementing better mobile application software. A proper energy accounting infrastructure will help both application developers and Smartphone users to extend the battery life of their devices and to make informed decisions about where to spend the remaining device power, potentially in real-time measurements.

PHARMACOLOGICAL ASPECTS OF RADIATION

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SYNTHESIS AND BIOLOGICAL EVALUATION OF NOTA/DOTA CYCLO-RGD DIMERS LABELLED WITH GA-68 AS RADIOTRACER FOR CANCER DIAGNOSIS AND THERAPY FOLLOW-UP

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The αvβ3 integrin receptor, expressed on tumor cell membranes can be preferentially targeted by peptides containing the RGD sequence, resulting in a versatile cell recognition system. DOTA-E-[c(RGDfK)2] and NOTA-SCN-Bn-E-[c(RGDyK)2] were labelled with Ga-68 and tested for radiolabelling yield, purity, stability, in vitro binding and ex vivo biodistribution.

The radiolabelling was performed using an automated system with inline quality control and Ga-68 eluate from a tin oxide based Ge-68/Ga-68 generator, purified and concentrated to 400MBq in 0.1 mL water on an anionic exchanger resin. DOTA/NOTA-derivatised peptides were labeled by heating at 95°C. Elution, concentration, labeling and purification procedures took 20 min. The ex vivo biodistribution of 68Ga-DOTA-E-[c(RGDfK)2] and 68Ga-NOTA-SCN-Bn-E-[c(RGDyK)2] was tested in tumor bearing animal models. Real-time quantification of biomolecular interactions was determined: on- and off-rates, affinity of DOTA/NOTA cyclo-RGD dimers to tumor cell-surface receptors.

Nanomoles of peptides were labeled and purified, RCP>98%. The biodistribution pattern of 68Ga-NOTA-SCN-Bn-E-[c(RGDyK)2] in melanoma rats shows high and stable tumor uptake up to 11.6% ID/g. The blood clearance is fast, the renal elimination is more rapid than in the case of 68Ga-DOTA-E-[c(RGDfK)2]. Higher tumor to background ratios was observed. Binding to receptors is achieved in the first 3 min of incubation and remains stable for 30 min.

The radiolabelling with Ga-68 of very promising candidates for imaging targets of interest in cancer diagnosis and therapy follow-up such as αvβ3 receptors, were successfully adapted on the automated module, reducing reaction time and operator exposure. The biological evaluation of 68Ga-DOTA-E-[c(RGDfK)2] and 68Ga-NOTA-SCN-Bn-E-[c(RGDyK)2] show a high and stable tumor uptake of both compounds.

A NEW FACILITY FOR RADIOPHARMACEUTICALS RESEARCH AT IFIN-HH

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The commissioning of CCR (Radiopharmaceuticals Research Centre) at IFIN-HH is reviewed. CCR is a state-of-the-art facility based on a cyclotron and radiochemistry, dedicated to radioisotopes studies and preparation of radiopharmaceuticals for clinical use. Its unique characteristics and performance open new perspectives for significant future achievements in these multidisciplinary areas.

THE STUDY OF NEW COMPOUNDS BASED ON HYALURONIC ACID FOR NEUTRON AND PHOTON CAPTURE THERAPIES

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At present days the therapy of radioresistant malignant tumours remains urgent problem in medicine. One of the approach to solve this problem is to use the binary methods of irradiation such as neutron-capture therapy (NCT) and photon-capture therapy (PCT). The feature of such techniques is the necessity uptake in tumour of chemical elements, which interacted with thermal neutrons (NCT) and X-rays (PCT) with local formation secondary ionization particles that allow to increased absorbed dose only around an interaction area (tumor). To maximize an effect the targeted delivery of this substance to cancer cells should be implemented. To date, a more hundred of such substances had been synthesized but most of them do not provide the desired therapeutic effect. A number of complex compounds were designed with use of various chemical elements, e.g. boron and gold. The aims of this investigation were the synthesis of the complexes hyaluronic acid with boron (for NCT) and hyaluronic acid with gold (for PCT and diagnostics) and study distribution of these compounds in organs and tissues in tumor-bearing animals (mice with melanoma B-16) for estimate expediency using as agents for NCT and PCT. The technology of modification of hyaluronic acid and sodium decahydroborate using Bridgman anvil have been developed. Received complex structure was studied. According to Raman and infrared interferometer spectroscopy data hyaluronic acid and polyborates are able to form a net of cyclic polychelate complexes with hyaluronic acid as polydentate ligand. Organs and tissues distribution of hyaluronic acid-based boron compound (3 mg of boron per ml) was studied on mice with melanoma B-16 after single (0.1 ml) intratumoral administration. Optimal time for BNCT session is 30 min after compound administration when boron concentration in tumor is more than 30 μg/g and exceeds boron content on surrounding tissues. The concentration ratios tumor/muscle and tumor/blood were 3 and 5, respectively. Moreover, there is not significant accumulation of compound in the liver, the spleen and the lungs. The accumulation of complex of hyaluronic acid with melanin and gold (20 mg per ml) also was studied. Maximal gold content in tumor (180-260 mg/g) was obtained in 30 minutes after single (0.1 ml) intratumoral compound administration on mice with melanoma B-16 that is quite high in comparison with existed gold-containing compounds used in similar problems. Note that the high ratios of gold in tumour and surrounding tissues in 0.5 and 1 h after administration was obtained that is an important and necessary condition for forming of local absorbed dose in tumor during PCT. On the basis of obtained data it is possible to assume about perspectives of these non-toxic compounds for use in neutron and photon capture therapy.

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ESTIMATION OF ANTIOXIDATIVE PROPERTIES OF NICOTINE USING PULSE RADIOLYSIS

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Nicotine (*3-(1-methyl-2-pyrrolidinyl)pyridine*) is a natural pyridine alkaloid found mainly in tobacco plants and is characterized by a stimulant action. It interacts with the nicotinic acetylcholine receptors and causes the release of many neurotransmitters responsible for mood (e.g. noradrenaline, serotonin and dopamine). This is the main reason of its strong addictive power, however it has also positive aspects. Stimulating effects of nicotine are used in the therapy of some neurodegenerative disorders and diseases [1].

Nicotine has another interesting property with potential medical application. Neurodegenerative diseases, such as Alzheimer's and Parkinson's diseases or Tourette's syndrome, are usually accompanied by an extensive oxidative stress, where nervous tissue is exposed to the presence of oxygen radicals beyond a threshold for proper antioxidant neutralization. Nicotine can easily pass through the blood-brain barrier and prevent this destructive radical action thanks to its antioxidative properties. There are some evidence that nicotine can react with the most dangerous $^{\bullet}OH$ radical producing neutral or less aggressive radical products [2]. However, it has not been confirmed so far and more data about the mechanism of nicotine radical processes should be obtained. The knowledge about the kinetic of these reactions is also important, because the rate of nicotine radical reaction need to be high enough to exclude competitive reactions.

The main experimental technique used to study $^{\bullet}OH$ induced oxidation of nicotine was pulse radiolysis coupled with a time-resolved UV/Vis detection system. Experiments were performed with the LAE 10 (Institute of Nuclear Chemistry and Technology) and Titan Beta Model TBS-8/16-1 (Notre Dame Radiation Laboratory) linear accelerators. The dissociation enthalpies of the C-H bonds in nicotine molecule were determined using DFT calculations. In order to get more insight into different reaction pathways, the oxidation of pyridine and N-methylpyrrolidine – nicotine molecular components, was also studied. Nicotine reaction with azide radical, which is a strong one-electron oxidant, was studied as well. Nicotine protonation plays important role in its radical processes as it can influence the reaction rates and even block the reaction pathways. For this reason analysis was done in the broad range of pH giving data for protonated and unprotonated forms of nicotine.

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RESEARCH ONTO BAMBOO KNITTED FABRIC IRRADIATED WITH AIR-PLASMA FOR THE ENHANCEMENT OF SURFACE ATTRIBUTES

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The main result and characterizing aspect of the research consist in the effectiveness of the air plasma treatment as a powerful tool of functionalization of textile support by improving its surface energy available. The augmentation of carboxyl, hydroxyl and aldehyde groups amount induced bonding of a higher number of microcapsules to the fibers.

Methodology consists of functionalization of a textile knitted support with 3D surface geometry. The surface of the bamboo knitted fabric was pre-functionalized by an air-atmospheric plasma treatments before applying microcapsules by padding process , the characterization and quantification of the amount of microcapsules being carried out using gas chromatography and mass spectrometry (GC-MSD), SEM microscopy, surface energy and electric parameters analysis (zeta potential ξ) and determination of air permeability. The morphological, structural and chemical properties of the samples were examined, in terms of a co-assisted investigation system: SEM images for the morphology, EDX analysis for surface composition, FTIR spectroscopy and X-ray diffractometry for structural samples features.

GAMMA RADIOLYSIS OF ACONITIC ACID IN AQUEOUS SOLUTION

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The synthesis of molecules necessary for life from abiotic process is a cornerstone in the Oparin-Haldane hypothesis for the origin of life. In this hypothesis the steps that precede the appearance of life is call "chemical evolution", which is the process through simple compounds lead to the generation of organic compounds essential for the development of life. On the other hand, radiation-induced reactions have been proposed, as mechanisms for synthesizing organic compounds under conditions existed in the primitive Earth.

Despite that advances which have been made in the prebiotic chemistry of amino acids, bases and other biological important compounds, still the formation of carboxylic acid is limited. Carboxylic acids have multiple functions in biological systems, for example, as members of metabolic pathways.

The present investigation is an attempt to establish the interconversion of aconitic acid (HOOC-CH_2-C (COOH) =CH-COOH) into acids associated to metabolic process. A route for this compound through the irradiation induced synthesis.

For these purpose, O_2-free solutions of 0.1moles L^{-1} of aconitic acid were studied after received several doses of gamma radiation (1.6 to 68 kGy). Gas chromatography and gas chromatography-mass spectrometry were the main analytic tools for the analysis of the radiolysis products.

The major feature of the oxygen-free radiolysis of aqueous solution of aconitic acid is the addition reaction to the double bonds by the water radiolytic products. These reactions formed appreciable amounts of non-volatile carboxylic acids related to the Krebs cycle: citric, isocitric, succinic and tricarballylic acids. The yields of those products are dose-dependent in the range studied. Other compounds were also identified like itaconic and carboxy-succinic acid.

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ALPHA AND ICP-MS SPECTROMETRY APPLICATION IN ANALIZING VARIATY OF MATRICES AND ACTIVITY CONCENTRATIONS

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To determine the activity of man-made alpha-emitting radionuclides is important task in the field of radiation protection and radioecology because of long physical and biological half-lives of some of them and their high radio toxicity. Variety of analytical methods exists in order to separate and detect alpha radioactive isotopes: α-spectrometry, mass spectrometry or ICP-MS, γ- and XRF spectrometry if applicable, etc. In case of alpha spectrometry and quantitative separation of the isotopes of the certain element from the matrix elements is required. In case of ICP-MS if the sample is environmental there is no need from such quantitative separation, but it can be measured only radioactive isotopes with very long half-live (such as ^{239}Pu). In the present paper the results from alpha spectrometry measurements of the thin sources prepared after radiochemical separation of environmental and Low-level radioactive waste samples (LL RAW) are discussed in relation to the different factors contributing to the quality and uncertainty of the activity results. There was made a comparison between results from alpha spectrometry and ICP-MS. Alpha spectrometry of the samples was performed by ORTEC Octete Alpha Spectrometric system equipped with 8 Ortec ULTRA-SA™ low background ion implanted detectors with 300mm^2 active area and energy resolution of 20 keV (FWHM) at the 5.486 MeV (^{241}Am peak). The calibration of the detectors was performed with certified sources, traceable to NIST for 2 geometries. If other geometry is measured most suitable was preparation of the calibration source from standardized solutions of the tracers in use. ICP-MS measurements are performed by using of VARIAN-820MS with quadrupole mass separation system and 90 degrees ion optics. The calibration was performed with 10mg/l multielement solution (C.P.A. Chem). The connection of mass and radioactivity was used for calculating activity concentrations of Pu isotopes.

In radiochemical separation schemes ion-exchange resins, high selective chromatographic materials (TRU, TEVA and UTEVA (Eichrom Technologies)) and other purification techniques were combined. In about only in 2 % of the cases the quality of the final source was considered as not useful to quantify the activity concentration.

One of the problems in increase uncertainty arises from not-complete chemical separation and peak overlapping of α-emitters of different element. This is demonstrated in the case of contaminated Pu and U eluates in complex procedure of radiochemical separation of Low-level RAW. The other case of increase of uncertainty is observed when tail of the higher energy peak is continue under the lower energy one (case of close tracer and analyte peaks for example of ^{243}Am and ^{241}Am) especially when source is prepared by co-precipitation technique. Tail correction is required also if ^{208}Po tracer is used to determine ^{210}Po activity. The other significant source of uncertainty is related to the chemical yield determination based on the tracer activity. In general the highest increase of uncertainty in some of the analysed RAW material is due to the unbalanced tracer activity added, due to unknown activity of specific radionuclides in the sample initially. It could contribute up to 50 percentage in combined standard uncertainty. During ICP-MS analysis of Pu-isotopes, one of the main sources of uncertainty is coming from sampling of very small aliquots from the main sample (in the cases of determination of uranium as main element, not as trace element).

HETEROGENEOUS RADIOLYSIS OF UREA. IMPLICATIONS FOR ASTROBIOLOGY AND PREBIOTIC CHEMISTRY

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Urea is a very important organic molecule in actual living organisms. Historically, it was one of the first organic molecules synthesized in the laboratory. In prebiotic chemistry urea readily forms in different laboratory simulations that include the use of different energy sources. Furthermore, the role of solid surfaces, particularly minerals, should have been crucial to the increased complexity of the organic matter and the subsequent emergence of life on Earth.

In this work, the radiolysis of urea in the presence of clay is studied, to determine to what extent the role of mineral surfaces influence the decomposition of organics. On the one hand, the results indicate that urea is relatively stable to ionizing radiation in liquid solutions and after 20 kGy no decomposition is observed. Moreover, the presence of a mineral (sodium montmorillonite), by a mechanism until now unknown, affects the radiolytic pathway and the urea remains in the heterogeneous solution without concentration change even at very high doses. These results indicate that solids could have protected some organics, like urea, from degradation enabling them to remain in the environment on the primitive Earth.

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RADIOLABELLING OF PEPTIDES WITH ^{68}GA FROM TIN OXIDE BASED ^{68}GE/^{68}GA GENERATOR: POSTPRECESSING, CHELATORS, AUTOMATION AND QUALITY CONTROL

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^{68}Ge/^{68}Ga generators provide cyclotron-independent access to positron emission tomography (PET) radiopharmaceuticals. The 67.6 half-life of the ^{68}Ga matches the pharmacokinetics of many peptides and other small molecules owing to rapid diffusion, localization at the target and fast blood clearance. The ^{68}Ga solutions eluted from the generator are usually containing small amounts of other cations (Fe, Zn, breakthrough of Ge), thus has to be purified and/or concentrated. Purification using anion resin and fractioned elution are feasible leading to a high quality eluate suitable for peptide radiolabelling. Neurotensin (NT), vasointestinal peptide (VIP) and octreotide (TOC) were radiolabelled and comparative evaluated. The influence of chelators and suitable radioanalytical method for analyzing the radiopeptides are presented. The radiolabelling processes were optimized and then adapted to an automated synthetizer, to reduce the dose to operator, assure reproducibility and reduce the total synthesis time (including pre- and post-purification). The synthesis time was 20-30 min, radiolabelling yield 80%, and the radiochemical purities higher than 95%.

RADIATION TREATMENT OF AGED MODEL TEXTILE SAMPLES

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Sensitivity of natural fibers to biological deteriorants is a serious problem in protecting textile heritage objects [1]. Radiation treatment is a common method of pest control and decontamination. In processing of objects of cultural heritage doses are selected according to contamination - up to 0.5 kGy for disnsection, 4-10 kGy for fungi control and 5-20 kGy ensures microbiological decontamination . Along with many other cultural heritage objects, textile items mainly ethnological significance were treated in 60Co gamma radiation source Ruder Boskovic Institute in Zagreb, Croatia [2] and were efficiently disinsected by applying of radiation dose of less than 2 kGy . In order to meet the high standards of conservators possible effects of higher doses should be assesed.

Tests were conducted on model samples of the most common materials in heritage items - silk, flax cotton, and wool. To ensure that any of the radiation effects will be observed a high dose of D=120 kGy in contact with air was applied. A part of the samples were heat- or UV - aged before exposure to γ - irradiation. Changes were determined by thermal analysis: differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA). The results indicated that even such a large doses caused almost no change in the materials based on protein fibers (silk , wool), while those based on cellulose (cotton, flax) showed somewhat reduced thermal stability on irradiation. SEM images confirmed those observations. Despite the high dose changes due to radiation were comparable to or lesser than those caused artificial aging. Based on these results it can be concluded that the radiation treatment iof heritage textile materials will not cause damage if performed fat the doses needed for controlling fungi.

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IN SITU REDUCTION OF AFLATOXIN B_1 LEVEL BY GAMMA IRRADIATION

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Various commodities predominantly crops can be contaminated with moulds that can lead to economic losses in agriculture and in food industry. More importantly, some moulds produce mycotoxins, their toxic secondary metabolites, indicating that mould except economic loss can represent threat to animal and human health. One of the most toxic mycotoxin is aflatoxin B_1 (AFB_1) with hepatotoxic, teratogenic, immunosuppressive and carcinogenic properties. Due to its toxicity International Agency for Research on Cancer (IARC) classified AFB_1 in group 1 as carcinogenic to humans. Countries around the world have limited the maximal level of mycotoxins in different food and feed commodities and in EU maximal tolerable level of AFB_1 in cereals and cereal-based products is set to 2.0 μg/kg. The level of AFB_1 in various commodities depends on climatic conditions under which the crops are harvested, stored and processed and higher AFB_1 level can be expected with higher humidity and temperature that favourable mould growth. It is important to try to control growth of moulds that can produce AFB_1, or at least to keep their growth and production of AFB_1 to minimum.

It is known that gamma irradiation could be effective in inactivating the growth of moulds, thus reducing AFB_1 level in commodities indirectly. The aim of this study was to investigate if gamma irradiation can be use as a method for direct reduction of AFB_1 level in corn/feed samples intended for animal consumption. For this purpose two separated experiments were performed. In the first experiment corn seeds, ground corn seeds and feed samples were artificially contaminated with known AFB_1 concentration (50 or 100 μg/kg), that can be expected in nature. For the second experiments corn seeds samples (n=30) naturally contaminated with AFB_1 and intended for animal consumption were collected in Eastern part of Croatia. In both experiments gamma irradiation at 5 and 10 kGy were tested. Results of first experiment showed that gamma irradiation of feed samples with added AFB_1 at dose of 5 kGy reduced AFB_1 level for around 65%, while at dose of 10 kGy AFB_1 level was reduced for around 85%. In naturally contaminated corn samples overall reduction of AFB_1 level after 5 kGy irradiation was 69.8% while the overall mean toxin reduction was 94.5% when 10 kGy was applied. Together, these results indicate that gamma irradiation can be used in reducing AFB_1 level in various commodities intended for animal and human consumption thus minimizing animal and human exposures to this carcinogenic mycotoxin.

THERMAL ANALYSIS OF SOME IRRADIATED POLY(ETHYLENE-TEREPHTALATE)NANOCOMPOSITES

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Radiation resistant polymers can be advantageously used for biomedical devices, scintillators, in space environments and as radiation shielding materials that protect personnel and equipment from the damaging effects of radiation [1]. A full understanding of the effects of irradiation on polymer and polymer-based composites is neccessary for design and construction of such materials. The radiation response of polymers and (nano)composites with a polymer matrix mainly depends on polymer properties and the type of radiation. Gamma rays, energetic ions/electrons, etc interact with matter producing ions and excited molecules. The distribution of these species throughout the polymer is determined by linear energy transfer rate of a corresponding radiation type. Free radicals formed on irradiation cause further reactions like polymer chain scission and/or bond formation. The overall outcome depends on the chemical structure of the irradiated polymer and it can be degradation, cross-linking or latent track formation. Since most thermoplastic polymers are partially crystalline, some degree of recrystallization and amporhization is to be expected. Changes in morphology, electrical, optical and mechanical properties result and are related to changes of thermal properties like glass transition, melting and crystallization temperatures and heats of fusion and crystallization. Differential scanning calorimetry (DSC) offers insight into thermal properties of various materials and is a fast and effective method for assessing the effects of ionizing radiation.

Polyethylele terephtalate (PET) is widely used polymer with excellent engineering properties and relatively high radiation stability that can be further increased by addition of appropriate (nano)fillers [2]. PET nanocomposites containing 1% nano-diamonds and a combination of 0.5 % nano-diamonds and 0.5% graphene were irradiated at RBI with gamma radiation at ^{60}Co source and with high energy protons at Van der Graff tandem accelerator. To assess the extent of radiation induced changes in those nanocomposites DSC measurements were performed. Only slight changes in phase transformation temperatures and heats in samples irradiated up to 0.5 MGy of gamma irradiation. Proton irradiation produced much more damage that was observed as widening of phase tranformation peaks in thermograms. The heats of fusion and crystallization were significantly lower but the reproducibility of those data was relatively poor indicating inhomogeneous spatial distribution of proton irradiation effects. Graphene containing nanocompoite was more radiation resistant than the one containing only nano-diamonds.

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SYNTHESIS OF GOLD NANOPARTICLES USING γ-IRRADIATED WATER-IN-OIL MICROEMULSION

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The physico-chemical properties of nanoparticles (NPs) strongly depend on the material they are made of, their surface properties as well as the size and shape. The physico-chemical characteristic of NPs is especially important for their biomedical applications such as the use of NPs as contrast and radiosensitisation agents. Water-in-oil microemulsions technique offers a very good control over particle size, dispersity, shape and phase composition of final product. A water core of the water-in-oil microemulsion serves as nanoreactor for the synthesis of nanoparticles and surfactant monolayer restricts the nanoparticles growth. By combining the microemulsion technique with γ-irradiation technique additional advantages arises. The main advantage is that γ-irradiation produces reductive conditions with no need for extra reducing agent. In addition, experimental conditions can be easily controlled (by controlling the absorbed dose, dose rate, atmosphere), synthesis can be performed at the room temperature and under ambient pressure and there is no restriction regarding the volume of the reaction because of the extremely high energies of γ-radiation. In previous work, it has been shown that magnetite (Fe_3O_4) NPs could be synthesised using γ-irradiated water-in-oil microemulsion. By controlling the γ-irradiation dose and dose rate reductive conditions in microemulsions were controlled and hence the size, phase composition and stoichiometry of magnetite NPs. In this work we investigated the factors that influence the micro-emulsion synthesis of gold NPs. Fig. 1 shows XRD patterns and corresponding SEM image of gold NPs synthesised using water-in-oil microemulsion.

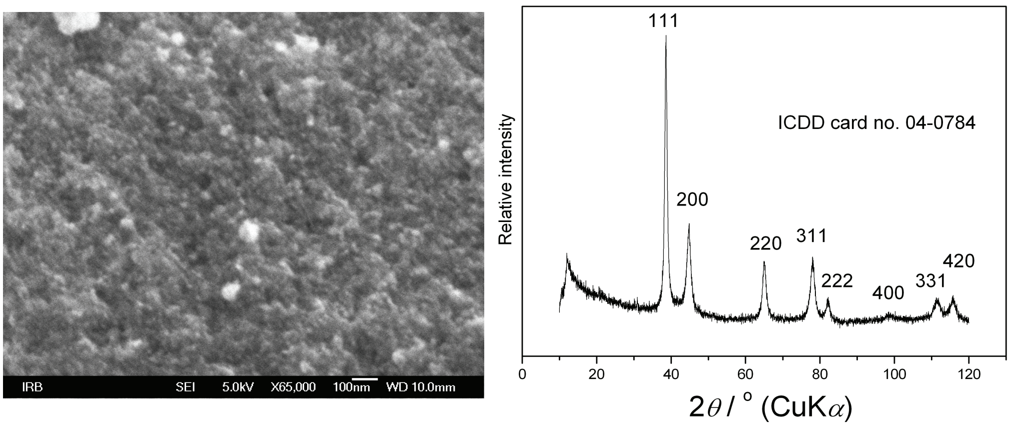

Fig. 1. SEM micrographs and XRD patterns of gold nanoparticles synthesised using water-in-oil microemulsion technique.

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DEVELOPMENT OF *IN-VIVO* DIAMOND DOSIMETRY FOR BRACHYTHERAPY

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A project on development of in-vivo dosimetry during brachytherapy will be presented. The project aims for development of array of dosimeters mainly single crystalline diamond detectors which can be inserted in the brachy therapy catheters and subsequently used during the therapy for two purposes: on-line verification of dose rate and received dose and localization of the treatment source. We will present the initial detector studies with source measurements, GEANT4 simulations of the phantom and prospects of developing compact readout with sensors mounted on a thin flexible hybrid circuit of small dimensions.

DEVELOPMENT OF A SEGMENTED SILICON DETECTOR FOR ON-SENSOR ANTIPROTON ANNIHILATIONS

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Silicon sensors have long been used for tracking of minimum ionizing particles in high energy physics experiments. The same sensors can be used for detection of higher-ionizing particles, such as MeV protons and heavy ions. Such prongs are produced with relatively high multiplicities in annihilation events and can thus be used as a signature of the latter. In our application, the antiproton annihilation takes place on the silicon sensor, producing a typical signature that has been observed and compared against Geant4 simulations. The understanding of this process allows producing detectors and reconstruction algorithms fine-tuned to provide the best spatial resolution on the annihilation event.

We present here the status of the development of a novel silicon strip detector targeted to measure on-sensor annihilations with a resolution of few microns.

The Universities of Bergen and Oslo are currently developing such a sensor for the AEgIS experiment at CERN. The experiment aims at direct measurement of the gravitational acceleration of antimatter in Earth gravitational field.

DETECTORS OF IONIZING RADIATION BASED ON CRYSTAL SCINTILLATOR STRUCTURES

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The main topics of the presented research are design, development and manufacture of detectors of ionizing radiation with high precision and reliability to make diagnose of physical processes in nuclear-energy facilities, in particular to control the radiation conditions on nuclear power plants on base of fast neutrons. There are described methods of creation of scitillator detectors on base of LaBr3(Ce) and YAlO3(Ce), described works on experimental validation of applicability of detectors on base of CsJ(Tl), BGO and LSO and on base of YAlO3(Ce) and LaBr3(Ce). There is detail consideration on experimental research of created prototypes to measure activity of gas media, and also registration of gamma radiation from liquid media. It is shown, that in condition time measurements is 100 c the extreme measured activity of gas media is about 10^7 Bq/m^3. Range of measured activity in liquid media in condition time of measurements is 100 c for the source Cs-137 is about following: A min=3,79·102 Bq/l and A max. = 1,08·108 Bq/l.

DEVELOPMENT OF THE FAST RADIATION DETECTOR FOR ONLINE MONITORING OF BETATRON BREMSSTRAHLUNG BEAM STABILITY

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Nondestructive defectoscopy based on the gamma-radiation beams plays an important role in testing of different big industrial objects. Bremsstrahlung generated by 9 MeV electrons allows, for example, to test steel details with thickness up to 300 mm.

Tomsk Polytechnic University develops and manufactures accelerator (betatron) based complexes for defectoscopy, homeland security and other application. Compact betatron that is used as electron accelerator and bremsstrahlung generator has a big advantage of the compact sizes (diameter of the magnets is about 50 cm), low weight and low cost. In order to compensate rather low betatron pulse current (pulse charge is about 10^10 electrons) the accelerator operates at the frequencies up to 400 Hz.

The next step in the increasing of gamma-radiation imaging quality is a developing of the tomography system. Such a system allows 3D mapping of the defects in the objects. One of the problems of tomography is connected with a fact that the object should be irradiated for a long time that calls for the high gamma-beam stability or a precise knowledge of the relative number of photons that irradiate each projection. In the case of betatron one needs to measure each radiation pulse with approx. 5-10 microseconds duration and 400 Hz frequency.

In order to increase betatron gamma-radiation yield the feedback system based on the ionization chamber is typically used. The gamma-beam passes through the chamber and the feedback system analyses the chamber signal and tries to maximize it. However, the ionization chamber cannot measure intensity of each radiation pulse of the betatron.

In this report we would like to present the developed system for measurement of betatron gamma-radiation intensity based on the plastic scintillator and PMT that allows to measure each pulse of the accelerator. In the report we discuss the linearity of the developed system, influence of background conditions and a feasibility of such a system use for the gamma-ray tomography system based on the compact betatron.

MULTIPLE CURRENT METHOD APPLIED TO CHARACTERIZATION OF RADFETs

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Introduction: Metal-Oxide Semiconductor Field Effect (MOSFETs) have been used as control dosimeters in clinical radiotherapy. In this work, several samples of pMOS transistors manufacted by Tyndall National Institute, Cork, Ireland, were tested as in [1], but in this case using algorithms designed by our research group.

Experimental Setup: Three models of 400 nm thick oxides transistors with different oxidation processes have been tested. Every model has transistors with two different dimensions: 300/50 and 690/15 of Width/Length of channel. Transistors were irradiated with photons of 6 MeV in sessions of 1.56 up to 14.13 Gy with a field of 10x10 cm^2. The source was LINAC Siemens Mevatrons KDS, at the Hospital “San Cecilio” in Granada (Spain).The sensor response was measured by a reader unit developed by the Dep. of Electronics and Computer Technology at the University of Granada [2], that provides the threshold voltage shift (ΔV_T) biasing the transistor sequentially with three drain currents. This reader unit applies the three current method to reduce the noise, with pulse current, and increase the linearity and reduce the thermal drift [3].

Preliminary Results: The dependence of the threshold voltage shift with the dose has an exponential relationship given by $\Delta V_T = A \cdot D^n$ [4], which can also be expressed as log (ΔV_T)= n*log (D)+log(A). The values of n and log (A) were obtained for all the transistors for every model, to test which model and which algorithm works better with the different 400nm oxide transistors (see Table 1).

Table 1: Fitting paremeters (n and A) of the response to radiation of different RADFETs

Algorithms	Model	Type	n	Log(A)
3 Currents Algorithm and Continued Current	400nm_W8	300/50	0.921±0.001	1.504±0.001
		690/15	0.885±0.003	1.779±0.003
3 Currents Algorithm and Pulsed Current	400nm_W8	300/50	0.916±0.003	1.709±0.003
		690/15	0.891±0.003	1.550±0.003
3 Currents Algorithm and Continued Current	400nm_W7	300/50	0.900±0.002	1.842±0.002
		690/15	0.895±0.001	1.846±0.001
3 Currents Algorithm and Continued Current	400nm_W5	300/50	0.903±0.003	1.824±0.003
		690/15	0.916±0.001	1.789±0.001

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COMPREHENSIVE INVESTIGATIONS OF POINT AND CLUSTER RADIATION INDUCED DEFECTS IN SILICON

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The incident particles can interact with silicon atoms in the bulk of the detectors material, leading to displacement damage in the lattice, creating damage and affecting the properties of the silicon sensors. Many radiation induced defects are well characterized and identified. However, the trapping centers proved to control the device performances at the operating temperature were only recently detected and no information about their chemical structure exists. They are known as E(30K), H(116K), H(140K) and H(152K) defects. Our study is a step forward in this respect and is based on the following approach: to determine the evolution of point and cluster defects by irradiating the test n-type Si structures having different O and C concentrations, with electrons of different kinetic energy (1.5MeV-27MeV) and performe correlated electrical characterization (with Thermally Stimulated Current technique-TSC) and specific defect structure investigations by means of High-Resolution Transmission Electron Microscopy (HRTEM) and Electron Paramagnetic Resonance (EPR). In order to correlate the impact of trap levels on the electrical properties of detectors a comparison with the macroscopic parameters (leakage current, depletion voltage and effective doping concentration), extracted from the capacitance-voltage and current-voltage measurements is discussed. The electrical investigations show that the ratio cluster and point defects increases with electron energy, the density of cluster continue to increase also with the annealing time after the irradiation (especially for the H defects). The HRTEM investigations have shown that irradiation produce plate-like defects like “coffe beans” that are mainly oriented in the {-110} direction. Annealing experiment revealed that this type of extended defects evolve in other type of extended defects, agglomeration of vacancies (on {111} direction) and interstitials (on {113} direction) of 5-7nm lenght and after heat treatement at temperatures above 200C longer complex defects start to be formed (30nm) from combination of {111} and {113} defects. These results are consistent with the evolution of H type defects determined from the electrical measurements. The E(30K) defect is largely generated in oxygen rich material. Therefore, special samples for EPR studies concerning the chemical structure of E(30K) defect were prepared by enriching the silicon with 17O isotopes. Measurements at 120K low and microwave powers (0.15mW) resulted in changes in the EPR spectrum with the observation of several easily saturable narrow lines (0.1mT) of equal separations of 0.8 and 0.6 mT, due to the superfine interactions with 17O nuclei (I=5/2). Further investigations (angular dependences) at T<100K to reveal their structure will be presented.

GENERAL ASPECTS TO CALIBRATE TEPCs IN TERMS OF LINEAL ENERGY

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Depending on the application or in its physical dimensions, tissue-equivalent proportional counters (TEPCs) do not always allow built-in calibration alpha-particle sources, and the lineal energy calibration of these counters must be performed with an external radiation able to penetrate the detector walls. The external irradiation field can be used as a self-calibration, if a particular marker point of known lineal energy is identified in the measured spectrum. In a proton or neutron spectrum, a common marker is the so-called proton-edge, which corresponds to the maximum amount of energy imparted by protons in the given volume. If the proton edge cannot be identified precisely, a gamma source can be used instead, identifying the maximum lineal energy (e-edge) in the measured spectrum. The calibration procedure consists of two steps: first a marker point is identified in the microdosimetric spectrum of a ^{137}Cs gamma-source, and then a precise value of lineal energy is assigned to it. A method that uses a Fermi-fit function to identify the marker point was already described allowing the calibration of cylindrical TEPCs with an overall uncertainty of 5%(1). Later, the study has been extended to spherical detectors also with an overall uncertainty smaller than 5%(2). For each counter geometry, a simple power equation was given which allows to calibrate spherical TEPCs or cylindrical TEPCs filled with propane-based tissue-equivalent (propane-TE) gas at different site sizes from 0.5 μm and 3 μm at density 1 g/cm^3 using an external gamma source.

The aim of this study is to analyse the consistency of different calibration techniques (e-edge, proton-edge, alpha-particle calibration source) and describe the different elements that influence and contribute to the overall uncertainty of the calibration: the calibration technique, the identification of the marker point, the value to assign to the marker, the geometry of the counter, and the gas filling type (e.g. propane-TE or pure propane gas). A summary of the calibration will be presented for its use in practical applications.

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X-RAYS DETECTORS BASED ON THE CRYSTALS OF CALCIUM IODIDE

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Creation and improvement of X-rays detectors is one of the important problems of nowadays science. Devices based on X radiation technologies are used in biology, astronomy, medicine and other applications. Sensitive, high-speed and compact detectors are needed in these areas. Also these detectors should not use deep cooling because it needs bulky equipment.

It is known that calcium iodide scintillators have better spectrometric characteristics than iodide scintillators based on the sodium iodide. In this regard, there is practical interest to study the possibility of using them to make longwave X-rays detectors. Based on the Spectral and Scintillation properties of pure and doped crystals of calcium iodide there were developed methods of obtaining thin-layer and composite scintillation detectors for fluorescent X-ray radiometric analysis.

These measuring are aimed to estimate the Scintillation properties of detectors prototypes with different physical yield which were made from CaI_2 and CaI_2: Fe^{2+}. It was found that at amplitude separation signal equal to 4 Mo K_α- line best samples were split power 72 and 27% respectively for the crystal with extinguishing impurity luminescence and without it. These detectors are on their parameters almost answered composite detectors with different technical yield, which are made from two crystals CaI_2 or CaI_2: Eu with using neutral filters. Crystals CaI_2 and CaI_2: Tl in a pair can be used for the manufacture of preparing the composite detectors with different time flashings. At room temperatures they were characterized by X-ray spectra of maxima in the 400-450 nm. They have luminescence yield about 1.75 and 1.5 times more than in scintillators NaI: Tl. These results could be used for production of high-speed detectors of X-rays.

DEVELOPMENT BY LANDAUER OF A NEW PASSIVE DOSIMETER BASED ON THE OPTICALLY STIMULATED LUMINESCENCE TECHNOLOGY FOR IEC 62387 COMPLIANCE

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A new version of the IEC 62387 standard concerning methods of testing and acceptable performances for dosimeters has been published by the International Electrotechnical Commission in 2012. This standard has been directly transposed by the French authority under the code name NF EN 62387-1:2012.

In order to meet with an increased range the more stringent recommendations given in this standard, Landauer has developed a new dosimeter based on the Optically Stimulated Luminescence (OSL) technology. This dosimeter aims at measuring dose generated from exposure to X-Rays, gamma and beta. It has undergone a comprehensive serie of tests that have been performed according to the standard. The irradiations were done by the French reference laboratory for ionising radiation metrology. To complete this evaluation a dose estimation algorithm of a novel type has been developed. It is based on a pseudo Monte-Carlo method. In the end the dosimeter was declared compliant with the NF EN 62387-1:2012 for all the tests undergone.

During this presentation the dosimeter itself as well as the general principles of its associated algorithm will be presented. Also the assessed metrological performances will be discussed.

REVIEW OF RECENT RESULTS FROM RD50 COLLABORATION ON DEVELOPMENT OF RADIATION HARD PARTICLE DETECTORS

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The main challenge of CERN RD50 Collaboration "Radiation hard semiconductor devices for high luminosity colliders" is to look for the ultimate radiation hard semiconductor sensor technology for its usage at future HEP experiments. The concepts and technology steps developed for ionizing particle detectors however have applicability also in other fields of research. An overview of the collaboration activities will be given with special emphasis on recent studies of microscopic characterization of radiation induced defects and their impact on the sensor performance, understanding the device models through simulations and exploitation of impact ionization for improving the charge collection.

* A full list of RD50 members (52 Institutes) can be found on http://cern.ch/rd50/

DOSIMETRIC RESPONSE FOR CRYSTALLINE AND NANOSTRUCTURED ALUMINIUM OXIDE TO HIGH CURRENT PULSE ELECTRON BEAM

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High current pulse electron beams with the energy of 100-300 keV find an increasingly wider range of applications in radiation technology and scientific research. The absorbed dose of ionizing radiation can reach the value of 1-100 kGy. Thermoluminescent (TL) detectors based on Al_2O_3:C single crystals are widely used to estimate low absorbed doses (up to 10 Gy). TL from deep traps is of great interest for high-dose dosimetry. Moreover, the application of nanostructured modification of Al_2O_3 is promising for such purposes. The aim of this work was to study the dosimetric properties of the single-crystalline and nanostructured aluminum oxide under irradiation by a pulse electron beam.

Samples of standard single-crystalline detectors based on Al_2O_3:C and anion-defective nanoceramics of aluminum oxide with the grain size not exceeding 150 nm were studied. The samples were irradiated at room temperature by an accelerator electron beam with the pulse duration of 2 ns with the mean electron energy (130±1) keV and current density of 60 A/cm^2. The absorbed dose of irradiation by one pulse was 1.5 kGy for a single-crystalline sample and 0.76 kGy for a nanostructured one.

In the research of TL in Al_2O_3:C single crystals irradiated by an electron beam, the peaks at 300, 400, 430 and 550 ^oC connected with the deep trapping centers are registered. The dose characteristic of the TL peak at 430^{o}C possessing maximum radiation sensitivity goes sublinear and remains approximately $\propto D^{0.5}$ up to 100 kGy. Such a character of behavior of dose dependence can be interpreted in terms of the kinetic model based on competitive trapping of charge carriers by deeper traps at the heating stage.

Deep trap TL of nanostructured Al_2O_3 has peaks at 320 and 510 ^oC. The dose characteristics of these TL peaks increase sublinearly up to 6 kGy. With this, the standard deviation of TL response readings in one detector did not exceed 10%. Residual TL signal measured by means of the sample reheating was not higher than 1%. In the work the calculation assessment of the nanostructured sample fading on the base of the approximation parameters of the isothermal TL decay curves at high temperatures was carried out. The calculation showed that the fading did not exceed 1% at T=20 ^oC and 10 % at T=100 ^oC.

The results obtained point to the possibility in principle to use single-crystalline and nanostructured Al_2O_3-based detectors for high-dose dosimetry of pulse electrons at higher environmental temperatures.

RAMAN AND THERMOLUMINESCENCE DOSIMETRIC INVESTIGATIONS ON P_2O_5-BAO-K_2O GLASS SYSTEM

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In the present work the P2O5-BaO-K2O glass system is investigated by Raman and thermoluminescence as a possible dosimetric material.

Raman spectra of the investigated glasses contain two significant adsorptions around ~700 cm^{-1} and ~1150 cm^{-1}. Beside these two intense bands in the Raman spectra of phosphate glasses, other supplementary bands under 600 cm^{-1} can be observed. These weak signals are due to the well-known boson peaks and to the complicated internal vibrations such as the skeletal deformation vibrations of phosphate chains and PO_3 deformation vibrations of pyrophosphate segments.

UV-Thermoluminescence emissions have been registered under a controlled heating rate of 5 °C/s immediately after 25 Gy of β irradiation up to 500°C. Simple phosphate glasses did not exhibited TL signals. Thus, it can be inferred that the observed TL peaks correspond to different defects generated by the modifier ions (Ba^+, respectively K^{2+}) inserted into the glass network.

In the case of $0.5P_2O_5$ -0.5BaO freshly irradiated glass, two main peaks have been observed, one centered at 200 °C and the other peak at about 400 °C. For 0.5 P_2O_5 - 0.5 K_2O the intense TL peak is centered at about 280°C. In the case of $0.5P_2O_5$ - x BaO - (0.5-x) K_2O glass systems with $10 \leq x \leq 40$ mol% TL emissions consist of an overlap of the above-mentioned peaks, with the high temperature most intense emission appearing at lower temperatures as the concentration of K_2O is increased. A very good linear dependence ($R^2 > 0.99$) of the integral TL signal as function of dose was observed for doses up to 50Gy. Reproducibility tests have been carried on ten aliquots, each aliquot being repeatedly irradiated and heated to 500 °C. None of the investigated aliquots showed a specific sensitization or desensitization trend. We have also obtained acceptable batch homogeneity with a standard deviation of less than 10%. Thus, P_2O_5-BaO-K_2O glass system is a possible candidate material for medical dosimetry in the dose range investigated.

DOSIMETRIC CHARACTERISTICS OF $Li_2B_4O_7$: MN SINGLE CRYSTAL

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In this study, dosimetric characteristics and kinetic parameters of newly developed $Li_2B_4O_7$:Mn single crystal phosphor is reported. It is very attractive material in personal dosimetry because of its near tissue equivalency (Z_{eff}=7.25). The crystal was grown by Czochralski method from high purity compounds. Glow curve, dose response, fading and reproducibility properties of this material were investigated. Its TL glow curve showed two well separated peaks at about 105 and 220 °C with a heating rate of 2 °C s^{-1}. The main peak at 220 °C has linear dose response up to 60 Gy. The thermal fading ratio of the material is about 8% for main peak in 10 days. The results showed that the $Li_2B_4O_7$:Mn single crystal dosimeter can measure the beta doses with less than 2.5% variation for 15 sequential measurements. Apart from the dosimetric properties above, the TL kinetic parameters of the main peak at 220 °C of $Li_2B_4O_7$:Mn single crystal phosphor have been also calculated using various heating rates (VHR), initial rise (IR), isothermal decay (ID) and peak shape (PS) methods. All results obtained using these methods are compared and discussed. Activation energy was found as 1.21, 1.24, 1.18 and 1.20 eV, respectively. Similarly, the frequency factors were determined using VHR, ID and PS methods and found as 3.75×10^{11}, 7.85×10^{11} and $3.27 \times 10^{11} s^{-1}$, respectively. All results obtained using these methods are compared and discussed.

EFFECT OF THERMAL QUENCHING ON THERMOLUMINESCENCE PARAMETERS OF $LI_2B_4O_7$:AG SINGLE CRYSTAL

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In this study, the effect of thermal quenching on thermoluminescence (TL) parameters of Ag doped $Li_2B_4O_7$single crystal was presented using various heating rates. Lithium borate based dosimeters have more importance from the clinical dosimetry because of near tissue equivalency (Z_{eff}=7.25) nature. The crystal was grown by Czochralski method. The glow curve of the $Li_2B_4O_7$:Ag single crystal consists of three peaks at about 100, 160 and 230 °C using 1 °C/s heating rate. The maximum peak temperatures shift to higher degree when the heating rate is increase. The glow curve is deconvoluted using computerized glow curve deconvolution (CGCD) program. The influence of the thermal quenching of the main peak on maximum peak temperature, peak area, FWHM and symmetry factor were investigated. The activation energies were calculated using various heating rates (VHR) and peak shape (PS) methods for each heating rate. All results obtained for $Li_2B_4O_7$:Ag single crystal using different method are compared and discussed.

MEASUREMENTS WITH RADIOCHROMIC DOSIMETERS IN PROTON BEAMS OF VARIOUS ENERGIES

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In radiotherapy evaluations, the linear energy transfer (LET) of radiation is an important parameter, because it affects the biological effects of radiation. This fact is significant in the case of protons or heavier charged particles, for which a noticeable increase of radiobiological efficacy (RBE) is verified with increasing radiation LET. This fact is exploited by Hadrontherapy. For most of the solid state detectors, the effect of radiation LET on the dosimeter response is opposite to that on RBE: a not negligible reduction of the response with increasing LET is typically found. Therefore, it is evident the importance of performing studies of the dependence on the LET of the response of the detectors used for dosimetry in radiation beams with high LET and of developing appropriate methods to make corrections on the acquired data.

The interest of this work is aimed towards radiochromic dosimeters, with which it is possible to make measurements of spatial distributions of absorbed dose: Fricke gel dosimeter layers and EBT3 gafchromic films. Both dosimeters have been analyzed by detecting the light transmittance images, at suitable wavelengths, acquired utilizing a laboratory-made instrumentation consisting of a plane and uniform light source and a CCD camera with optical filters. The absorbed dose is obtained from the difference in optical density (ΔOD) measured before and after irradiation. A filter around 585 nm was utilized for Fricke gel dosimeters, and around 630 nm for EBT3 films. These films have been analyzed also with a commercial scanner equipped with specific software.

Studies have been carried out, in a similar manner, with the two detectors. Calibration curves were achieved both with ^{60}Co photons and high energy protons. Then, dosimeters were exposed (in a water phantom) to mono-energetic proton beams of various energies, Bragg peak profiles have been extracted from the images of ΔOD and dose profiles were obtained by means of calibration data. The depth-dose profiles measured with Fricke gel dosimeters and EBT3 film were compared with those obtained using an ionization chamber (IC). The ratios of the values obtained with the IC and with the studied dosimeters were evaluated for each incident energy and each depth in water and the dosimeter response lowering was correlated to proton LET.

Exposures to proton beams with multiple energies have been performed too, and a method for correcting the dose images detected with EBT and gel dosimeters has been studied.

ESTIMATION OF UNCERTAINTY OF HPGe EFFICIENCY CALCULATED BY EFTRAN USING VIRTUAL POINT DETECTOR MODEL

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The most accurate procedure for obtaining full energy peak efficiency for the high purity germanium (HPGe) detectors is often the most expensive one and most time consuming. That is why many methods, such as Monte Carlo simulations and different analytical efficiency transfer methods have been proposed and examined. One of those methods is virtual point detector method, the approximation of whole bulk detector with a point detector, located at the effective interaction depth. It is useful in the situations where only point sources are available for the calibration of the detector. Also, one of efficiency transfer programs is EFTRAN, the software that calculates efficiency and coincidence summing corrections based on data considering the geometry of detector and geometry and composition of the source. The aim of this paper is to use EFTRAN software for obtaining effective interaction depth of the detector, needed for virtual point detector method calculations. Since the effective interaction depth represents the geometry of the detector, the discrepancy between the calculation and measurement can be used to estimate uncertainty, originating from the defining of detector geometry when EFTRAN is used for efficiency calculation. For the purpose of estimation of uncertainty, a semiempirical formula for calculating efficiency based on virtual point detector model, will be utilized.

Key words: HPGe detector, efficiency, effective interaction depth, efficiency transfer

PERFORMANCE STUDY OF A PASSIVE RADIATION DETECTOR FOR AVIATION PURPOSES USING THE MONTE CARLO METHOD

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Aircrews, as pilots and flight attendants, are subjected to cosmic ray doses which can be higher than the average doses on workers from the nuclear industry. The diversity of particles of high energies present in the radiation field on board of aircrafts, turns the determination of the incident dose and requires special care regarding dosimetric systems to be used in this kind of field. The Brazilian Air Force, through the Institute for Advanced Studies (Instituto de Estudos Avançados, IEAv/DCTA) in conjunction with the Institute of Energetic and Nuclear Research (Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP) are working on this subject since 2008. A prototype of a radiation detector for aircraft measurements was previously built and tested in flight and laboratory conditions. The detector is able of measuring a quantity known as absorbed dose (using passive dosimeters), which will subsequently be correlated to the ambient dose equivalent and the effective dose received by aircrews. In this context, a theoretical approach through Monte Carlo simulations with the computational codes MCNP5 and MCNPX was used to model and characterize the detector response at such experimental conditions. This work presents the preliminary results of the computational modeling, with special emphasis on the comparison between the absorbed dose quantity (measured and simulated) and its relationship with the ambient dose equivalent and the effective Dose for this detector.

SIMPLE DETECTORS FOR CRITICALITY ACCIDENT DOSIMETRY

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Studies on detectors for accident dosimetry, including criticality accident dosimetry, are performed in Radiation Protection Measurements Laboratory (LPD) in the National Centre for Nuclear Research (NCBJ) in Poland in frames of the Strategic Polish Programme: Technologies Supporting Development of Safe Nuclear Power Engineering. One of the designed detectors is a micro-gap air filled ionization chamber polarized with specially selected capacitors. While testing the capacitors and during the studies of the effect of radiation on behavior of different type of them it was possible to select also capacitors which were sensitive to radiation. The relationship with the absorbed dose, the time elapsed from irradiation and the type of radiation source was well recognized.

Some specific types of capacitors were able to react with every kind of radiation. After irradiation the leakage current of the capacitor was at least four times higher than before irradiation and the signal was increasing with the increase of the absorbed dose. Fading of the signal with time after irradiation was observed and investigated. The paper will present the results of irradiation of several types of capacitors in different radiation fields. The signals of the capacitors were measured just after irradiating and tested up to few days later. The radiation sources taken into consideration were the reference LPD isotopic sources: beta ^{90}Sr, gamma ^{137}Cs, neutrons ^{252}Cf and ^{239}Pu-Be. The tests were also performed in more realistic condition i.e. in the neutron beam at horizontal channel H8 of NCBJ nuclear reactor MARIA.

The results for styrofleks axial 4.7 nF capacitor working under the voltage 300 V after exposing at the dose level of about 2 Gy have stable signal at the level above 1 pA after 7 minutes stabilization (irradiated in the field of isotope ^{252}Cf). The signal from capacitor is readable up to 48 hours with satisfactory good accuracy (using 2.5 kV capacitor give larger signals and remain readable up to several days).

Further investigation is needed but main statement is that such capacitor is suitable for accident criticality dosimetry what will be shown in the paper. It is worthy to add that the mentioned capacitors irradiated in the reactor (and also exposed in beta and gamma sources) have larger signals of about 5 pA after stabilization and remaining measurable much longer even up to 300 hours at the level above 1 pA.

GAMMA-RAY DOSIMETRIC PROPERTIES OF $(BA_{0.88}SR_{0.12}SO_4)_{99.8\%}:EU_{0.2\%}$ NANOPHOSPHOR USING THERMOLUMINESCENCE TECHNIQUE

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A sensitive thermoluminescence (TL) nanophosphor based on $(Ba_{1-x}Sr_xSO_4)_{99.8\%}:Eu_{0.2\%}$ ($0 \le x \le 1$) has been prepared using the chemical co-precipitation method. Precipitated samples were characterized using X-ray diffraction (XRD), dynamic light scattering (DLS) and high resolution transmission electron microscope (HRTEM) techniques. The obtained XRD patterns of the prepared samples exhibit an orthorhombic structure. It has been found that the TL sensitivity of the nanomaterial changes with varying the value of x. The maximum TL sensitivity was observed at x = 0.12. The DLS data reveals that the grain size of this sample is about 28 nm. A comparative study of $(Ba_{0.88}Sr_{0.12}SO_4)_{99.8\%}:Eu_{0.2\%}$ nanophosphor with its corresponding prepared microcrystalline form has been made. The dose response of nanosample was found to be less than that of the microcrystalline at dose range from 0.5 - 40 Gy. The dose response for microcrystalline and nanophosphor samples have linear behavior in the dose range from 0.5 to 750 Gy and 0.5 Gy to 1 kGy, respectively. The fading and reusability studies of both samples are also included.

COMMERCIAL pMOS AS RADIATION SENSOR FOR IORT

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Introduction: Intra-operative radiotherapy (IORT) is a technique in which therapeutic levels of electron radiation are applied to a target area during surgery, in only one session. IORT is used just after removing the tumour to destroy the remaining cancer cells [1]. Metal-Oxide Semiconductor Field Effect (MOSFET) are very suitable as dosimeter in this type of radiotherapy treatment [2]. In this work the response of the well known integrated circuit CD4007 that could be a good candidate as a radiation sensor for IORT is studied.

Experimental Setup: CD4007 manufactured by Texas Instruments have been tested. Four different configurations single and two stacked transistors, in unbiased and biased mode, were tested to increase the sensitivity. Twenty transistors were irradiated with electrons of 6 MeV in sessions of 1.8 Gy up to 59.4 Gy with a field of 25x25 cm^2. They were placed to 100 cm of the source, at the isocentre. The source was LINAC Siemens Mevatrons KDS, at the University Hospital "San Cecilio" in Granada (Spain). The sensor module consists of a CD4007 using one or two PMOS transistors, and one, two or three Junction Field Transistors (JFETs) with its discharging resistor, depending on the configuration. The JFETs are cut off or on, which depends on the radiation process or the readout process of V_T . In both cases the transistor operates in the saturation region. The sensor response was measured by a reader unit developed by the Department of Electronics and Computer Technology at the University of Granada, that provides the threshold voltage shift (ΔV_T) biasing the transistor sequentially [3].

Results and Conclusions: As it was expected the sensitivity has improved with the biased mode. The voltage V_{GS} during the radiation period has been tested in 0 and 0.6 V only because there is a protection diode between the source and the gate that turns on if a voltage higher than 0.6 V is applied. High linear response and low dispersion have been found in all the configurations with sensitivities between 4.6 and 13 mV/Gy. Therefore two stacked transistor configuration of CD4007 could be a good candidate for IORT.

TABLE I – SENSITIVITY (mV/Gy)

Configuration	VGS (V)	Sensitivity (mV/Gy)	σ (mV/Gy)
Unbiased Single Mode	0	4.6	0.1
Biased Single Mode	0.6	7.2	0.1
Unbiased Two Stacked Mode	0	9.5	0.7
Biased Two Stacked Mode	0.6	13	1

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THERMOLUMINISCENT DOSIMETRY IN CLINICAL KILOVOLTAGE BEAMS

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Aim: This study aimed at calibrating a new set of GR-200A thermoluminiscent dosimeters (TLD) in low and medium orthovoltage energy photon therapy beams and in a diagnostic beam of known beam quality in order to determine their response and to establish if the same set of TLDs could be used across both environments for in vivo dosimetry purposes.

Methods and Materials: A set of 20 TLDs was used for the study. An oven type PCL_3 was used to aneal the TLDs. The response of the TLDs was read using the Reader type LTM manufactured by Harshaw Bicron. Vacuum tweezers were used to transfer the TLDs at the time of measurements and calibration. TLDs were kept in a subdued ultra-violet environment between the annealing and irradiation process. TLDs were placed on a 30 x 30 x 17.6 cm^3 Polymethylmethacrylate (PMMA) phantom during irradiation. A calibrated Orthovoltage machine was used to deliver a known absorbed dose to the TLDs using 95 kVp (3.00 mm Al HVL), 180 kV_p (1.00 mm Cu HVL) and 300 kV_p (3.00 mm Cu HVL) therapy beams. A cylindrical ionization chamber (PTW 30001) and an electrometer (PTW 10008) were used to confirm the absorbed dose delivery of the orthovoltage machine at the time of measurements. Likewise, a calibrated LX40 radiotherapy Simulator was used to deliver a known diagnostic absorbed dose to the TLDs using an 80 kVp beam of 2.97 mm Al HVL. A TM77334 ionization chamber was used similarly to confirm the absorbed dose. The TLDs were also irradiated on the PMMA phantom to generate element correction coefficient (ECC) and readers calibration factor (RCF) necessary for calibration of the reader before actual calibration of the TLDs. The accepted variation in raw response of the individual TLDs from the average of the batch was compared and a deviation of less than + or - 20 % was considered within tolerance. A 10 % tolerance was subsequently considered suitable for the measurement of absorbed dose.

Results: Of the 20 TLDs calibrated in the 95 kV_p therapy beam, 17 were within the accepted response level (i.e. + or - 20 %), 17 in the 180 kV_p therapy beam, 16 in the 300 kV_p therapy beam and 15 in the diagnostic beam of 80 kV_p. 16 of the 17 TLDs were within + or - 10 % dose tolerance at 95 kV_p whereas all the TLDs that were within the accepted response level at the 180 kV_p and 300 kVp, were within the + or - 10 % dose tolerance. 12 of the 15 TLDs at diagnostic beam energy were within the + or - 10 % dose tolerance. 3 of the TLDs were therefore rejected at all energies.

Conclusion: The study concludes that the same set of GR-200A TLDs could be used across both kilovoltage therapy and diagnostic fluoroscopy environment for in vivo dosimetry purposes.

Keywords: GR-200A thermoluminiscent dosimeters, orthovoltage energy therapy beams, beam quality, diagnostic beam energy

REUSABLE MOS DOSIMETERS FOR RADIO-THERAPY REAL TIME MONITORING. CALIBRATION AND FIRST IN-VIVO MEASUREMENTS

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MOS transistors are known to be well suited for quality assurance and dose monitoring in Radio Therapy for their extremely small size, ability to storage dose information, easy to read during or after irradiation, dose rate independence, etc. [1]. One important weakness is the lack of linearity in its response which diminishes with absorbed dose limiting its lifespan.

In previous works we developed techniques for overcoming this limitation through different ways for neutralizing the trapped charge in the oxide. In the present work an application of one of them is presented. [2]

MOS transistors were used as sensors in a real time dosimeter for dose monitoring in Radio-Therapy sessions. After a pretreatment the sensors showed high repeatability in their responses to dose after partial recovery of the threshold voltage Vt by Radiation Induced Charge Neutralization (RICN). In this way it was possible to use each sensor many times in a narrow Vt range where it can be thoroughly calibrated.

The repeatability of a 2 Gy measurement is within +/- 1% over about 100 Gy without recalibration. The sensitivity changes at a rate of 0.01% / Gy. Temperature dependence is within +/- 2% in the range 20ºC to 40ºC. The angular dependence is within 2%.

Percentage Depth Dose (PDD) Measurements in water phantom coincides with the response of a ionization chamber within the measurement error (+/- 1.5% at 1 Gy) from 5mm on for a Co60 source and from 15 mm for a 6MeV LINAC. The field size dependence is also as the ionization chamber within 2%.

First results of in-vivo measurements are presented.

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ADVANCED TECHNOLOGY FOR NEUTRON REGISTRATION TO REPLACE WIDELY USED HELIUM DETECTORS IN PARTICULAR WITH SCINTILLATOR DETECTORS

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The aim of proposed topic is to present analysis of task to replace widely used detectors on base of helium-3 to modern technology of neutron registration. The task of replacement is the consequence of two facts: 1) current shortage of helium-3 for the requests for planned activities in the near future; 2) wide current use of detectors on helium-3 in the working system and so needs to support facilities on security and safety as for example portal neutron detectors systems.

The following main criteria applicable for the evaluation and selection of technology are described and analyzed: a) high efficiency for neutron registration (for experiment it may be proposed efficiency not lower then 1,5 count per a second when radiation from 1 g of Cf^{252} after moderator is registered; b) low sensitivity to register gamma-radiation; b) keeping neutron registration efficiency in case of essential increasing number of gammas in compare with number of neutrons (rejection coefficient should be between 0,9 and1,1 in conditions of irradiation by source of 10 mc Roentgen per hour).

The additional (technological and economical) criteria are also described and analyzed:

a) technology for creation of detectors (materials for detectors and systems for readout information) should exist or should be realizable; b) estimation of technology costs should be close to costs of technology based on helium-3; c) received date keeping should be reliable and safe; d) novel detectors should be compatible with existing and working systems of data treatment; d) detectors should keep the stable characteristics in severe radiation conditions; f) detectors support during working period should be not highly recourses consuming (or detectors are not needed in support at all during the working period); g) technology based on new detectors should be friendly useful for personnel, who are not highly technically educated; h) detectors should be applicable for the numerous of application to allow the standardization of construction.

Scintillation detectors are proposed as substitutions for helium detectors as far they may have big sensitive square and high resolution. But it is necessary to find out optimal detector, what has simultaneously low sensitivity to gamma, high output of photons and high transperansy and to find out optimal method of readout. Taking into account the described tasks the following scintillators technology based on Li are considered:

1) Glasses $^6Li:Ce^{3+}$
2) $^6LiI:Eu^{2+}$
3) $^6LiF/ZnS:Ag+$
4) $^6Li_6Gd(Bo_3)_3:Ce$
5) $Cs_2LiYCl_6(Ce)$ (CLYC)

The other materials (in particular B) based scintillators are also considered.

ROOM-TEMPERATURE SEMICONDUCTOR CDZNTE DETECTORS FOR VARIOUS APPLICATIONS

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Nowadays CdZnTe (CZT) nuclear radiation detectors of various designs and sizes are widely and successfully used for various applications due to their favorable detection properties – good energy resolution, high efficiency, small dimensions and weight and possibility of operating at room temperatures. There are different devices based on these detectors application, starting from a rather simple detection probes that consists of a detector and preamplifier placed inside of a common sealed case to spectroscopy systems with high energy resolution. Depending of a task can be used CZT detectors of a planar geometry or special detectors design based on a single polarity charge collection method. Among them there are hemispherical or quasi-hemispherical detectors simple by design and in manufacturing, do not require special electronics for their application, but are very good by spectrometric performance. Progress in improvement of CZT crystals characteristic and in technology of detector fabrication allow production of high quality hemispherical detectors with sensitive volumes from a very low of 0.5 mm^3 to a few cubic centimeters. Now these detectors are routinely made and commercially available from RITEC company (Latvia). RITEC produces various commercially available miniature spectrometric detection probes types SD310 which are very convenient for application in difficult for access places and other different devices based on CdZnTe detectors application.

Use of CZT detectors allows for construction of highly sensitive spectrometric (energy-compensated) dosimeters with outstanding size-sensitivity ratio far outpacing devices featuring GM detectors. Personal Radiation Detector (PRD) γ-Tracer Model GT 2-1 is a pocket-size device with built-in high-sensitive room temperature operated semiconductor CZT detector. PRD GT2-1 is made to address growing demand for portable multi-functional devices and integrates functions of energy-compensated dosimeter, search tool, high-resolution spectrometer and logger/recorder in the single enclosure. Particular focus in the design is detector eco-system tailored to CZT material specific. Use of modern ARM architecture microcontrollers significantly improves power consumption characteristics while allows comprehensive monitoring of the detector operation conditions. Device spectrometric engine may be used for both general radiation spot search and for identification of weak gamma-radiation activity superimposed upon significant background level.

Based on application of quasi-hemispherical CZT detectors Gamma-Radiation Micro spectrometer μSPEC was built. The μSPEC fulfills measurements of gamma-radiation spectra and storing it for processing in a PC. It is a self-sufficient very compact device consists of the high quality CZT detector, charge sensitive preamplifier, main amplifier, digital signals processor, high and low voltages power supplies and computer interface. The μSPEC communicates and powered from the PC via USB port. The changeable detection modules contain the high quality detector of volume 60 mm^3, 500 mm^3 or 1500 mm^3.

Examples of applications and some gamma-spectra obtained with CZT detectors are shown.

INVESTIGATION OF RADIATION SURVEY METERS IN X AND GAMA RADIATION FIELDS

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The aim of this work was to investigate the different type of radiation detectors commonly used for radiation protection purposes. The study was performed on survey meters which work is based on different detectors including ionization chamber, GM and proportional counter and scintillation probe. They were tested for energy dependence and angular response in x- and gamma radiation fields. As a source of gamma radiation, ^{137}Cs and ^{60}Co were used while x-ray radiation field was made by using industrial x-ray unit (high voltage ranges from 30 to 320 kV). Commercially available survey meters were investigated: ionization chamber Victoreen 451P, Geiger counter MRK-M87, proportional counter 6150AD6-k and scintillation counter 6150 ADB. The properties of the counters studied in this work were in compliance with manufacturers recommendations. However, they show larger deviation at lower energies. GM counter exhibits strong energy dependence for low energy photons what was expected and already known in literature.

MINIATURE SILICON PHOTOMULTIPLIER (SIPM) BASED SCINTILLATOR SYSTEM FOR LOW POWER HIGH PERFORMANCE DETECTION APPLICATIONS

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SiPM (Silicon PhotoMultiplier) is a silicon photodetector which has great potential to replace state of the art PhotoMultiplier Tubes or silicon photodiodes in a range of applications. The SiPM detector consists of an array of Geiger mode silicon photodiodes pixels. When a single photon of light is absorbed in the pixel, the Geiger mode silicon photodiode outputs a very large electronic pulse. This allows lower power and less complex electronics to be utilised in processing the detector pulses. We have developed a miniature scintillator based system based on SiPM technology from Sensl which can be targeted for radiochemistry and homeland security applications. The system exhibits excellent performance in terms of count linearity and energy resolution while at the same time consuming low power making it suitable for battery powered applications.

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RADIOCHROMIC DOSIMETRY FILMS IN RADIOTHERAPY

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Purpose: Dosimetry films have certain advantages over matrices of diodes or ionization chambers because their high spatial resolution and flexibility in the use with a number of tissue equivalent phantoms for dosimetry in radiotherapy. Radiochromic films are easier to handle than radiographic films because they do not require processing after irradiation.

Since Gafchromic EBT films were released two other generations, EBT2 and EBT3, became available. The purpose of this study was a comparison of physical properties of the three generations of Gafchromic films and their performance when used with flat bed scanners.

Material and Methods: The factory size 8 in × 10 in films were cut to obtain 5 cm × 10 cm samples. Three types of radiochromic films: Gafchromic EBT, EBT2 and EBT3 were exposed directly to UV radiation of sunlight and to Co-60 radiation or 6MV and 15 MV X-ray from the Varian Clinac2300 linear accelerator in the water equivalent phantom. During irradiation of films the reference conditions of field size, depth and source-to-phantom distance were used for which the dose rate of X-ray sources were determined. The exposed films were scanned with two EPSON flat bed scanners: PERFECTION V750 PRO and EXPRESSION 10000XL. The color separation (red, green and blue) was performed to obtain digital images. The response curves of three types of films for different radiation energy, orientation of scanning and two types of scanners were generated and compared in each of red, green and blue color channel. The orientation effect for each film type and for each scanner was evaluated as well as energy dependence and UV sensitivity. A tissue equivalent phantom was used to test the film performance in dose distribution verification in radiotherapy.

Results: For all color channels the EBT films shows much higher sensitivity to UV radiation compared to EBT2 and EBT3 being the least sensitive. The sensitivity of the EBT films to X-rays is also the highest when compared to two newer EBT2 and EBT3 generations. Each type of films shows similar orientation effect for both scanners. There was no energy dependence observed for any of the film type in the examined energy range (Co60 and 15MV X-rays). The results of comparison of calculated and measured dose distributions are presented.

Conclusions: The reduction of sensitivity to UV radiation in subsequent generations of Gafchromic films was in coincidence with lower sensitivity for high energy X-rays. Lower optical densities of EBT2 and EBT3 films may cause higher uncertainties during the dose measurements compared to the former EBT films. The Gafchromic films are a useful tool for pretreatment dosimetry verification of complex radiotherapy dose distributions (IMRT, VMAT etc.).

HIGH PRECISION MEASUREMENT OF THE HALF – LIFE OF ^{19}NE

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The aim of the experiment was to measure the half – life of ^{19}Ne with high precision of 0.01% and to estimate the influence of the environment on the beta decay. The experiment was conducted in the Grand Accélérateur National d'Ions Lourds – GANIL, Caen, France. The radioactive beam of ^{19}Ne was implanted in two targets made of two different materials: lead as a metallic environment and CsI as a dielectric environment. The targets have been installed on the same moving arm, allowing us to change the target swiftly after every implantation – measurement cycle. Through repeating procedure of implantation and measuring cycles, the influence of systematic uncertainties on the comparative measurement of the half-life of ^{19}Ne in two different environments was significantly reduced. Special attention has been paid to reduce the influence of systematic uncertainties on the absolute measurement of the ^{19}Ne half-life (dead-time, gain shift, threshold change, beam intensity, triggering rate). Herein the preliminary results will be presented.

HIGH-LEVEL TL DOSIMETRY FOR HIGH-TEMPERATURE ENVIRONMENT

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The growing demand for high-level dosimetry materials and methods due to intensive development of radiation technologies and nuclear installations is a big challenge of dosimetry nowadays. Highly sensitive LiF:Mg,Cu,P (MCP) detectors enable measurement of radiation doses from tens of nanograys up to a few kilograys, at which dose the saturation of the signal of the main dosimetric peak occurs. In 2006 unprecedented high-temperature emission of MCP detectors heated up to 600°C was observed, after exposures to radiation doses ranging from 1 kGy to 1 MGy [1,2]. All the results of subsequent experiments showed the presence of a high-dose high-temperature peak 'B' in the glow-curves of MCP detectors exposed to radiation doses higher than 30 kGy, following significant changes of their shape for lower doses starting from a few kGy.

On the basis of this behaviour of MCPs at high and ultra-high doses, a new method of TL measurement of radiation doses ranging from 1 kGy up to 1 MGy, has been recently proposed and developed at the Institute of Nuclear Physics (IFJ) [3]. The method is based on the relationship between the TL signal, integrated in the given temperature range, and dose. It is quantified by a parameter called the 'ultra-high temperature ratio' (UHTR). A very important issue is the question of temperature resistance of the UHTR TL method. Thus, the next step of its development was investigation of an elevated temperature influence, during high dose exposure, on the peak 'B' features. The challenge was to examine the TL signal (peak 'B') stability at high temperature and to determine the temperature range of applicability of the UHTR method.

Exposure of TL samples was carried out using an electron beam with energy of 6 MeV at a distance of 2.7 m from the accelerator exit window. Detectors mounted on a structure coupled to the electric heater were initially heated to the selected temperature and maintained at this temperature during exposure. Temperatures 45°C, 130°C and 180°C have been chosen, while for each of them three exposures: 1 kGy, 20 kGy and 100 kGy, of groups of about 30 TL detectors, took place. The experiment allowed checking and confirming the high resistance of the UHTR method to thermal loads. Preliminary experimental results confirm the temperature stability of the peak 'B' amplitude up to about 130°C. The theoretical explanation of the ultra-high dose behaviour of MCP detectors is still unknown so the work can therefore be both of practical and cognition importance.

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SOL-GEL DERIVED IONIC COPPER-DOPED GLASSES AND MICROSTRUCTURED OPTICAL FIBERS: A POTENTIAL RADIATION DOSIMETER

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Optical fiber-based dosimeters present a key advantage over their electronic counterpart components and sensors as they are insensitive to electromagnetic interferences and operate without electrical power. Moreover, the fiber architecture is suitable in applications requiring monitoring over a long distance. On the other hand, specific needs in the medical domain have emerged from new treatment methods like stereotactic or intensity-modulated radiotherapy. In those techniques, small field dosimetry requires efficient detectors with high spatial resolution and low response correction. Radio-sensitive optical elements like doped glasses and optical fibers could fulfill these requirements.

Two kinds of conventional optical fiber-based dosimeters have been developed so far. In the first, the radiation-sensitive element is a specially formulated quartz fiber, whereas the second one consists of a small bulk radiation-sensitive material. In both cases, the sensitive element is coupled to an optical fiber which guides the emitted signal to the detector [1].

Now, such a radio-sensitive glass compound may be obtained with a high doping concentration using the sol-gel process. Indeed, sol-gel synthesis has become a mature and pertinent technology in the preparation of optical materials such as silica-based glasses and nanocomposites. We have recently prepared high purity-grade silica glass rods using the polymeric sol-gel route. Furthermore, these sol-gel silica rods with a large cross-section have been used as starting materials to achieve passive or active microstructured fibers [2].

We present our results of photoluminescence (PL), radioluminescence (RL) and optically stimulated luminescence (OSL) related to copper-doped sol-gel vitreous rods and fibers exposed to UV or X-rays. In particular, we show the influence of the gel-to-glass process atmosphere on the visible PL quantum efficiency. All of the samples exhibit a reversible linear response of the light emission intensity versus the dose or the dose rate, confirming their potentialities for in vivo or remote dosimetry measurements. In the all-fibered configuration, the same fiber may act simultaneously as the waveguide and the sensitive material [3].

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VHF PORTABLE RADIO TRANSMITTERS: THEORETICAL AND EXPERIMENTAL DOSIMETRY

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The device under test (DUT) as electromagnetic field source was the portable radio transmitter "Radiy-301" manufactured by "Izhevskiy radiozavod" (Russia). This device is a generic type of portable radio transmitter. Our dosimetric investigations were both theoretical (numerical) and experimental in the VHF radiofrequency range (171 MHz) using the radio transmitter "Radiy-301" with 5W output power. In a flat homogeneous phantom the specific absorption rate (SAR) distribution was measured from the portable radio transmitter. The theoretical calculations of SAR were performed using the FDTD-based simulation software SEMCAD X v.14.8 (SPEAG AG, Switzerland). The experimental determination of the SAR values was performed using the dosimetric scanning system "DASY 52 NEO" (SPEAG AG, Switzerland). The portable radio transmitter was located parallel to the flat phantom ELI4 (SPEAG AG, Switzerland) in a low loss energy holder at distances of 0 mm (touching) and 50 mm from the case of the radio. The phantom was filled with liquid simulating tissue. The dielectric properties of the liquid simulating tissue HSL175 (SPEAG AG, Switzerland) at 170 MHz were: relative dielectric constant = 52.58 and conductivity = 0.80 S/m. The dosimetric isotropic probe used was the ET3DV6 (SPEAG AG, Switzerland). A scan is used to evaluate the SAR distribution and to reveal the maximum absorption areas where the "hot spot" (the SAR peak) is located. The calculated peak SAR's were 0.66 mW/g at distances 0 mm and 0.38 mW/g at distances 50 mm. The measured peak SAR's were 0.66 mW/g at distances 0 mm and 0.43 mW/g at distances 50 mm. The simulated and measured peak SAR values are the same at 0 mm distance, but the peaks are located at different points over the surface of the phantom. The spatial difference can be explained by the impossibility of simulating all the metal part in the radio case. The results at 50 millimeter distance show that the peak SAR values are collocated over the phantom and within the experimental uncertainty of the SAR measurement equipment. The results point out that the radio model can be used to correctly predict peak SAR values of the simulated radio equipment. Accordingly, we conclude that experimental dosimetry should be used for touching position to properly locate the peak SAR values and that radio models should be sufficiently accurate to predict peak SAR values and locations for other distances.

DETERMINATION OF BIOGENIC FRACTION IN SOLID AND LIQUID FUEL BY THE ^{14}C METHOD

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An increased level of CO_2 concentration in the atmosphere is a direct consequence of intense fossil-fuel combustion over a last century. Search for alternative energy sources and reduction of emission of CO_2 from fossil fuels by production of energy from biogenic material are topics of intense current studies. The “environmentally kind politics” of the European Union stimulates the production and use of biofuels by lower excise and income tax relief. In this context there is a need for control of producers and dealers of various types of fuels and independent determination of the biogenic fraction in fuel. Here, the term “biogenic” refers to a compound produced in natural processes by living organisms but not fossilized or derived from fossil resources.

The European Standard EN 15440:2011 specifies three normative methods for the determination of the biogenic fraction in solid recovered fuel (a mixture of biogenic and non-biogenic substances): the selective dissolution in a hydrogen peroxide/sulphuric acid mixture, the manual sorting method, and the method based on^{14}C content. The ^{14}C method of the biogenic fraction determination is based on different ^{14}C content of biogenic and fossil compounds: bio-fuels reflect the ^{14}C activity of the atmosphere during the growth period due to the use of atmospheric CO_2 for the photosynthesis, while fossil fuels do not contain ^{14}C. Therefore, a simple linear mixing curve with well-defined end members can be used to determine the fractions of biogenic and fossil carbon within a product.

The ^{14}C method is suitable for samples of all types of fuel, both solid and liquid. Any of the measuring technique for ^{14}C content, widely used in the radiocarbon dating laboratories, may be used: (i) benzene synthesis and measurement by liquid scintillation counter (LSC), (ii) absorption of CO_2 in a scintillation cocktail, followed by LSC measurement, or (iii) conversion to graphite and measurement by accelerator mass spectrometry (AMS) technique. All these techniques are accurate and precise, but are also time-consuming and expensive, so there is a need for simple, fast, reliable, sensitive, accurate, and not expensive technique. When liquid fuel is concerned, a direct measurement of fuel mixed with an appropriate scintillator by LSC is possible. The advantages of direct measurement are fast sample preparation and low analysis cost, but there are still some problems before the method can be standardized, such as higher uncertainty and the problem of colour.

This paper will compare advantages and disadvantages of the ^{14}C techniques used for determination of the biogenic fraction of various types of fuel, present the techniques used in the Zagreb Radiocarbon Laboratory and discuss some results obtained for both solid and liquid fuel.

RADIOLOGICAL CHARACTERIZATION OF THE DECOMMISSIONED UNDERGROUND RADIOACTIVE EFFLUENTS PIPES FROM THE IFIN-HH VVR-S NUCLEAR RESEARCH REACTOR

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The IFIN-HH VVR-S Nuclear Research Reactor was built between 1955 - 1957 and operated until 1997. During his life time, it was functional a number of 113,467 h, including 2,000 h at 3.0-3.5 MW power. The total thermal energy produced was 9,510 MW/d. Decommissioning of the reactor started in 2010 and will be completed in three phases, until 2021. The reactor was fitted with a 30 m^3 radioactive effluents leakages pond connected by an underground pipe with two 300 m^3 radioactive effluents storage ponds belonging to the IFIN-HH Radioactive Waste Treatment Plant (STDR). There were three types of pipes that were decommissioned: A radioactive effluents transporting stainless steel pipe (exterior diameter 108 mm, wall thickness 5 mm, buried at depth of 2.75 m ÷ 7 m), a ventilation carbon steel pipe for the 300 m^3 ponds (exterior diameter 62 mm, wall thickness 5 mm, buried at depth of 1.5 m ÷ 2.5 m) and a ventilation carbon steel pipe for the exhausted filter storage (exterior diameter 108 mm, wall thickness 5 mm, buried at depth of 1.5 m ÷ 2.5 m). Due to the preparatory activities (sitting, authorization and building) for the European Light Infrastructure - Nuclear Physics Facility (ELI-NP), it was necessary to remove the underground pipes. Radiological characterization was carried out for pipes discharged from the site, including soil, cutting mixture and pipe smear samples. There have been two types of measurements: indirect measurement of beta-gamma contamination by sampling smears and gamma spectrometric analysis to determine the specific activity of the samples. The involved measurement techniques allow detection of many radionuclides. The main identified radionuclides were: Co-60 and Cs-137. The obtained results for soil sample measurements have shown no contaminations. The contaminated samples are the following: mixture from pipes cutting points (Cs^{137}: 0.30 Bq/g ÷ 23.89 Bq/g, Co^{60}:0.03 Bq/g ÷ 0.13 Bq/g) and smears in cutting points for pipes emplacement evacuation (Cs^{137}: 0.910 Bq/cm^2 ÷ 25,970 Bq/cm^2, Co^{60} 0,006 Bq/cm^2 ÷ 0,135 Bq/cm^2). Total contamination level for Cs^{137} and Co^{60} during the pipes cutting operations for packaging was between 11 Bq/cm^2 and 75 Bq/cm^2 and the dose rate at 10 cm from de pipe exterior varied between 0.16 μSv/h and 0.44 μSv/h.

RAPID METHOD FOR TRITIUM MEASUREMENTS WITH LIQUID SCINTILLATION COUNTING ON QUANTULUS 1220

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Taking into account the tritium low level in the environment, special conditions have to be fulfilled in order to obtain accurate and reliable tritium measurements. Low activity concentration of natural water samples demands high and stable overall efficiency of counting system for the detection of low energy beta particles together with a low and stable background. Results of experiments were obtained using Ultra Low Level Liquid Scintillation Spectrometer Wallac 1220 Quantulus with EASYView and WinQ software.

To optimize tritium analysis in waters by ultra-low background liquid scintillation spectrometer Quantulus 1220 the optimization of sample/scintillant ratio, choice of appropriate scintillation cocktail and comparison of their efficiency, background and minimal detectable activity (MDA), the effect of chemi- and photoluminescence and combination of scintillant/vial were performed. Accessible cocktails in our laboratory at this moment are OptiPhase HiSafe 2 and OptiPhase HiSafe 3 which we used for comparison of their efficiency, FOM values, background and minimal detectable activity (MDA). Possible interference of chemiluminescence and photoluminescence in liquid scintillation counting in energy range of ^{3}H had been investigated, we determined maximal waiting time for background and samples with very low/high activity and estimated half-life of chemiluminescence decay.

ASTM D4107-08 method had been successfully applied in our laboratory for two years. The goal of this paper is to demonstrate development and optimization of new direct method in our laboratory proposed by Pujol and Sanchez-Cabeza 1999, which turned out to be faster and simpler than ASTM method. The calculated efficiency for OptiPhase HiSafe 2 and OptiPhase HiSafe 3 were (35.1 ± 0.5)% and (30.5 ± 0.6)% , respectively. The minimum detectable activity achieved was 2.0 $Bq \cdot l^{-1}$ for a total counting time of 300 minutes.

MEASUREMENT OF GAMMA SPECTRUMAT PWR REACTOR COOLANT SYSTEM WITH CZT SEMICONDUCTOR DETECTOR

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Radiation filed information in nuclear power plants should be provided for optimal job planning and workers dose management. It can be categorized with radiation type, incident direction, energy distribution and dose rate for external exposures. Survey meters and multiple personal dosimeters are used to obtain the information but the energy distribution analysis is not generally carried out. Photon energy distribution information can be used to design proper shielding for high dose jobs or to reconstruct workers specific organ doses. So, it is important to monitor the radiation source terms to analyze the radiation field.

Generally, portable scintillation(NaI) spectrometers or high purity germanium(HpGe) detectors with In-situ object counting system(ISOCS) can be used to measure the radioactivity directly for the assessment of photon energy field characteristics in the working places. However, both devices cannot be easily applied to the detection of source terms in reactor coolant systems because of the low energy resolution and the inconvenience with liquid nitrogen cooling respectively.

Radiation detectors using CdZnTe(CZT) can overcome these weak points. A CZT has much higher energy resolution than scintillation detectors and not need additional cooling devices. So recently, the CZT detectors are applied to radiation protection tool at several nuclear power plants and the reports show good results. CZT detection systems, however, still need the in-situ calibration process for proper measurement conditions before application like ISOCS or other in-situ devices.

So, in this study, CZT detection systems were used to analyze radionuclides inside the primary reactor coolant systems in pressurized water reactor type to estimate the possibility of application.

Three different sizes of CZT element (GBS SDP310, CZT 500, CZT 1500) and Multi-Channel Analyzer (MCA-166) were used for various dose rates during reactor shut down water chemistry process and then the photon energy spectrum were obtained directly from outside surface of major pipes. The measurement points are S/G inlet Man-Way and S/G Cold Leg.

Generally, the contents of radionuclides in RCS are influenced by the condition of S/G, primary coolant pipes and reactor operation. In the results, several radionuclides were detected and it can be used to estimate the RCS status in the view of radiation protection. Also, it can be considered to be used to detect the radioactive CRUD inside the major pipes in RCS and give the proper information of major radiation source to workers for establishing pre-job dose planning.

MONTE CARLO SIMULATIONS AND BENCHMARK STUDIES OF RADIATION ENVIRONMENTS AT CERN'S INJECTOR CHAIN AND RESPECTIVE CONSTRAINTS FOR INSTALLED ELECTRONIC SYSTEMS

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Electronic devices operating in hostile radiation environments (e.g. those found close to high-energy particle accelerators) can suffer from different types of radiation induced failures. At CERN, the mixed particle and energy radiation fields present at the Large Hadron Collider (LHC) and its injector chain can give rise to both stochastic and cumulative effects causing radiation induced failures of exposed electronics and materials, impacting component, system lifetimes and maintenance requirements, thus possibly limiting the overall accelerator performance.

In the framework of the Radiation to Electronics (R2E) project, together with a detailed analysis of available dosimetry and beam monitoring results, several FLUKA Monte Carlo calculations and benchmark studies were carried out in order to evaluate the radiation levels along the LHC injector chain. This is combined with an inventory of exposed components and systems allowing to evaluate possible mid- or long-term radiation impacts and, if deemed necessary, to propose and implement mitigation actions.

This paper analyses the different radiation environments and levels present along the CERN Injector Chain. Details on radiation energy spectra and annual cumulative radiation values are presented for various critical accelerator locations (e.g. close to the respective beam lines and at several points of interest where electronic systems are installed). The study focuses on the effects of both, radiation on electronic devices, as well as overall radiation damage issues. For benchmark studies, dosimetry results are combined with FLUKA Monte-Carlo calculations emphasizing the powerful interplay between precise calculations and detailed radiation monitoring.

Finally, within the framework of the LHC Injector Upgrade (LIU) project, the expected future evolution of radiation levels for critical areas will be highlighted. This analysis is put in contrast with equipment installed in critical areas, together with respective preventive and mitigation measures to be taken.

APPLICATION OF EPR DOSIMETRY IN BONE FOR VERIFICATION OF DOSES IN RADIOTHERAPY PATIENTS

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Ex vivo Electron Paramagnetic Resonance (EPR) spectroscopy enables a reliable retrospective dosimetry of ionizing radiation in such human tissues as enamel, dentine, bone and nails. This method is based on detection and quantitative characterization of EPR signals from stable free radicals generated in these materials by ionizing radiation. In bones, long-lived $CO_2^{\cdot-}$ radicals are induced by radiation in hydroxyapatite matrix of bone and relative intensity of their EPR signal and is used for dosimetry. EPR biodosimetry is one of a few methods of biodosimetry allowing to determine radiation doses absorbed by humans, who were not equipped with personal dosimetry devices and was used in dosimetry in victims of radiation accidents.

The main scientific goal of this study is to explore the accuracy, limitations and applicability of EPR dosimetry in ex post determination of radiation doses absorbed by people. Focusing the research on bone samples from radiotherapy patients assured their exposure to radiation in controlled in vivo conditions.

In the presented study, bone samples from three patients treated in different facilities in Poland, were used. The samples were obtained during a surgical treatments of the patients performed due to medical indications. The excisions of the samples were performed within 1 year after their radiotherapy treatment. For the retrospective dose determinations, sensitivity of the radiation-induced EPR signal was individually calibrated in the samples by in vivo re-irradiation of the samples with known doses. EPR signals of irradiated bones were numerically decomposed into symmetrical, background component, which is assigned to the bone's organic content, and to the radiation-induced asymmetric component, assigned to $CO_2^{\cdot-}$ radicals. The second component is dose dependent and its intensity was used in dose estimation. The measured doses were compared to the doses delivered to the samples during radiotherapy, which were calculated at positions of the bone samples by radiotherapy treatment plans. The doses measured by the EPR method in the three samples were 45.6 Gy, 28.0 Gy and 70.0 Gy, the doses calculated by treatment plans were 45.0 Gy, 28.7 Gy and 70.0 Gy, respectively.

It is concluded, that the EPR dosimetry, if performed on samples extracted within one year after irradiation can be an accurate retrospective biodosimetry method for doses above 20-30 Gy. Our study proofs applicability of EPR dosimetry in bone in accidental dosimetry and for verification of doses calculated by radiotherapy treatment plans.

RADIATION MEASUREMENT TECHNOLOGY USING AN OPTICAL FIBER AND OPTICALLY STIMULATED LUMINESCENCE AND ITS APPLICATION TO RADIATION MONITORS FOR NUCLEAR POWER PLANTS

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The situation following the March 2011 accident at the Fukushima Dai-ichi Nuclear Power Station (F1) has shown the needs for a radiation monitor that can expand multipoint measurement easily and measure dose rate without electrical noise. A radiation monitor based on optically stimulated luminescence (OSL) and using an optical fiber (OSL radiation monitor) was developed to meet the needs. The OSL has the characteristic of accumulating deposited energy by exciting the level of an activator and maintaining the excited level. The accumulated energy can be measured as luminescence which is released by irradiating light of a certain wavelength. In order to apply the OSL to a monitor, the OSL radiation monitor was developed that consisted of a sensor head with OSL element which is set to a terminal of the optical fiber, an optical coupler with two branches which is set to another terminal of the optical fiber, a laser diode which is set to a branch of the coupler, and a photomultiplier tube (PMT) which is set to another branch of the coupler. The signal of the OSL can be output using a PMT and a multichannel scalar (MCS), and the value of the dose rate is calculated by an integrated time period and a conversion factor which is obtained using a calibrated radiation source. In order to investigate the feasibility of the OSL radiation monitor, the dependence of the accumulated doses was examined using a prototype instrument. The OSL element used was BaFBr:Eu. The counts with irradiated times were measured for 0.1 mSv/h (^{137}Cs gamma source). It was confirmed that the accumulated dose of the range of 50 μSv to 10 mSv could be obtained within the measurement error of ± 10 %. Furthermore, the error of - 62.8 % at the accumulated dose of 495 mSv was obtained. This was due to counts loss and pileup of pulse signals with high count rate of the MCS.

The OSL radiation monitor can be applied to not only the gamma-ray measurement but also charged particles and neutron measurements by optimizing sensor head and using neutron convertor. Application as a ^{90}Sr/^{90}Y monitor was investigated. Interest in this application is high due to the problem of ^{90}Sr contaminated water leaking from temporary storage tanks at the F1. In order to evaluate the applicability, the discrimination performance of background gamma-rays and the sensitivity were examined. The counts were measured with and without ^{90}Sr (2.1 MBq) for 8 mSv/h (^{137}Cs gamma source) for the evaluation of the discrimination performance. It was confirmed that the count with ^{90}Sr was 7.3 times larger than that without ^{90}Sr. Furthermore, the dependence of the accumulated doses was measured using ^{90}Sr solution of 1.0×10^4 Bq/cm^3 for the evaluation of the sensitivity. Through this examination, the sensitivity of 2.2×10^{-2} counts/h/(Bq/cm^3) was obtained. From the results, it was estimated that measurement frequency was 1.7 min for dose rate of 0.1 mSv/h when ^{90}Sr concentration of contaminated water was 2.0×10^5 Bq/cm^3.

SECONDARY RADIATION IN HIGH-ENERGY LINAC RADIOTHERAPY USING INTENSITY MODULATED TECHNIQUES

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Radiation therapy using linear medical accelerator operating in high-energy (>=10 MeV) mode is accompanied by secondary radiation, i.e. neutrons and induced gamma activity originated in photonuclear (gamma,n) as well as capture (n,gamma) reactions. The neutron source strength Q of given linac model depends on a set of materials used in its construction in terms of cross section for above mentioned nuclear mechanisms for particular elements. Whereas the neutron absorbed dose depends strongly on the spectrum of neutron flux reaching the particular part of the body. Although neutron source strength as well as neutron spectrum has been widely studied in the last decade in simple geometry of linac beam emission, from clinical point of view there is still a need to investigate this whole body dose in specialized techniques, e.g. IMRT, dMLC (dynamic MLC) and VMAT which become more popular nowadays and require more monitor units than conventional static techniques to be emitted to deliver the prescribe dose to PTV.

The aim of presented study was to assess the additional secondary radiation dose received by a patient who undergoes high-energy radiation therapy employing IMRT, dMLC or VMAT techniques. Elekta Synergy linear accelerator with Agility collimator working in 10 MV and 15 MV photon modes was used in the study. Neutron flux density as well as neutron doses were measured in various locations inside the anthropomorphic phantom, which correspond to PTV, organ at risk as well as a distant radiosensitive organs. Neutron activation method of ^{115}In foils, TL detectors LiF as well as LB 123 N neutron dose rate meter were used for this purpose. Linac induced gamma-activity spectrum after completion of fractional irradiation was analyzed with the use of a semiconductor HPGe detector in terms of radionuclides identification and photon flux at chosen distance estimation. Organ specific doses were assessed using fluence-to-dose conversion coefficients given in ICRP report 74.

The neutron flux density depends strongly on the photon beam energy used in the therapy as well as on the location of organ of interest and is of the order of 10^4 – 10^5 per cm^2 per 1 Gy of the prescribed therapeutic dose. Among the set of activated radioisotopes the dominant contribution comes from collimator materials, flattening filter and the target, originated via neutron capture (n,gamma): ^{28}Al, ^{56}Mn, ^{66}Cu, ^{185m}W, ^{187}W, and photonuclear reaction (gamma,n): ^{57}Ni, ^{53}Fe. Among them, the short-lived radionuclides ^{28}Al, ^{53}Fe, ^{66}Cu and ^{185m}W contribute the most, whereas long-lived component of linac decay curve could be assigned to ^{56}Mn, ^{187}W isotopes. Therefore the effective half-life of investigated activity of linac head is of the order of several minutes and the photon dose rate measured 10 cm from the collimation system can reach 2 microSv/h.

COMPARISON OF NEUTRON FLUENCE ENERGY DISTRIBUTIONS MEASURED WITH NE213 PROTON RECOIL SPECTROMETER AND NE230 DEUTERON RECOIL SPECTROMETER AT THE ITHEMBA LABS TIME-OF-FLIGHT FACILITY

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Measurements of neutron fluence energy distributions are required in pure and applied nuclear research since neutron interaction cross sections are energy dependent [1]. In application such as neutron radiotherapy, knowledge of neutron beam fluence energy distributions is required inside and near to the area under treatment by the neutron therapy beam to calculate the energy spectra of secondary charged particles and to characterize the radiation quality and absorbed dose both inside and near to the area under treatment. These neutron fluence energy distributions can either be measured experimentally or calculated by Monte Carlo Methods [2].

Research has shown that both the neutron detectors, the natural hydrogen organic liquid scintillators NE213 [3] and the deuterated organic liquid scintillator NE230 [4], can be use as recoil spectrometers to measure neutron beam fluence energy distributions in-situ (a water phantom simulating human tissue). The work with the deuterated organic liquid scintillators NE230 has been carried out with the motivation that an NE230 deuteron recoil spectrometer has potential advantages [4] over an NE213 proton recoil spectrometer to provide more stringent information in research supporting neutron cancer therapy and related application.

This paper reports on work completed in a project which compares neutron beam fluence energy distributions measured at the iThemba LABS time-of-flight facility with an NE230 deuteron recoil spectrometer in air and in a water phantom with those measured with an NE213 proton recoil spectrometer, to investigate if the use of the NE230 does improve the results. In particular the preliminary results obtained of comparisons between neutron beam fluence energy distributions with the recoil spectrometers in air will be presented and discuss.

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INFLUENCE OF SOIL HUMIDITY AND WEATHER CHANGES ON β- AND γ-RADIATION FIELDS IN THE GROUND ATMOSPHERE

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The report presents the results of theoretical and experimental researches by studying of influence of soil moisture on the characteristics of fields of alpha, beta and gamma radiation in the near-surface atmosphere. Also modeling the special cases of radiation transport during periods of rain and heavy rainfall, melting snow in the spring time of the year. Discussed possible schemes of impact of the rainfall on radioactive aerosols in near-surface atmosphere, given the discussion of variants combined manifestation of the consequences.

The results of calculations using the model of radionuclide transport in the atmosphere, as well as data on their nuclear-physical characteristics showed that rainfall strongly influenced by the amount of atmospheric activity concentration of radionuclides and its vertical distribution.

At the earth surface is increased concentration of radionuclides, which leads to increased fluxes of ionizing radiation (IR). Precipitation change the physical state of the surface layer of soil, which affects the lower penetration of soil emissions of radionuclides and leads to a decrease in atmospheric fluxes of IR.

Moreover, increasing water saturation topsoil leads on the one hand, to decrease the flux density of radon from the ground into the atmosphere, which reduces the concentration of atmospheric radionuclides and therefore fluxes of IR.

On the other hand, wetland soil is a blocking layer for soil radioactive gases, leading to an increase in their activity. Thus, the number of decay events is increasing and fluxes of IR in atmosphere are increases. Shows a comparison model results with observations of the characteristics of IR fields of surface atmosphere in 2009-2013.

A NEW LARGE SCALE METAL REFERENCE STANDARD FOR RADIOACTIVE WASTE MANAGEMENT

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A new large scale metal reference standard with certified activity of Co-60 and Ag-110m has been developed within the framework of EMRP-project (European Metrology Research Programme) "ENV09" with the acronym "MetroRWM" (Metrology for Radioactive Waste Management). It is to be used for calibration of free-release radioactivity monitoring systems. The overall aim of MetroRWM is to develop accurate approaches for the measurement of the radioactivity in radioactive waste and environmental samples from operation and/or decommissioning of nuclear facilities. Several gamma-ray emitting calibration standards of extended volumes (of the order of 200-400 L and having the size of a Europallet) and different materials (metal, concrete and light material) have been developed, to match real measurement conditions. The calibration standards are of two types: real contaminated material and phantoms that are either spiked or filled with radioactive sources. In the present work the development of the real contaminated metal standard is presented.

The real contaminated metal standard has the geometrical configuration of tubes. It is composed of gray cast iron which is contaminated with Co-60 and Ag-110m at about 0.3 Bq/g and 3 Bq/g, respectively. The material was produced using centrifugal casting from a smelt in which a known activity of Co-60 was added and one piece of neutron irradiated silver wire was progressively diluted. The iron castings produced were further machined to the desirable dimensions. The final material consisted of 12 iron tubes of 20 cm outer diameter, 17.6 cm inner diameter and 40 cm length and 246 kg total mass. The material was placed onto a Europallet-sized container (volume 120x80x40 cm^3). The activity certification measurements were performed using 10 additional disc-shaped samples that were prepared from the same batch of raw material. In addition, from each tube 3 samples of small metal chips (shavings) that were removed with a lathe from the outer surface were sampled. All samples were measured using HPGe based gamma-ray spectrometry. Due to the relatively low total activity of the shavings samples (mass 15 g), they were measured in the JRC's ultra low-level laboratory located 225 m underground. The discs (mass 370 g) were shared among the three project partners to provide an independent activity certification. The final certified activity values were determined by combining the independent measurements of the partner laboratories. The final uncertainty associated with the certified activity value included the activity characterisation and the homogeneity components.

The material will be further used to calibrate the new prototype facility for free release of radioactive waste developed within the same project. Further possibilities of use of the material by stakeholders and interested waste management facilities in Europe exist.

THE RADIOLOGICAL HAZARD DUE TO NATURALLY OCCURRING RADIONUCLIDES IN SOIL AROUND THERMOELECTRIC POWER PLANT

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Primordial radionuclides, ^{238}U, ^{232}Th and ^{40}K in soil samples collected in the vicinity of the largest thermoelectric power plant in Serbia were analyzed gamma-ray spectrometrically. Mean values of radionuclide activity concentrations were 50.7 Bq/kg for ^{238}U, 48.7 Bq/kg for ^{232}Th and 560 Bq/kg for ^{40}K. Based on measured activity concentration the radiological hazard due to naturally occurring radionuclides in soil was assessed. The annual effective dose outdoor due to analysed radionuclides, ranged from 51.4 to 114.2 μSv, was geographically mapped. The distribution pattern of natural radionuclides in the environment surrounding thermoelectric power plant and their enrichment in soil at some sampling sites were attributed mainly to windblown ash from open ash dumps. The obtained results indicated that the operation of thermoelectric power plant has no significant negative impact on the surrounding environment with regard to the content of natural radionuclides. However, much effort should be made regarding ash storage in order to minimize the windblown of ash to surrounding environment.

DETERMINATION OF VERY LOW CONTENT OF RADIUM ISOTOPES IN DRINKING AND MINERAL WATERS

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Assessment of Radium isotopes in drinking waters at very low level of concentration is an important problem especially when those waters are to be consumed by infants. The Lower Limit of Detection (LLD) of the routine liquid scintillation analytical methods in some European countries currently amount to 10 mBq/L and 30 mBq/L for Ra-226 and Ra-228 respectively (Chałupnik & Lebecka, 1993; Chau et al., 1997; Versterbacka et al. 2006). Such as levels of the radium isotopes concentrations correspondent to the far above 0.1 mSv/year of the committed effective dose for teenager and children in the groups of 0 to 2 years old, assuming every person consumes two liters of water per day. That means the routine methods are not able to be used in assessment of the radium isotopes in the waters for babies and teenagers. In purpose of the reducing of LLD the authors of this paper attempted to invest the measured intensities of the background samples and the possibility of the influence of Ra-226 contents on the Ra-228 determination and versa. The background samples were prepared using distilled water follow the same procedure as the analyzed water samples. In reality the measured background originates not only from electronic noise of the measuring system and from the radiation of the surrounding environment, but also is connected with chemical compounds used in chemical procedures. The investigation showed that the intensities resulting from the first two factors were very low and varied in the small interval, if the measurement conditions were kept stable. On the other hand the intensities originating from the chemical compounds were significantly higher and increased with time elapsing from the ending of the preparing of samples and reaching to the constant value after 500 h. On the basics of the dependence of the measured intensities of the background samples on the elapsing time, the concentration of the radium-226 in the $BaCl_2$ chemical compound was determined and amounted to 57 ± 2 Bq/kg. If the chemical compounds were not contaminated, the LLD for Ra-228 isotope would be reduced by factor of 3 and for Ra-226 by factor of 2 and the committed dose for infants caused by water intake could be estimated.

The measured results of the water samples artificially contaminated by various low amounts of ^{226}Ra and ^{228}Ra activities indicate that there is no influence of one radium isotope on the second one in the assessment processes of these isotopes.

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RELATIVE DEPTH DOSE PROFILE AND PEAK SCATTER FACTORS MEASUREMENT FOR CO-60 TELETHERAPY MACHINE USING CHEMICAL DOSIMETRY

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The suitability of a Fricke dosimeter for the measurement of a relative depth dose profile and the peak scatter factors was studied. The measurements were carried out in the secondary standard dosimetry laboratory at CRNA Algiers using a collimated ^{60}Co gamma source teletherapy machine. To study the influence of the irradiation geometry on the peackscatter factors, the measurements were performed for different field sizes of 5 x 5 cm^2; 7 x 7 cm^2; 8 x 8 cm; 10 x 10 cm^2; 12 x 12 cm^2; 15 x 15 cm^2 and 20 x 20 cm^2 at the phantom front face, at a fixed source-to-phantom distance of 80 cm. The dose measurements were performed by first placing the dosimeters free-in-air at the distance-source-detector (DSD) of 80.5 cm from the source. The output of the ^{60}Co source in terms of air kerma dose rate at this DSD was 1 Gy.min^{-1}, previously determined using the reference chamber calibrated in terms of air kerma at the International Atomic Energy Agency reference laboratory. Additional measurements were made with the phantom in place. The water phantom type Med-Tec 40 x 40 x 40 cm for vertical beam was used in this work as scattering martial. The phantom was placed on the irradiation bench of the cobalt unit at the SSD of 80 cm from the beam focus and the centre of the field coincided with the geometric centre of the dosimeters placed at the depth in water of 5 mm. The peak scatter factor (PSF) for a photon beam is defined as the ratio of the total dose and the primary dose at the depth of dose maximum. Relative depth dose profile and Peak scatter factors measurements were carried out using our Fricke system. This was intercompared with similar measurements by ionization chamber under identical conditions. There is a good agreement between the relative percentage depth–dose profiles and the PSF values measured by both systems using a water phantom. The maximum difference between the relative values measured by both systems was found to be within ± 0.5%. We thus believe that the tissue equivalent Fricke dosimetry system can measure the dosimetric parameters for ^{60}Co with a reasonable accuracy.

NATURAL RADIONUCLIDES AND RADIATION RISK ASSESSMENT IN SOUTHERN THAILAND SOILS

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The natural radioactivity and uranium activity ratio in soil samples from four provinces in southern Thailand have been studied. These four selected provinces are proposed as potential sites to set up thermal power plants by the Government of Thailand. There are plans to construct nuclear power plants (NPPs) as well as coal-fired thermal power plants in those provinces to meet the growing industrial demand for electricity in a safe and environmentally responsible manner. Therefore, it is important to focus on environmental protection and monitoring and risk assessment to general population. Thus, we have carried out a systematic study of distribution of natural radionuclides and estimated radiation hazard parameters. These data should be established and available before construction and during operation of power plants. A total number of thirty-seven soil samples were collected from those four provinces. The concentration of natural radionuclides including ^{226}Ra, ^{228}Ac and ^{40}K were determined using gamma spectroscopy. Activity concentrations of ^{226}Ra, ^{228}Ac and ^{40}K vary from 3–159 Bq/kg with an average of 49 Bq/kg, 6–225 Bq/kg with an average of 69 Bq/kg and 0–1422 Bq/kg with an average of 328 Bq/kg, respectively. We have noticed that most of the soil samples that collected from one of the four provinces show higher activity concentrations of radionuclides than others. This province is one of the high uranium and thorium level area in Thailand, reported by the Department of Mineral Resources, Thailand. The radiation hazard parameters including absorbed dose rate (D), annual effective dose equivalent (AEDE), radium equivalent activity (AGDE) and external hazard index (Hex) were calculated and compared with the international recommended values. Concentration of uranium was determined using the inductively coupled plasma mass spectrometry (ICP-MS). Concentrations of U vary from 1.4–32.0 μg/g with an average of 9.4 μg/g. Isotopic composition of ^{234}U/^{238}U and ^{235}U/^{238}U were determined using thermal ionization mass spectrometry (TIMS) to estimate activity ratio.

PRELIMINARY RESULTS OF ^{210}PB DATING METHOD IN THE DANUBE DELTA LACUSTRINE SYSTEM FROM ROMANIA

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The Danube Delta represents the sedimentary gateway at the interface between the lower Danube River and the Black Sea. It is, therefore, very important to broaden the present knowledge of the processes that control the sedimentation behaviour within the Danube Delta in order to understand the existing anthropogenic impacts like dams construction, and how to deal with it. The aim of the present work focuses on the study of the sedimentation rate pattern applying for the first time high resolution radiometric dating on the lacustrine sediments from the proximity of the danubian branches. The ^{210}Pb measurements have been used to estimate sedimentation rates over the last ~150 years, while the ^{137}Cs measurements provided a useful independent time marker for validation purposes. Sediment cores were collected from lakes of 1-2 m depth using gravity corers. Fine layers of sediment samples were analysed for physical properties and specific activities of ^{210}Pb, ^{226}Ra and ^{137}Cs were determined employing both alpha and gamma spectrometric techniques.

UNDERGROUND LABORATORY IN ULTRALOW RADIATION BACKGROUND IN SLANIC-PRAHOVA, ROMANIA

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IFIN -HH underground laboratory is located in Unirea salt mine in Slanic-Prahova, Romania . The lab was built in 2006. Unirea salt mine was chosen as the site of the laboratory due to extremely low radiation background . The average dose rate of radiation in the salt mine is about 1.3 nSv/h, about 70-80 times lower than ambient dose rate at the surface. This feature allowed us to install 3 different types of experiments: dosimetry, high resolution resolution gamma spectrometry in low background radiation and measurements of atmospheric muons. Depth in meters water equivalent determined from experimental measurements of atmospheric muon is about 610 mwe. In laboratory, two high-resolution gamma spectrometry systems produce by Canberra are operating. The first system equipped with a detector with a relative efficiency of 22.3 % is installed in a shield of 10 cm Lead and 2 cm Copper. The second detector has a relative efficiency of 120% and is installed in a shield of 15 cm Lead and 5 cm Copper. Background radiation in the range 40 keV 3 MeV due to this special experimental arrangement, in measurement space inside the shield is about 3600 times lower compared to spectra collected in onground laboratories without screen.

DOSIMETRY FOR A NEW RESEARCH FACILITY, ELI-NP

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Aurelia Celarel, Constantin Cenusa

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ELI will be the only European and International Center for high - level research on ultra-high intensity laser, laser-matter interaction and briefmess will go beyond the current state-of-art by several order of magnitude. The third pillar of this project, ELI-NP, is going to be realized in Magurele (near Bucharest, Romania) and will focus on laser -based nuclear physics.The radiation beams and fieds that will be produced in the ELI-NP (Ectreme Light Infrastructure- Nuclear Physics) are strongly different from all the aplications of dosimetry developed in Romaniaq until now.The development of dosimetry for ELI-NP must be done in two distinct fields: a)Dosimetry for Radiological Protection; b) Beam/Process Dosimetry. The main aspects in the development of dosimetry for ELI-NP (fr both fiels) must take into account some significant characteristics of the radiation to be detected and measured; - type of radiation:particles (gamma, neutrons, charged particles); - energy range of the radiation (a wide range of energy for each type od particles);- radiation beam/fields parameters (pulse frequency, pulse width, etc.);-other special conditions (for instance, intense electromagnetic fieldds). The paper presents the types of radiation to be encountered in the ELI-NP facility and their most important characteristics, from the point of view of the dosimetry. A selection of the dosimetric systems able to be used in the ELI-NP facility, together with their specific characteristics are also given; a special attenuation is given to these characteristics which allow to use them in the special conditions encountered to eli-NP (intense electromagnetic fields, for instance).

SOLID STATE NUCLEAR TRACK ETCH DETECTORS, 2D AND 3D ANALYSIS OF ALPHA TRACKS

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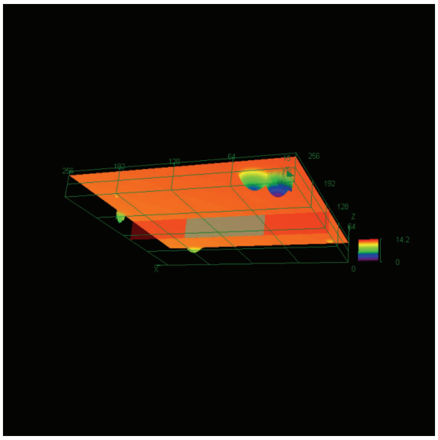
For health monitoring purposes, radon gas concentrations in air are typically assessed using CR-39 (and LR115) detectors which are assessed by 2-D image analysis of surface images. 3-D analysis has the potential to provide information relating to the angle at which alpha particles impinge on the detector, and to provide information on co-incident tracks, track clustering and track profiles.

In this study we used a “LEXT” confocal laser scanning microscope (Olympus Corporation, Tokyo, Japan; OLS3000 and 4000 series) to image tracks on a series of CR-39 detectors from several manufacturers / suppliers. We were able to identify patterns of single and coalescing tracks from 3-D visualisation. This gives the potential for more accurate interpretation of radon measurements.

This work is of immediate importance because around 9% of lung cancer deaths and 2% of all cancer deaths in Europe can be attributed to raised radon concentrations. It has been suggested that dose-response appears to be linear with no evidence of a threshold dose, this there is no ‘safe’ lower limit (Darby et al., 2004). There is also evidence to suggest that the risk to smokers is much greater.

As well as alpha tracks, we have also begun to examine tracks left by neutrons. Thus this method may provide a means of detailed 3-D analysis of Solid State Nuclear Track Detectors.



Example of conventional 3D LEXT imaging of radon track detector from below surface showing tracks (x50 objective).

TESTING OF HOMOGENEITY OF MATERIAL DISTRIBUTED IN INTERLABORATORY COMPARISON

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Interlaboratory comparisons are widely used for evaluation of the performance of laboratories for specific tests or measurements and they are obligatory for accredited laboratories. Materials prepared for proficiency tests and other interlaboratory studies are usually heterogeneous to some degree, despite best efforts to ensure homogeneity. When such a bulk material is split for distribution to various laboratories, the units produced vary slightly in composition among themselves.

Accreditation body of Serbia organized interlaboratory comparison for gammaspectrometry measurement in fertilizer samples. The samples were prepared and checked for homogeneity in the Department of Radiation Protection and Environmental Monitoring, Vinča Institute of Nuclear Sciences.

The assessment of homogeneity was performed before distribution of samples to the participants. In total 14 fertilizer samples were prepared for homogeneity measurements. A high-purity germanium detector system was used for the measurements. Each sample was measured 3600 s. The between-bottle homogeneity was tested by the determination of total spectrum counting rate and the net peak area for two gamma line of ^{238}U (63 keV and 1001 keV), one gamma line for ^{40}K (1461 keV) and one common line for ^{235}U and ^{226}Ra (186 keV). The reproducibility of the measurements was tested performing a series of measurements in one sample without moving the sample.

All samples passed Cochran's test for homogeneity.

RAD 2014

A NEW GENERATION OF RECOMBINATION CHAMBERS

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Recombination chambers are detectors for determination of LET-dependent radiation protection quantities, like radiation quality factor and dose equivalent. Initial recombination of ions takes place in gas filling the chamber.

Many types of recombination chambers are known, but only one type (REM-2) was commercially available, well investigated and successfully used (during last 40 years) for radiation protection dosimetry, mainly in the fields of high energy accelerators, medical accelerators and reactors. Since number of years, the REM-2 chambers also are not commercially available. Recombination chambers of a new generation have been designed and are investigated now in Poland, however still no decision exists about production of the chambers on a commercial scale. All elaborated chambers (preliminary denoted as REM-3) can be considered as detectors for determination of ambient dose equivalent H*(10), in mixed radiation fields of any composition and any energy spectrum, however variant solutions are advantageous for specific situation. For example:

- the twin recombination chamber (denoted REM-3.9), containing a monitor chamber in the same housing, is advantageous when intensity of radiation is unstable;
- the differential recombination chamber (REM-3.8) is advantageous when a continuous reading of the ambient dose equivalent rate is required, however with a limited accuracy;
- appropriate percentage contents of nitrogen in gas and sufficiently big mass of hydrogen in the chamber elements are essential in chambers destined for reactor fields, where a contribution of low energy neutrons is considerable;
- sufficiently small distance between electrodes is important to prevent volume recombination of ions in radiation fields of high intensity and of pulsed character;
- the effective wall thickness of the chamber should be about 10 mm according to definition of H*(10), but higher wall thickness is preferable for the chambers used in high energy radiation fields.

The influence of a chamber construction and elemental composition on useful dosimetric parameters of the chamber will be accurately considered in the paper.

The basic model of REM-3 chamber is 16 cm in diameter, 35 cm long. It contains 21 disc electrodes made of 4 mm thick conducting polypropylene. The distance between electrodes is 8 mm. Gas filling the chamber contains ethane with addition of nitrogen under pressure of 600 kPa. The dose rate range for REM-3 detector: 1μGy/h to 1Gy/h. The uncertainty of determination of H*(10), due to energy response curves, in real mixed radiation fields is below 20% using advanced recombination methods and below 25% using simple methods.

CHARACTERIZATION AND VERIFICATION OF A LATCHUP PROTECTION SWITCH IN RADIATION ENVIRONMENT

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The paper presents a single event latchup protection technique based on use of redundant circuits (and power domains) and custom switches for power-supply control. The protection switches of different types and sizes have been characterized by irradiation tests and corresponding measurements.

The integrated circuits and systems used in space environment require protection against a single event latchup (SEL) effect. The circuitsaffected by the latchup should be disconnected from the main supply line for a period of time in order to stop the extremely high current through the NPNP structure of a CMOS integrated circuit (Figure 1).

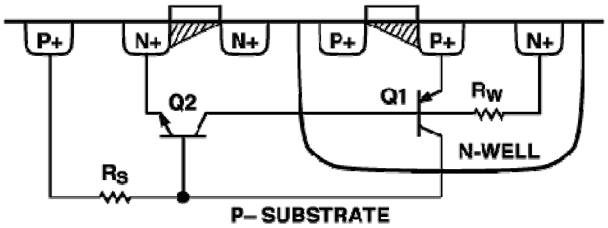

Figure 1: The parasitic NPNP structure

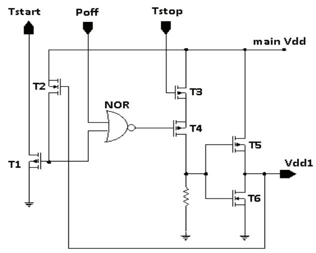

Figure 2: SEL protection switch schematic

This paper proposes a description of SEL protection switch (SPS) as well as the characterization results. The SPS must quickly react and simply disconnect the harmed part of the circuit. A simplified SPS schematic is presented in Figure 2.

In order to prove the functionality of the SPS cell, three groups of test circuits are implemented. A test chip named LUT-03 (Figure 5) is designed and fabricated as a test field of the nine different structures.

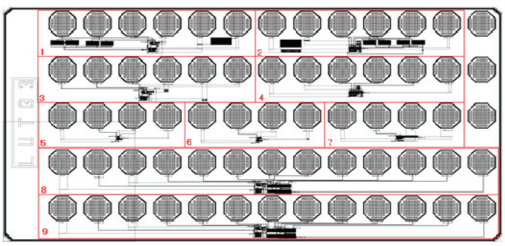

Fig. 5 Layout of the LUT-03 test chip used for SPS characterization

After successful functional verification, the irradiation tests of SPS cells were performed at the Radiation Effects Facility at the Cyclotron Institute located in the campus of Texas A&M University in College Station, Texas (USA) at different temperatures and ion energies up to 74.8 MeVcm2/mg.TAMU-REF is equipped with a K500 super-conducting cyclotron and an ECR ion source allowing a diverse range of particle beams and energies. These beams provide a wide range of LET values with energies high enough to obtain deep penetration in DUTs.

The successful characterizationand irradiation tests have shown that the proposed latchup protection technique presents a good hardware solution for the problem described in paper. The irradiation measurements have been conducted for the standard heavy ion cocktail which emulates the irradiation in space. The presented measurement results in paper are providing a basis for the further development steps and implementation of the proposed solution in a standard design flow for the fault-tolerant designs.

OVERVIEW OF RADFET TECHNOLOGY AND ITS APPLICATIONS

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Radiation Sensing Field Effect Transistor (RADFET) is a p-channel MOSFET optimised for radiation sensitivity. Owing to its small size, low cost, and simple and non-destructive read-out, RADFET has found applications in space, radiotherapy clinics, high energy physics laboratories, and accidental personal dosimetry of first responders.

Tyndall National Institute from Cork, Ireland, has been a world leader in R&D and commercialisation of RADFET technology. Tyndall supplies RADFETs to virtually all space exploration agencies, has co-operation with CERN related to RADFET use in LHC, and has been involved in commercial applications in quality assurance of radiotherapy and accidental personal dosimetry. We present the basics of RADFET operation and discuss its current and potential applications based on our direct interactions with the customers over the recent years.

SPECTRAL STABILITY OF STIMULATION SOURCES FOR OSL READERS

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Optically stimulated luminescence (OSL) is a two-stage luminescence phenomenon typically used for estimating dose of absorbed radiation in dosimetry as well as the age of archeological and geological materials in luminescence dating applications. In OSL technique after irradiation the solid (detector) could be stored for some time – even many years. Luminescence is triggered by optical stimulation. We observe light emission at shorter wavelengths than the stimulation wavelength. In continuous wavelength mode of OSL (CW-OSL) the stimulation light is cut off by optical filters. The emitted luminescence is proportional to the dose of radiation absorbed by the material.

The OSL response is strongly dependent on the stimulation light. In most OSL readers monochromatic high power LEDs are used for this purpose. These are cheap and easy to use light sources. Unfortunately, they also have many disadvantages. During detector readout, which may last up to 100 s (or during a sequence of measurement series up to many hours), the LEDs may significantly change their properties, influencing accuracy of dose determination.

This paper presents results of spectral and temporal studies of several LEDs produced by various manufacturers and typically used in OSL readers. Some hints for correcting the intensity variations during dose determination are given also.

Acknowledgements:

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ENHANCEMENT OF THE PRECISION AND ACCURACY OF RESULTS FOR AN HPGE DETECTOR USING FAILURE ANALYSIS

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The activity of *α, β, γ Spectrometry and Radon Measurements Laboratory* (SALMROM), part of Life and Environmental Physics Department from IFIN-HH, consists in regular monitoring of the environmental radioactivity, on a daily/monthly basis, in the area of the institute and nearby. Routinely measured isotopes in environmental samples are ^{40}K, ^{60}Co, ^{137}Cs, ^{241}Am and progenies of ^{238}U and ^{232}Th series. Some other activities, devoted to research programs, are related to the evaluation of radon concentration in salt mines, caves, construction sites or former industrial areas, to radionuclide inventory in water, soil or vegetation in the environment.

Beginning with 2010, for the last three years, the SALROM laboratory has participating in national and international inter-comparison with good results for the radionuclides measured with a high-purity germanium detector.

The feedback from the final reports of the organizers demonstrates the performance of the laboratory; where 34 out of 39 radionuclides measured pass all acceptance criteria of the tests. The rest of 5 results which failed served to improve the laboratory analysis and to optimize accuracy measurements. For these radionuclides, ^{134}Cs, ^{226}Ra and ^{241}Am, corrective actions are needed. In case of ^{241}Am the failure was considered to be due to inaccurate efficiency calibration in gamma-ray spectrometry in the energy range lower than 100 keV, difficult to obtain due to the lack of suitable radionuclide standards. As well, a high background of the detector is recorded in this low energy region that could lead to this failure. In case of ^{226}Ra the failure result could be due to the interferences with ^{235}U isotope. As for ^{134}Cs, the failure could originate from the correction for true coincidence summing.

Based on the lessons learned, to optimize accuracy measurement the laboratory uses an appropriate matrix reference material for quality control and an appropriate self- attenuation correction factor. New efficiency calibration coefficients are calculated taking into account all possible sources of failure analysis. Subsequently, using multiple factors can affect the precision and accuracy of gamma measurement in samples valid results of measurements are obtained for mid-and long term.

RESEARCHING OF NATURAL RADIATION DOSE LEVEL IN THE AROUND OF BEYŞEHIR LAKE OF TURKEY

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We can measure natural radiation level with a radiation meter in a region that is experienced. The radiation sources that people exposure in their environment are generally occure from cosmic and terrestial radiation. Natural radiation is a radiation which we cannot protect ourselves as long as we live. It is necessary to know the current dose in order to detect the quantity of natural radiation in an experienced region. We can determine the amount of natural radiation as a result of measurements taken at periodic intervals in different points of determined region. We determine the radiation in this manner which is increasing in different and adverse conditions with the income of technology.

In this study, a natural radiation level located around Beyşehir Lake within the borders of Konya, in Yenişarbademli located in Isparta, indoors and outdoors venues, in Pınargözü cave. Pınargözü cave is 10km away from Yenişarbademli, is measured from certain height with a Geiger-Mueller LND712. Also, this region has different altitudes. At the same time the natural radiation changes due to elevation difference has been identified. Besides the seasonal variation, amount of natural radiation changes at different times of day were observed. Measurements are taken three times in five minutes each time and its average value was determined from cpm (count per minute) genus.

The amount of natural radiation is determined in the measurement areas. It is also found that the natural radiation level is not high level for public health.

Key words: Natural Radiation, Beyşehir Lake, Pınargözü Cave, Yenişarbademli, cosmic rays, LND712

TOOLS FOR DETERMINATION OF RADIOACTIVITY BACKGROUND AT THE LOCATION OF PLANNED NUCLEAR POWER PLANT

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The possibility of a reliable assessment of the impact of nuclear power on the environment and on the population requires the determination of the radiological "zero level" in areas where a nuclear power plant is expected to be constructed. One of the tools to perform such measurements is gamma spectrometry *in situ*.

The study was carried out with the use of portable gamma spectrometer with HPGe semiconductor detector and a set of collimators ISOCS Shield Systems Model ISOXSHLD. The software GENIE 2000 for spectrum analysis was used.

A main problem in this type of measurements is a proper efficiency calibration. For *in situ* measurements the efficiency calibration curve was determined with the ISOCS software dedicated just for our HPGe detector. The important parameter in determining of efficiency curve is a depth of soil layer that is defined in the software. This value was established basing on laboratory spectrometric measurements of soil samples in a specific geometry.

Test *in situ* measurements of radionuclides content in the surface soil layer of 10 cm depth measurements were carried out in the area of the Institute of Nuclear Physics PAN in Krakow using a set of collimators 90°.

The results of *in situ* measurements were compared with the results obtained in the laboratory measurements of soil samples collected from the test area. The portable shielding system makes it also possible to perform laboratory measurements of collected soil samples. For this purpose, a cylindrical geometry (height of 40 mm and diameter of 70 mm) was applied. The satisfactory agreement of these results was obtained.

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RADIOMETRIC MEASUREMENTS AND EVALUATION OF RADON CONCENTRATION IN SOME NORTHERN ROMANIAN SALT MINES

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The knowledge of radon concentration levels in underground environments is essential for therapeutic purposes of different respiratory and rheumatic diseases. In order to develop speleotherapy in Romania, this paper presents the results of an indoor radon concentration levels survey in some salt mines in Romania.

The survey was carried out using radon monitor Pylon AB-5 system methodology. In order to investigate whether differences in depth and microclimate parameters translate into significant differences in salt mine indoor radon concentrations, have been chosen three salts mine test sites placed in the Northern part of Romania (Cacica [1, 2,], Ocna Dej [3] and Ocna Turda) in stable areas of the mining field at 32–120 m depth.

Environmental microclimate conditions (mean values of air temperature 10–14.5 ^{0}C, air humidity 65–80 %, air velocity 0.2 m/s saline aerosols and low microbial factors) have anti-bacterial, anti-microbial, and anti-inflammatory properties and recognized therapeutically effects on human body's health.

The measuring of the natural background ionizing radiation in salt mines was made using the Berthold Umo LB 123 portable integrated impulse debit meter (used in rate mode) equipped with a gamma probe - Counter-timer and at an integration times of 3600 s/measure. The measurement and calibration procedures were conducted in conformity with the procedures of the accredited (SR EN ISO/CEI 17025: 2005) SALMROM laboratory. Dose rate in various locations in salt mines were between 2 nSv/h ± 4.9% and 4 nSv/h ± 9.6%.

The analyzed environmental conditions and recorded low levels of indoor mean radon concentration 6.9 ± 0.39 Bq/m^3 demonstrated the best suitability of the investigated three salt mines in Romania for speleotherapeutic applications.

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EXPERIMENTAL NEUTRON AND γ-RAYS ABSORBED DOSE EVALUATION IN SUPERFICIAL SKIN LAYER USING RADIOCHROMIC FILM

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Absorbed doses from ionizing radiation in sensitive skin cells which are responsible for skin reactions while radiation treatment was experimentally evaluated. The radiochromic film Gafchromic EBT2 was used. The film thickness was 285 μm, the sensitive 30 μm thick layer was placed at 80 or 175 μm depth from the front or back surface, respectively. The optical density was measured in 24 hours after irradiation.

A calibration analysis performed for irradiation with 14 MeV neutrons and ^{60}Co γ-rays under conditions of secondary charged particles equilibrium showed that radiochromic film was less sensitive to neutron irradiation than to γ-rays by 40-65%. This difference is due to different spectra of secondary charged particles. Under the secondary particles equilibrium the major contribution to the tissue absorbed dose is made by electrons in the case of γ-radiation. In the case of neutrons the main contributors to dose are protons (73%) followed by ions C, N O (12%) and α-particles (11%), the total LET spectrum ranging from 6 to 1300 keV/μm.

Taking into account that epithelial cells may be at a various depth, the depth dose distributions for neutron and γ-ray beams were measured in the 10 mm thick PMMA phantom. The measured absorbed dose maximum was at 2 mm depth in neutron beam case and at 4 mm depth for γ-rays case which agrees with the maximum ranges of corresponding charged particles (proton recoils and secondary electrons) in PMMA.

At 80-110 μm depth the absorbed dose from γ-ray beam was 63% of the equilibrium value. In neutron irradiation case the partial dose from protons increases with depth, while dose from C, O and α-particles remains virtually the same. This results in significant LET changes with depth in the transition zone where secondary charged-particle equilibrium does not prevail. Thus, experimental evaluation of absorbed dose under non-equilibrium conditions is not a trivial problem while taking into account insufficient data of EBT2 sensitivity dependence on LET.

PERFUSION CT DOSE ASSESSMENT FOR ACUTE STROKE: COMPARISON OF BISMUTH SHIELD AND ORGAN-BASED TUBE CURRENT MODULATION

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Purpose: The goal of this study was to assess the organ doses and effective doses to patients of two novel multi-slice CT scanners for acute stroke examinations.

Materials and Methods: The radiation doses were measured at Aquilion ONE (Toshiba Medical Systems, Otawara, Japan) and Definition Flash (Siemens Medical Solutions, Forchheim, Germany) CT scanners. The organ doses were measured using GR200A thermoluminscent dosimeters (TLD) chips inserted into RAN100 anthropomorphic phantom for the ischemia stoke CT scan protocol. The protocol included non-enhanced, perfusion, and neck enhanced (or neck CT angiography procedures) scans. The measured organ doses were used to calculate the effective doses according to ICRP tissue weighting factors. The bismuth shield and organ-based tube current modulation (OB-TCM) technique was used to reduce absorbed doses to radiosensitive surface organs.

Results: The absorbed doses to eye lens within scan range during non-enhanced, perfusion , and neck enhanced (or neck CTA) were 46.7, 151.5, 12.4 mGy for Aquilion ONE CT scanner and 38.48, 287.71, 9.91 mGy for Definition Flash CT scanner. The skin dose within scan range within three scans were 36.11, 114.37, 216 mGy for Aquilion ONE CT scanner and 37.28, 218.45, 11.27 mGy for Definition Flash scanner. The effective doses according to ICRP 103 report were 2.02, 5.18, 6.43 mSv for Aquilion ONE scanner and 2.39, 8.64, 4.0 mSv for Definition Flash scanner. The radiation dose reduction using the bismuth shield were 19.7% to 46.9%. The radiation dose reduction using OB-TCM was 32.2%.

Conclusion: The effective doses of ischemia stoke CT protocol include non-enhanced, perfusion, and neck enhanced (or neck CTA) scans were 13.6 mSv for Aquilion ONE CT scanner and 15.0 mSv for Definition Flash CT scanner. The bismuth shield and OB-TCM technique can effectively reduce the absorbed doses to radiosensitive surface organs. We proposed these two methods for radiation dose reduction to superficial organs especially in acute stoke CT examination.

RETROSPECTIVE ACCIDENT DOSIMETRY USING UBIQUITOUS MATERIALS

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The luminescence properties of various materials were investigated in order to establish their potential as emergency dosimeters for determining general public exposure to ionizing radiation following an unexpected nuclear event. The dosimetric properties of an extensive variety of electronic components and chip card modules removed from mobile phones were investigated in detail with regard to OSL (using blue stimulation and UV detection) and TL (5°C/s) signal intensity, signal reproducibility, dose response, sensitivity and homogeneity, fading and minimum detectable dose. Among electronic components investigated, the alumina rich resistors and chip card modules seem particualrly promising for retrospective dosimetry purposes. These components exhibited intense OSL and TL signals, remarkably small change in sensitivity over multiple cycles of irradiation and optical stimulation, a linear dose response in the studied dose range (0.2-8 Gy) and good signal reproducibility. Also, very encouraging values of the minimum detectable dose for immediate measurements were estimated (for resistors - 4 mGy when no thermal pre-treatment was used and 16 mGy following a preheat of 10 s at 120°C and a readout temperature of 100°C; for chip card modules – 7 mGy without preheating). Laboratory fading measurements were performed for the resistors, the results indicating a pronounced signal loss in the first day following irradiation as the signal droped to 70% (without preheating) and 65% (with preheating at 120°C for 10 s and a readout temperature of 100°C) of the initial value. Also, several types of dental materials used for dental prosthetics restoration were studied aiming to determine their usefulness as retrospective dosimeters. Dental ceramics showed bright and reproducible TL and OSL signals along with a linear dose-response relationship and a relative high degree of homogeneity (relative standard deviation of 12%).

ABSORBED DOSE AND EFFECTIVE DOSE IN FOOD IRRADIATION: MEASUREMENT AND VALIDATION WITH DIFFERENT PHANTOMS

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Food products are processed by different technologies in order to increase its safety and shelf-life. Food irradiation is regulated in European Union by the Directive 1999/2/EC, approved by international organizations of food (FAO – Food and Agriculture Organization) and health (WHO – World Health Organization) and the demand for post-harvest processed food products without use of chemicals could be an opportunity to boost irradiation technologies, that are already currently used for food preservation, namely for ripening delay, insects' disinfestation or food decontamination.

Before starting an irradiation process a dosimetric study is always performed to characterize the absorbed dose taking in account food product characteristics, namely bulk and volumetric density, in order to guarantee the desired effect, without compromising the main physico-chemical parameters.

The dose inside the food product can only be assessed indirectly or estimated by computational methods. The effective dose, a concept used more in human radiotherapy, takes in account the type of radiation and tissue. In food irradiation the effective dose could be estimated from the absorbed dose, considering the physical characteristics of the product.

The irradiations of food and food phantoms were performed in a Co-60 experimental chamber, with a total activity of 198 TBq (5.33 kCi) in November 2012 (Precisa 22, Graviner Manufacturing Company Ltd, U.K.). The dose was estimated for each fruit in three different positions in the chamber and the values of absorbed dose were obtained by spectrophotometric methods, using previous calibrated routine Amber Perspex dosimeters (batch V, from Harwell Company, U.K.).

Using an experimental approach, the estimated absorbed dose for different phantoms are presented and corrected with the physical characteristics, dimensions, density and radiation mass attenuation coefficient of the food product to obtain the effective dose, that could be used to better characterize the irradiation process.

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MEASUREMENT OF SPATIAL DISTRIBUTION OF HARD X-RAY DUE TO RUNAWAY ELECTRONS IN DAMAV AND TOKAMAK LIMITER

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In this work the spatial distribution of ambient dose equivalent due to bremsstrahlung of runaway electrons colliding with limiter are measured in the distances of 0.5, 1 and 1.5 m from a tokamak vacuum vessel. For this aim, three flat plates with area of 70cm×70cm, 120cm×70cm and 40cm×40cm had been installed at the distances of 0.5m, 1m and 1.5m from the tokamak vacuum vessel respectively. The ambient dose equivalents have been measured using GR-200 TLDs (in trio packs) at each points which are located as matrixes of 7×7, 5×11 and 3×3 respectively on the plates.

The measured and calculated dose distribution from TLDs on plates shows two peaks with maximum values in a defined solid angle. The maximum dose per shot on the mid-plane of machine at the distance of 0.5m from limiter was measured around 1.56mSv, and that of 0.57mSv at the 1m. As well, the measurements indicate a uniform reduction rate of 2.7% in radiation dose from one plate to another.

It can be concluded that the area 1.5 m around the limiter may cases high occupational exposures to the operators, if it is not considered any limitation in number of its operations in a limited time.

DOSIMETRY IN PROCESS CONTROL IN RADIATION PROCESSING

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Radiation processing means the use of radiation energy for making a product useful and covers many areas like radiation sterilization, food treatment or polymer modification. In all cases, the quality of products depends on absorbed dose during the irradiation process. Dosimetry is essential to the irradiation process since enables quality assurance and documentation that all parts of the product have received an absorbed dose within certain prescribed limits: high enough to accomplish certain desired effect but not so high to cause adverse effects. For this purpose the all measurements of absorbed doses have to be traceable to national or international standards and the uncertainty of measurements is known and with appropriate confidence limits. These are the prerequisites when dosimetry is enabled to establish the specified absorbed dose limits, validation and routine control of the irradiation process. The irradiation sterilization process at the Radiation Plant of the Vinča Institute of Nuclear Sciences will be the practical example how dosimetry can define the irradiation process.

COMPARISON OF ^{210}PB DETERMINATION IN ENVIRONMENTAL SAMPLES BY LIQUID SCINTILLATION COUNTING AND GAS FLOW PROPORTIONAL COUNTING

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^{210}Pb is important from the viewpoints of radiation protection and environmental protection, due to its high toxicity. It is part of the ^{238}U natural series, formed by the decay of the gas ^{222}Rn, with a half-live of 22.3 years and emission of beta particles with 16.5 keV (80.2%) and 63.0 keV (19.8%). In this paper, the two most routinely used analytical techniques for Pb determination in environmental samples, Liquid Scintillation Counting-LSC and Gas Flow Proportional Counting-GFPC, were reviewed, with emphasis on methodological developments in sample preparation, preconcentration, separation, purification, source preparation and measurement techniques. The accuracy, selectivity, applicability and minimum detectable activity (MDA) of the two techniques are discussed.

^{210}Pb determination by LSC measurements was performed using a 1220 Quantulus™ Ultra Low Level Liquid Scintillation Spectrometer. The ^{210}Pb was separated by using a Sr-Spec resin from EICHRON. The chemical yield was determined by gravimetric analysis of lead precipitated as oxalate. The chemical yield achieved varied from 42.1 to 75 %. The MDA achieved was 6 mBq L^{-1} for a counting time of 24,000 s. The relative error and relative standard deviation was performed using reference material IAEA-326 – Radionuclides in soil, and a standard solution from Instituto de Radiometria e Dosimetria. The results obtained varied from 2.1% to 8.4 % and 1.8 % to 13.1 %, respectively.

The ^{210}Pb determination by GFPC measurements was performed using a low background gas flow proportional detector (10-channel Low-Level Planchet Counter LB 770 Berthold), through its decay product ^{210}Bi, after radiochemical separation of a precipitate of $^{210}PbCrO_4$. The chemical yield was determined by gravimetric analysis and the results obtained varied from 80 % to 93 %. The MDA achieved was 4 mBq L^{-1} for a counting time of 7,200 s. The results obtained for the relative error and relative standard deviation varied from 2.7 % to 7.9 % and 2.2 % to 7.6 %, respectively.

It was concluded that the two techniques presented good sensitivity and are suitable for the determination of ^{210}Pb in environmental samples.

SPATIO-TEMPORAL VARIATIONS OF ANTHROPOGENIC RADIONUCLIDES IN THE SEAWATER OF EAST SEA/JAPAN SEA BEFORE FUKUSHIMA ACCIDENT

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The anthropogenic radionuclides, ^{137}Cs, ^{90}Sr, and $^{239+240}$Pu, were determined in the water column at 8 sites of the East Sea/Japan Sea and 1 site of the western North Pacific Ocean during the period 1994-2007 before Fukushima accident, investigated spatio-temporal variations of vertical structure.

The concentrations of ^{137}Cs, and ^{90}Sr in the upper 500m layer have decreased with time from 1994 to 2003. Those of ^{137}Cs, and ^{90}Sr in the bottom layer have a little increased since 1994. The layer-averaged concentrations (LAC) were calculated to investigate the differences in the vertical distribution of radionuclides between the East Sea/ Japan Sea and the western North Pacific Ocean. LAC of ^{137}Cs, and ^{90}Sr in the upper 500 m layer were almost the same level in the East Sea/ Japan Sea and the western North Pacific Ocean. Below the 750m, there are a large difference of value ^{137}Cs, and ^{90}Sr LAC between the East Sea/ Japan Sea and the western North Pacific Ocean. LAC of $^{239+240}$Pu at all layer in the East Sea/Japan Sea were higher than those in the western North Pacific Ocean. The anthropogenic radionuclides in surface water of the East Sea/ Japan Sea may be the result of vertical transport of water mass to deeper layers by the deep convection in wintertime.

Rate of LAC in the ^{137}Cs, and ^{90}Sr each layer were calculated to analyzed variation of vertical structure of those. The pattern in Rate of LAC in the ^{137}Cs, and ^{90}Sr are the same in the layers at the the East Sea/Japan Sea and the western North Pacific, but these of LAC in the ^{137}Cs, and ^{90}Sr differ from the layer at two areas.

The pairs with cross-correlation coefficients of ^{137}Cs, ^{90}Sr, and $^{239+240}$Pu concentrations in the East Sea/Japan Sea are greater than 0.87, 0.64, 0.52, between all pairs among 8 stations. The cross-correlation coefficients of ^{137}Cs in upper 750 m are higher than 0.75, but the concentration variation of those in all anthropogenic radionuclides differ from that of bottom layer.

A GEANT4 BASED METHOD TO ESTIMATE RADON CONCENTRATION INSIDE LEAD CASTLE OF SHIELDED GERMANIUM DETECTORS

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One of the main contributions to the background spectrum of shielded germanium detectors comes from radon dispersed in the air inside lead castle. Knowing air radon concentration in the detector's vicinity can be of some importance for gamma spectroscopy measurements. Here we try to develop a fast and accurate method to estimate radon concentration inside lead castle using Geant4 based Monte Carlo simulation. The simulation has been developed to obtain response of germanium detectors in various applications in gamma spectroscopy measurements. Here, it is used to calculate detector efficiency to gamma radiation coming from the surrounding air. As a result, simulated spectrum is obtained and thus simulated detector efficiency for a given energy is derived. Validation of the simulation is performed using measurements of reference materials of known activity and comparing measured and simulated detector efficiencies. With measured net peak intensities of radon induced spectral lines in the experimental background spectrum and with simulated detector efficiency to gamma radiation from the air, radon concentration is determined.

STUDY OF TL AND OSL PROPERTIES OF ELECTROFUSED ALUMINA PELLETS

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The aluminum oxide composes the modern TL and OSL radiation dosimeters. TL and OSL phenomena are related to chemical elements present in the crystalline structure of α-Al_2O_3. The aim of this work was to study the TL and OSL dosimetric properties of white electrofused alumina commercially available as abrasive particles. Sintered pellets were obtained using soda-lime glass, a relatively inexpensive, chemically stable, reasonably hard, and extremely workable material, because it is capable of being re-softened and re-melted numerous times. The electrofused alumina-glass (EAG) pellets showed significant TL and OSL signals. The electrofused alumina and soda-lime glass powders and EAG samples were analyzed by X-rays diffraction and a micrograph of fracture of the EAG pellets was performed. Preliminary results on TL glow curves, OSL decay curves and dosimetric properties such as repeatability, dose response curves and useful dose range were also evaluated.

SPECTRAL REFLECTANCE MEASUREMENTS FOR DETECTION AND MONITORING OF PLANT DISEASES

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Remote sensing techniques are increasingly valued as useful tool for investigation of theinfluence of environmental changes on the plants and 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 many cases, remote sensing data can partially replace the often time consuming and expensive ground surveys. Green plants all have unique spectral features, mainly because of the chlorophyll and carotenoid and other pigments and water content can together constitute the spectral feature of a plant.

In this study a remote sensing technique, hyperspectral reflectance, was used for investigation of the responses of some plant spices (plum and apple trees, potato and tobacco plants) to natural stress factors such as some viral infections. Hyperspectral leaf reflectance data was collected by means of a portable fibre-optics spectrometer in the visible and near infrared spectral ranges (450-850 nm). Spectral analyses were performed in four regions: green (520-580 nm), red (640-680 nm), red edge (690-720 nm) and NIR (720-780 nm) where the differences between reflectance spectra were most significant. The statistical analyses by means of the Student's t-criterion, first derivatives and some vegetation indices were calculated to analyze the spectral behaviour of diseased plant spices. Comparative analysis was also applied with results from serological test DAS-ELISA on the same plants.

Key words: Remote sensing, leaf spectral reflectance, environment stresses, viral infection

STUDY OF THE EFFECTS OF TEMPORAL VARIABLES ON THE RESPONSE OF FRICKE-XYLENOL ORANGE GEL DOSIMETERS

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Over recent years, modern protocols of radiotherapy and brachytherapy have been developed involving very steep dose gradients able to destroy tumor tissues and save the surrounding healthy tissues. Therefore sensitive and stable three-dimensional dosimetric techniques are fundamental in order to develop new treatment protocols and to reduce dose inaccuracies.

The Fricke–Xylenol Orange gel dosimeter is a system highly reproducible, easy to prepare and low cost, that has been well used in combination with Magnetic Resonance Imaging (MRI) and optical techniques, such as CT scan, to make possible three-dimensional radiation dosimetry.

Homogeneity of dosimeter sensitivity and stability of the matrix are fundamental characteristics in order to perform optical or NMR analysis immediately after chemical stability is reached and before degradation of the spatial dose information due to Fe(III) ion diffusion.

With the aim of developing a 3D Fricke–Xylenol Orange gel phantom dosimeter suitable to perform optical CT scan, in this work a systematic analysis was carried out via spectrophotometric technique. Gelatin from porcine skin and agarose were investigated as gel matrices, in order to study the influence of temperature gradients and temporal variables of interest upon sensitivity, stability after irradiation, and homogeneity of the samples.

Samples were irradiated in PMMA cuvettes in the range of 3÷24 Gy. The sample responses were investigated at different time intervals between preparation and storage (up to 8 hours), preparation and irradiation (up to 7 days), irradiation and analysis (up to 6 hours).

Different cooling modalities were adopted between preparation and irradiation, and between irradiation and analysis. In particular, some samples were placed in a refrigerator when they were still in the liquid phase, others when they were already in the gelling phase, after a period of storage at room temperature.

The studied dosimeters showed good linear responses in the investigated dose range and an improvement of sensitivity was observed with the increase of the time interval between preparation and irradiation. Homogeneity of the dosimetric response was improved by storage time at room temperature before cooling.

The results obtained in this preliminary phase of the work are promising for future development of a 3D dosimetric phantom to be analyzed by means of the optical CT scan technique.

A PRACTICAL EXPERIMENTAL APPROACH FOR THE DETERMINATION OF GAMMA-EMITTING RADIONUCLIDES IN ENVIRONMENTAL SAMPLES

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High-resolution gamma-ray spectrometry can be a useful tool for fast and non-destructive analysis of natural and artificial radionuclides in environmental samples. Yet, accurate knowledge of detector efficiency is necessary for high quality results in the determination of gamma-emitting radionuclides. The experimental efficiency calibration of a coaxial n-type high-purity germanium detector (HPGe) was realized using the ^{238}U and ^{232}Th natural radionuclide chains in secular equilibrium, and additionally KCl crystals, covering the energy range of 25.57 – 1460.8 keV. The calibration procedure is presented with the aim to be further applied within the faculty laboratory for routine measurements of all gamma emitting radionuclides in different environmental samples. Besides calibration, the procedure presented here also concerns aspects related with background interference, self-absorption, coincidence-summing, spectral interferences and validation with respect to the IAEA reference materials. The performance evaluation in the recently concluded worldwide IAEA proficiency test confirms the reliability and traceability of the analytical measurement results provided by this experimental approach.

QUENCH EFFECTS IN TRITIUM MEASUREMENTS BY LIQUID SCINTILLATION COUNTING

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The liquid scintillation detection process in tritium radioactivity measurements involves conversion of kinetic energy of beta particles into photons of light. The main problem in LSC measurements of environmental samples is constant presence of varying quench effects. Quenching in the sample leads to reduction of efficiency of the energy transfer or absorption of photons. Two main types of quench (color and chemical) and their measurements are explained. Method of quench measurements accurately via high-resolution spectral analysis by determing SQP(E) is presented.

Behaviour of several quench agents (nitromethane, nitric acid, acetone, dimethyl-sulfoxide) was investigated as they were added in different amounts to tritiated water in order to obtain standard sets for quench calibration curves. Their usage is demonstrated. Scintillation cocktails OptiPhase HiSafe 2 and OptiPhase HiSafe 3 were used in this study in order to compare their quench resistance.

COMPARISON OF TWO METHODS FOR HPGE DETECTOR EFFICIENCY CALIBRATION FOR CHARCOAL CANISTER RADON MEASUREMENT

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The charcoal canister method of radon concentration estimation according to US EPA protocol 520/5-87-005, is the most widely used method of screening. This method is based on radon adsorption on coal and measurement of gamma radiation of radon daughters. For the purpose of gamma spectrometry, appropriate efficiency calibration of the measuring system must be performed. The most usual method of calibration is using standard canister, a sealed canister with the same matrix and geometry as the canisters used for measurements, but with the known activity of radon. In absence of standard canister, a different method of efficiency calibration has to be implemented.

This paper presents the results of efficiency calibration using EFTRAN efficiency transfer software. Efficiency was calculated using soil matrix cylindrical secondary reference material as a starting point. Calculated efficiency is then compared to the one obtained using standard canister and applied to a realistic measurement in order to evaluate the results of the efficiency transfer.

VERIFICATION OF RADIOTHERAPY DOSES IN PATIENTS' TEETH BY EPR DOSIMETRY

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EPR dosimetry in tooth enamel was used to measure doses delivered in teeth in radiotherapy procedures in 11 patients treated in Medical University in Gdansk. Enamel samples from 22 molars and premolars were obtained from patients undergoing teeth extractions due to medical indications. The samples had masses from 20 to 130 mg, depending on available amount of enamel in the teeth without signs of caries. After measuring of EPR signals in the samples, every enamel sample was irradiated ex vivo with additional dose of 25 Gy and measured again for the purpose of individual calibration of radiation sensitivity of the EPR dosimetric signal. The obtained results were compared with doses calculated by treatment planning system (TPS), in which the teeth regions with radiodensity above 1700 HU were defined as enamel. The doses planned by TPS at the positions of the measured teeth were within 15-67 Gy range. The results of EPR dosimetry showed high correlation ($R^2 = 0.99$) with the planned doses, which was reflected by linear relation between the planned d_p and measured d_m doses given by the equation: $d_m = 1.02 \times d_p + 0.21$. It is concluded, that EPR dosimetry can be successfully applied for verification of radiotherapy doses in patients irradiated with radiation fields covering teeth areas.

PRELIMINARY DETERMINATION OF DIFFICULT TO MEASURE RADIONUCLIDES IN NUCLEAR WASTE FROM IGNALINA NUCLEAR POWER PLANT DECOMMISSIONING

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The existing analytical methods for the determination of H-3, C-14, Cl-36 and I-129 in nuclear waste such as graphite, ion exchange resin, serpentinite, sand, and concrete were tested. Several methods were investigated for samples decomposing. For separation the H-3, C-14, Cl-36, and I-129 from the matrix elements the acid stripping techniques (different acids and their mixtures) or catalytic combustion using sample oxidiser were applied. Involved CO_2 was trapped in the mixture of CO_2 absorbing solution and scintillation cocktail or in NaOH solution. Simultaneously H-3, Cl-36 and I-129 were trapped in wash water, weakly acid or alkaline solutions as water, CO_2, Cl_2 and I_2. Interfering radionuclides were removed by means of ion-exchange chromatography. The Bio-Rad AG1 x 4 anion-exchange column (100 -200 mesh) and TRISKEM Cl resins columns were applied. The chemical yield was determined by ion chromatography and inductively coupled plasma mass spectrometry for Cl-36. The radiochemical recovery and procedures applied have been validated by standard addition of H-3 (water), C-14 (Na_2CO_3), Cl-36 (NaCl) and I-129 (NaI). The measured values agreed with the added ones within an uncertainty of 5-15%. Based on the investigated methods the data on preliminary specific activity of radionuclides in nuclear waste are reported.

IND04 METROMETAL PROJECT – SELECTED RESULTS

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EURAMET, i.e. organization of European metrological institutions, is an announcer of metrology research programs EMRP. In the framework of the EMRP project IND04 MetroMetal "Ionizing radiation metrology for the metallurgical industry", researched by a collaboration of 14 metrological institutions from countries of the European Union, the company ENVINET a.s. (member of the NUVIA Group) entered the collaboration in late 2012. By this way ENVINET participates on particular working packages of the project.

One of the tasks in the MetroMetal project deals with the preparation and distribution of a questionnaire focusing on the methods and devices used for measurement of radioactivity. The questionnaire was spread among addition stakeholders from the metallurgical industry (different from steel mills which were already asked earlier). Evaluation of the filled questionnaire revealed that some companies (like scrap facilities) do measurements as a competitor benefit and the other companies don't know what the radioactivity is.

Our next activities in the IND04 project was focused on the development and the manufacture of composite steel reference standards made of thin steel plates with the radioactivity located on its surface (two different source shapes, total activities below the exemption level by European legislative, altogether six samples). For both types of sources, which contain a mixture of ^{241}Am, ^{137}Cs a ^{60}Co radionuclides, a Monte Carlo model was created in the code MCNPX. The full-energy peak detection efficiencies were compared to the measurements resulting in the differences below 4%. These sources are available to the IND04 project partners as well as to laboratories of the metallurgical industry.

In addition, samples of dust from an oxygen converter, steel slug and fume dust from steel production were obtained. These materials were used for the preparation of reference sources in an additional measurement geometry (plastic vessels with the volume of 100 ml, mean diameter of 65 mm and the height of 35 mm). These samples were modeled in the MCNPX code as well.

Detailed information about the EMRP project IND04 MetroMetal is available at the project web site http://projects.ciemat.es/en/web/metrometal.

RESPONSE FLUCTUATION OF RADIOLOGICAL PROTECTION INSTRUMENTS USED IN NUCLEAR MEDICINE DEPARTMENTS

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Nuclear Medicine Departments (NMD) are one of the mostly vulnerable for radioactive contaminations laboratories due to the presents of open, liquid form radioactive sources. The unit activity of sources vary from few GBq up to tens of MGq. Basically in NMD the active instruments might to be divided for two group, first include a instruments for radiological protection purpose second group are instruments used for estimation of the activity of the administrated sources. This paper is focused for the first group of instruments employed for workers safety ensuring. The adequate radiological instrument is a priority. Basing on International Atomic Energy Agency (IAEA) safety Standard for NMD a controlled and supervised areas established in NMD should be periodically monitored using survey meters and contamination monitors. The instruments employed in NMD should fulfill two main requirements: they should be able to measure the specific kind of radiation present in particular Department and must be calibrated periodically for confirmation of their properly work. According to the Polish Atomic Law the radiological instruments can be calibrated only by the Laboratories holding the quality system approved by Polish Centre for Accreditation. The quality system must include the validated calibration procedures that give the certainty of properly calibration process. The calibration for particular instrument dedicated to dose rate measurement must be performed at least one per year. Exception are instruments with own certificated check source which should be calibrated not less than one per two years. Polish law was not specify the frequency of calibration for contamination monitors but basing on the experiences with the reliability of that kind of instruments it is recommended for calibration with at least one year frequency. The Laboratory for Radiological and Radon Instruments Calibration (LWPDiR) of Central Laboratory for Radiological Protection (CLOR) in Warsaw hold the accreditation certificate number AP057 since 2002. In framework of Laboratory four validated procedures are used. Two of them concern a calibration of dose rate meters using isotopic gamma sources and RTG, third relate to contamination monitors calibrations using alpha and beta radiation emitters. Fourth procedure is dedicated to radon instruments calibrations. For each calibration process the adequate Calibration Certificate is provided. The Certificate includes the basic information about instrument, results with uncertainty, tables, plots and the instruction for results application. Paper presents the procedures established in accredited Laboratory for calibration of dose rate and contamination meters used in NMD. Review of the dosimetric devices used in Polish NMD was performed. Basing on the results of calibration the changes of the properties for commonly used in NMD instruments, visualized by calibration factor fluctuation in time was presented.

APPLICATION OF ARGON FILLED IONIZATION CHAMBER FOR GAMMA/X RADIATION MEASUREMENTS AROUND *PLASMA-FOCUS* EXPERIMENTAL SYSTEM

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The synthesis of light elements is considered as a promising source of energy for the future. The first nuclear reactor based only on hydrogen isotopes fusion called International Thermonuclear Experimental Reactor (ITER) is under construction. It will be rapidly followed by the prototype of first nuclear power plant named DEMO. So the understanding of the nuclear synthesis phenomena as well as a hazard closely related to the radiative aspects of the above project is a challenge of currently conducted researches. In Poland extensive researches on thermonuclear synthesis are performed in the Institute of Plasma Physics and Laser Microfusion Association EURATOM. Here the Dense Plasma Focus (DPF) the biggest one device that has ever been constructed is operated. The temperature of plasma formed by the above machine is so high that allows to occur thermonuclear reaction within. There are a few type of immediate radiation that companion plasma formation by the DPF machine. Also there are delay gamma radiation that is a subsequent effect of activation due to strong neutron fluxes emission. The list of immediate radiation consist of neutrons, ions, electrons end electromagnetic radiation of different origin and energies. The hard electromagnetic radiation and neutrons escape from the plasma formation area and they are easily monitored outside the vacuum vessel walls or even far away from them. The origin of hard electromagnetic radiation is associated with a few phenomena. The 24MeV gammas are the results of subsequent channel of D-D reaction. The prompt hard gammas with energies above a few MeV are the results of the neutrons interactions with nucleuses that are present in plasma. In addition high energy electrons releases from the plasma focus are accelerated by the forces of magnetic field. That electrons bombard the surface of anode and caused the intensive bremsstrahlung radiation. All of that electromagnetic radiation are observed on the time of fly spectrometer as the peak that leading neutron radiation. The adequate assessment of occupational exposure coming from electromagnetic radiation is the subject of considerations. The presented work describe a theoretical consideration enriched with Monte Carlo simulations for possibility to use the argon filled high sensitivity ionization chamber for dose estimation in the mentioned mixed radiation field. The simulations were compared with the measurements results. The measurements were realized in three reference points using Reuter-Stokes RSS131 ionization chamber. As a measuring points were selected places where the staff may be present during experiments: (1) control room, (2) measuring room and (3) technical hall.

APPLICATION OF OPTICALLY STIMULATED LUMINESCENCE (OSL) DOSIMETERS IN PERSONAL DOSIMETRY

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This paper presents personal dosimetry system based on optically stimulated luminescence(OSL) dosimeters in the Department of personal dosimetry in PC “Nuclear Facilities of Serbia”. Two types of dosimeters (Inlight and nanoDot), microStar reader, basic characteristics and the practical features of the measuring system were presented.

DETERMINATION OF ^{14}C EFFICIENCY BY LIQUID SCINTILLATION COUNTER USING TWO METHODS: TRIPLE TO DOUBLE COINCIDENCE RATIO AND QUENCH PARAMETER EXTERNAL

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The liquid scintillation counting is a technique in which the sample is mixed to a chemical organic liquid, forming a scintillation solution, capable to convert the kinetic energy of nuclear emissions into light energy photons. Quench is a reduction in efficiency as a result of energy loss in the liquid scintillation solution. Due to quench, the energy spectrum detected from the radionuclide appears to shift toward a lower energy. The three major types of quench encountered are photon, chemical, and optical. The efficiency counting is determined by the relative quenching of the sample, using an external source. The aim of this study is to determine the efficiency for ^{14}C using two methodologies: Quench Parameter External (QPE) and Triple to Double Coincidence Ratio (TDCR)**.** The equipment used was the HIDEX model 300-SL Liquid Scintillation Counter, composed of three photomultipliers coupled with coincidence pulses and MikroWin 2000 software. QPE uses a ^{152}Eu external standard generating the parameter of indication of quench; the TDCR content is a primary measurement method based on calculation of the efficiency from the measured ratio of double and triple coincidence counting rates. For the determination of the quench curve and efficiency for the two methods, 15 quench cocktail standards with different quenching agents were used. The indication of quenching of cocktail standard varied from 410 to 813. The efficiency varied from 0.493 to 0.964 cps dps^{-1} for QPE and from 0.408 to 0.968 cps dps^{-1} for TDCR. Different efficiencies, above 10%, were obtained using the two methods in the range of 410 to 513 quenching, above this range the efficiencies were similar. The verification of the efficiencies was performed by measuring reference materials.

A HIGH RESOLUTION MAP OF GAMMA DOSE RATES IN CLUJ COUNTY, ROMANIA USING LIF:MG,CU,P DETECTORS

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Outdoor gamma radiation measurements in Cluj County, Romania have been performed using solid state thermoluminescence detectors in order to develop a high resolution database for natural gamma dose rates. Integrated measurements have been carrried out for an exposure time of minimum 3 weeks. As EU requires, the teritory has been divided in grids (70) of 10X10 km. In this study, 70 cells were monitored using 3 to 5 LiF:Mg,Cu,P (MCP-7) detectors. The calibration was performed using a ^{60}Co gamma source. The dose response was linear, with a determination coefficient of R^2=0.99. All obtained results (more than 250) were found to be consistent with the values stated by the 2008 UNSCEAR Report. For Somesu-Rece, Maguri-Racatau and Belis locations the results were 138±8 nGy/h, 150±8 nGy/h and 158±8 nGy/h respectively, higher than the average of the other values. These results can be explained by the existent geological substrate in this areas, a granitic one, with rocks rich in ^{235}U and ^{40}K. The values found ranged from 56±4 to 158±8 nGy/h, with an average value of 93±3 nGy/h, being in agreement with the 2008 UNSCEAR Report. A high resolution map of gamma dose rates in Cluj County, Romania is presented for the first time.

A CONTRIBUTION OF THE COMPTON SCATTERED RADIATION TO DOUBLE GAMMA COINCIDENCES SPECTRA AT THE 32-DETECTOR SYSTEM

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The Compton scattered radiation (gamma rays with energies 166 keV, 392 keV, 835 keV and 1115 keV, which follow decays of ^{139}Ce, ^{113}Sn, ^{54}Mn and ^{65}Zn, respectively) at the 32-detector *Crystal Ball* spectrometer ARGUS has been considered, as well as its registration in the spectrometer mode of double coincidences. Minimum counting rate of these double coincidences was obtained for the detector pairs at the angle of 63.43°, regardless photon energy, while maximum one varied in dependence on it (138.19° for the 166 and 392 keV, 41.81° for the 835 keV, and ~180° for the 1115 keV photons). On introducing 32 lead collimators, photoefficiency and total registration efficiency of individual detectors and whole spectrometer were reduced, but also background double coincidences caused by the Compton scattered photons. The geometry defined by the angle 41.81°, showed minimum counting rate (averaged over all such detector-duplet combinations) – for the photons with energy of 392 keV and 1115 keV, whilst those defined by the angles 79.19° and 37.38° – for the 166 keV and 835 keV photons, respectively. The Compton scattering effect is suppressed by a minimum factor of 25; and averaged over all pairs of detectors, the probability to detect the Compton scattered photons decreased around 130 times. A suppression was found to be minimal for the double coincidences registered by the detectors at the angle 116.57° (392 and 835 keV), but also 63.43° (166 keV) and ~180° (1115 keV). Except for the 166 keV photons, maximum suppression has been obtained for the geometry defined by the angle of 41.81°.

EPITHERMAL NEUTRON CALIBRATION FIELD

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Obtaining a field of neutrons of a specific energy is a difficult task. In contrast to the charged particles, neutrons are not deflected in a magnetic field, what would make possible the separation of those which are characterized by the desired parameters. In the case of neutrons from the decay of radioactive sources the only way to obtain neutrons with energies from a specific range is the use of filters from materials with specific cross-sections for reactions induced by neutrons.

The narrower range of energy we want to obtain, the thicker and more complicated filter is needed. Unfortunately, the use of a thicker filter is associated with a decrease in neutron flux as well as an increase in the size and weight of the filter itself.

Radiation Measurements Laboratory of the National Centre for Nuclear Research (LPD) is equipped, among others, with the source of the isotope Cf-252. In order to obtain the field of epithermal neutron, a filter is required for moderating the neutrons emitted by the source to the epithermal energy range and absorbing neutrons with thermal energies.

A number of moderating material were examined using numerical modeling methods. In the result of the study it was concluded that the optimal material for construction of a single-layer filter is lithium fluoride (LiF). This filter allows to obtain spectra from the epithermal range, comprised between 0.5 eV and 10 keV, additionally allows for obtaining a triple energy maximum about 0.08 MeV, 0.2 MeV and 2 MeV. Although all of these maxima are located above the epithermal area, lithium fluoride filter allows for obtaining a large number of neutrons from the upper region of epithermal energy range with a substantial reduction of low epithermal neutron energies. Neutron energy spectrum obtained using this filter is significantly different than that obtained by conventional moderators.

After the filter was designed and manufactured, further calculations were carried out using the model made on the basis of developed technical documentation. Then, using recombination methods and detectors as well as Alnor Studsvik 2202D neutron monitor, the set of parameters characterizing the obtained radiation field at the reference point and their distribution on the calibration bench at LPD.

The resulting calibration radiation field is useful to carry out scientific research on the development of therapeutic methods of neutron beams including the beams for BNCT.

RELATION BETWEEN DAILY GAMMA-RAY BACKGROUND AND RADON VARIABILITY IN THE UNDERGROUND LOW-LEVEL LABORATORY IN BELGRADE, SERBIA

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The most important background source in low-level gamma-ray spectrometry is radon which additionally causes background variability. Intensive daily radon variation at the same time with daily variation of gamma-ray background was already measured in our ground level laboratory. The new simultaneously measurements of radon concentration and gamma-ray background performed in the underground laboratory and correlation between them in a wide range of radon concentration was analyzed.

CHERENKOV COUNTING FOR BETA RADIOACTIVITY DETERMINATION WITH A LIQUID SCINTILLATION ANALYZER

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Cherenkov counting technique has become well established for the rapid assay of many beta and beta-gamma emitting radionuclides. Among the advantages of the technique are (i) extreme simplicity of sample preparation, (ii) the ability to count in aqueous systems without use of any organic fluors or reagents that could destroy the sample leaving the sample suitable for further tests and (iii) no interference is caused by other radionuclides in the sample with decay emissions that cannot produce the Cherenkov effect, such as ^{3}H, ^{14}C, ^{35}S, etc. Another important consideration is that conventional liquid scintillation counting equipment can be used without modification. We studied the reliability of activity determination by Cherenkov counting using a TriCarb 2100TR Liquid Scintillation Analyzer from Packard, Meriden, CT. The results obtained for a series of ^{90}Sr-^{90}Y samples with different known disintegration rates and various color quench levels both in glass and plastic vials are presented in this paper. The influence of sample volume, vial type, color quench level and sample turbidity on the counting efficiency was studied, also. All results showed that better performances are obtained with plastic counting vials, these being preferred over glass vials for Cherenkov counting.

MULTISIGNAL IONIZATION CHAMBER AS AN DIRECTIONAL NEUTRON SPECTROMETER

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Precise measurements of neutron doses and dose equivalents in mixed neutron-gamma fields require combining both dosimetric and spectrometric methods. Neutron spectra can be determined with Bonner Sphere Neutron Detector which is a small detector placed at the center of moderating spheres with size ranging from 2 to 12 inches. This method is time-consuming, complex planning including several accesses to the measured position because of performing several measurements with different sizes of moderator and finally manual calculating the result.

In National Centre for Nuclear Research (in Laboratory of Mixed Radiation Measurements) a multisignal ionization chamber as a directional neutron spectrometer was developed. An innovation, comparing to many recombination and ionization chambers earlier designed in the Laboratory, is the use of polarizing electrodes as moderating discs and simultaneous measurements of signals coming from all separate signal electrodes. In principle, this should make it possible to estimate the neutron spectrum in only one measurement. Instead of changing the moderator thickness as for Bonner Spheres method there is continuous thermalization of neutrons and online response reading from every signal electrode. Construction of the chamber is based on REM-2 chamber which is successfully used for long time (with respect of needs for innovation).

The project of multisignal ionization chamber as an directional neutron spectrometer will be presented together with principle of operation and Monte Carlo calculation for optimization. Additionally preliminary results of calibration in reference neutron fields (^{252}Cf and ^{239}Pu-Be) and measurements at the horizontal channels of reactor MARIA in National Centre for Nuclear Research (neutron beam) will be shown.

The design of the chamber was first modelled using the Monte Carlo code (FLUKA) to achieve proper thicknesses of the moderator. The deepest polarizing electrode corresponds to 12 inches Bonner sphere. Therefore one measurement is able to cover whole range of the neutron spectrum (from 10^{-7}MeV to 10^{2}MeV). To extend range of the neutron spectra (in case of expecting high energy neutrons) its proposed to shield designed chamber with an extra lead disk. Chamber housing is made of aluminum (1 mm) with overall dimensions: 326 mm (length) and 150 mm (diameter). The interior of the chamber consist of 7 polypropylene electrodes (cylinders of varying thickness: 2x10 mm, 2x20 mm, 2x30 mm and 40 mm – together 160 mm what corresponds to 12” Bonner sphere) mounted on a special insulating joints enabling separate signal connections to the multichannel electrometer. Measuring electrodes (and first voltage electrode) is made of thin aluminum plates of about 1 mm (to allow the first measuring signal to represent almost not moderated neutrons). The chamber is surrounded by 50 mm thick boron enriched polyethylene to cut off scattered neutrons (with window from the top of the chamber).

ALFA AND GAMMA SPECTROMETRY APPLICATION IN DATING LAKES SEDIMENTS FROM DANUBE DELTA, ROMANIA: PRELIMINARY RESULTS

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Lakes accumulate organic and mineral sediments continuously since their formation. Therefore, lake sediment sequences archive valuable environmental and climatic information over periods of time spanning decades to thousands of years. To establish a reliable chronology of the sediments, accurate dating methods and age-depth models are required. This work presents preliminary results of the application of high resolution radiometric dating on lacustrine sediments from the Danube Delta (Romania), in order to (i) generate a comprehensive understanding of the sedimentation pattern and (ii) evaluate the anthropogenic impact (e.g., dam constructions) on sediment accumulation. Sediment cores were collected from Iacob Lake to about 1 m depth using gravity corers. The sediment cores were further subsampled at 1 to 3 cm and the material was used for alpha and gamma spectrometry investigations. For the alpha spectrometric analysis of 210Po, samples have been dissolved and spontaneously deposited onto stainless steel discs. The 226Ra activities were measured using a HPGe gamma-ray detector with beryllium window.

CORRELATION OF DOSIMETRIC AND MAGNETIC NEAR FIELD FREE SPACE MEASUREMENTS

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Over the last twenty years a lot of portable radiofrequency electromagnetic field (RF EMF) sources have been introduced, which operate in the vicinity of the human body. Usually, in this case the user is located in the near field of the RF sources where electromagnetic field measurements may be not correct for safety (hygienic) assessment. There are two methods to establish compliance with the permissible exposure levels (safety conditions): measure the EMF in free space in far field and calculate the near field (Russian approach) or evaluate the specific absorption rate (SAR) in the phantom (International approach). Both method s have merits and drawbacks. We suggest a methodology to harmonized the two concepts. The idea of this approach is to measure the magnetic field in free space and compare it with peak SAR measurements at the same physical locations.

We investigate the magnetic field strength distribution in free space and SAR distribution in tissue simulating liquids in flat phantoms from typical dipoles. We used this approach because the fields that deposit RF energy in biological tissues have low characteristic impedance. This implies that the H near field should be evaluated for purposes of predicting SAR distributions. Using the automatic dosimetric system DASY52NEO (SPEAG AG, Switzerland) we produced accurate measurements for various conditions. The input power to the dipole was 250 mW, controlled by a power meter and a bidirectional coupler. We run the experiments at the frequencies of 900, 1800 and 2450 MHz which are mostly used for personal communications.

Preliminary research results mapping the SAR in a flat phantom and the corresponding near magnetic field measurements have shown good support for the suggested approach. The data presented the same spacial distribution for the H-field free space measurements and for SAR measurements in the phantoms at the same places. It is possible to evaluate a ratio between the peak SAR and the measured H-field that can be used at each frequency band.

These two measurement approaches to EMF assessment show that complex evaluation (dosimetry and free space measurements) is appropriate for such RF near field exposures. But for the detailed hygienic assessment it is necessary to find the correlation coefficient between basic restrictions and the reference levels. The suggested approach can be used to develop new harmonized RF exposure safety assessments.

ON THE POSSIBILITY OF THE USE OF THE LONG-TERM PHOSPHORESCENCE OF THE $Li_2B_4O_7$:CU AND $Li_2B_4O_7$:MN CRYSTALS FOR THE HIGH-CURRENT ELECTRON BEAM DOSIMETRY

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The comparative dosimetric characteristics of the $Li_2B_4O_7$:Cu and $Li_2B_4O_7$:Mn crystals grown using the Czochralski technique at the IEP NAS of Ukraine after the 9.8 mC/kg power Co^{60} gamma-quanta and accelerated (at the M-30 microtron) electron irradiation have been studied within the 7–14 MeV energy range at the fluences up to 10^{14} e/cm^2. The long-term phosphorescence at room temperature resulted from the $Li_2B_4O_7$:Cu and $Li_2B_4O_7$:Mn crystal irradiation by the high-current accelerated electron beams and the thermostimulated luminescence curves after the Co^{60} gamma-quanta and accelerated electron irradiation have been studied. It has been found that while the thermostimulated luminescence curve yield depends mainly on the irradiation dose and almost does not depend on the energy and intensity within the interval under study, the phosphorescence yield is sensitive to the fluence intensity. The mechanism that explains the cause of appearance of the long-term phosphorescence has been suggested. The boundaries of the linear dependence of the phosphorescence and thermoluminescence light sum yield on the irradiation dose have been determined. Combined measurements of the phosphorescence yield and thermostimulated luminescence curves allow one to determine, besides the irradiation dose, the fluence intensity of the high-current electron and gamma beams.

FIBER OPTICAL-BASED SYSTEM FOR IN-SITU MONITORING OF RADIOACTIVE WASTE CONDITIONING BY CEMENTATION

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Optical fiber sensors are for a long time used to monitor strain, displacement or vibration induced in civil engineering structures such as dams, tunnels, bridges, or buildings [1-3]. The most spread types of sensors for such tasks are fibre-Bragg-grating (FBGs), now a mature technology having the advantage of distributed spatial sensing through wavelength multiplexing. They can be either surface mounted or embedded into the structure (e.g. concrete, composite materials). FBGs sensors can be assembled into quasi-distributed sensing systems. Real distributed systems are based on scattering phenomena in optical fibers such as Rayleigh or Brillouin.

The present paper focused on a new application of discrete and distributed optical fiber sensors applied in monitoring of radioactive waste conditioning (solidification – stabilization) by cementation. This process is of interest for ordinary and modified Portland cement as some reactive metals as aluminum and magnesium are not compatible with the pore solution alkalinity. The pH developed in Portland cement matrix exceeds the value 13.0 which is outside of aluminum passivation domain. The chemical reaction implies formation of aluminum oxo-hydroxides and gaseous hydrogen, the effect being an internal stress as a result of waste volume change and cracks of the conditioning matrix. Monitoring of temperature evolution and internal stress are of great importance to understand the chemistry of the binder and to establish the optimal process parameters mainly for big volumes. Besides that, the localization of micro cracks offers additional information on the ongoing process. Temperature and internal stress evolution for a modified Portland cement matrix based to CEM-III A and CEM-V A as reference matrices and potassium magnesium phosphate cement as an alternative conditioning system is reported.

For temperature monitoring a set up including two thermocouples and one optical fiber temperature sensor was used. The data from the two thermocouples are collected automatically with a NI 9211, 4 channel, 24 bit, thermocouple differential analog input module, while the signal from the optical fiber sensor (FBGS temperature compensating probe is recorded by a Micron Optics sm125 interrogator). One of the thermocouples was employed to monitor the ambient temperature, and the other one works in parallel with the optical fiber temperature probe for comparison. These are embedded into the concrete tested block.

We suggest two set ups to monitor strain inside the concrete blocks: the first one is based on FBGs with temperature compensation, while the second uses a Draw Tower Grating. These sensors operate in connection with the Micron Optics interrogator or with Luna Innovation 4600 Optical Backscatter Reflectometer.

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APPLICATION OF TL DOSIMETERS IN MIXED FIELD BETA/PHOTON RADIATION

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Central Laboratory for Radiation Protection (CLOR) is owner of BSS 2 -Beta Secondary Standard Type 2, which has been produced by GSA Global GmbH. The source set consist of three β^--radioactive sources, i.e.: Pm-147, Kr-85, Sr-90/Y-90 with the mean beta particle energy of 0.06MeV, 0.24MeV, 0.8MeV, respectively. Running the BSS 2 required correct connecting of all elements and installing the latest version of correction factors and parameters provided by Physikalisch-Technische Bundesanstalt (Germany). The system and its methodology is fully in line with the requirements included in the ISO 6980. In accordance with the subject of work, test of personal dosimeters and a dosimetric instrument calibration for the beta radiation were performed. To this purpose thermoluminescent dosimeters LiF:Mg,Cu,P were used. The sources of gamma radiation were Cs-137 and Co-60.

Irradiation took place in accordance with accredited procedures of gamma and beta radiation and in accordance with international standards. In result, calibration curves were obtained, enabling the readout of individual dose equivalent Hp (10) and Hp (0.07) in mixed field beta/photon radiation. Limitation of the methodology and its application are presented and discussed.

RADIOACTIVE AEROSOL CONCENTRATION DETERMINATION BY SURFACE CONTAMINATION MONITOR

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The inhalation of radioactive aerosols is one of the most dangerous possibilities for inner-contamination of the human body. This paper presents the possibility of a direct field determination of the radioactive aerosol concentration. The concentration is estimated knowing the filtration efficiency and the volume of the air sampling, it is taking into account also the efficiency of detection for used radionuclides.

To determine the filter surface contamination we used the Colibry TTC radiometer with Alpha/Beta/Gamma detection probe SABG-15+ (produced by Canberra). The probe allows to distinguish the contribution of alpha, beta or gamma particles using the iron or plastic barrier that is inserted between the detector and source during the measuring.

The correction factor between the pulses measured per second and the volume concentration for the selected radionuclides was determined by the model in programming environment MCNPX. The generated code can be used to determine correction factors in different measurement geometry – different sizes of source or distances between the source and the detector.

As radioactive aerosols there were used especially short-term radon decay products, Tc-99m and La-140. These radionuclides were selected with regard to the different physical properties of the emitted radiation.

Acknowledgements:
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STUDY ON RECOMBINATION INDEX OF RADIATION QUALITY OF X-RAY RADIATION

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Diagnostic exposures to X-rays are always associated with a small risk of radiation induced cancer. Usually it is assumed that the risk depends on absorbed dose and on age of the patient. Quality of radiation is not taken into account, following the recommendations of International Commission on Radiation Protection (ICRP), which assign the radiation weighting factor equal to one to all X-rays and gamma radiation, with no dependence on the radiation energy.

However, there are several radiobiological experiments indicating that X-rays have higher biological effectiveness than gamma radiation of Cs-137 (commonly used as a reference radiation). The RBE values exceeding 1 for a given radiation are supposed to be associated with higher local ion density in tissue caused by this radiation, than those caused by reference radiation.

The main purpose of this work was to determine the recombination index of radiation quality (RIQ) of low energy X-ray beams. Values of RIQ reflect mean local ionization density of investigated radiation and can be correlated with its relative biological effectiveness. In this work RIQ was determined using a tissue-equivalent, in-phantom chamber of the F-1 type.

In the research an X-ray machine for medical applications was used. Measurements were performed for X-ray tube voltage ranging from 50 to 115 kVp in fluoroscopy (continuous beam) and in the range of 40 to 120 kVp in radiography mode. The results of measurements were related to the reference field which was the calibration field of Cs-137 gamma radiation source.

AN ASSESSMENT OF FLUORESCENT TRACER DYES USED FOR GROUNDWATER TRACING

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Dye tracers play an important role in hydrology and hydrological research. Tracer techniques are useful tool in understanding the water transport processes and quantifying their parameters. Fluorescent tracers are the most important of the artificial tracers because of their relatively easy handling, the seemingly simple analysis, the high sensitivity of the analysis, the low detection limit and, consequently, the small quantity of tracer needed in field experiments.

The wells network has been designed at nuclear objects site in Lithuania. The network was devided into two systems. The first system difines the first semi-confined intertill aquifer with depth of 10-19 m and the second system is installed in the unconfined aquifer with depth of 4.5-9 m. The injection masses of tracer amounted to 50 and 500 mg respectively. The concentration of sodium fluorescein was measured in 1-cm quartz cuvette by using a computer-controlled Aminco Bowman luminescence spectrometer (Thermo Electron Corporation, USA). The results of these experiment indicated hydrogeological parameters.

ALPHA SPECTROMERTRY APPLICATION IN ANALIZING VARIATY OF MATRICES AND ACTIVITY CONCENTRATIONS

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To determine the activity of man-made alpha-emitting radionuclides is important task in the field of radiation protection and radioecology because of long physical and biological half-lives of some of them and their high radiotoxicity. Variety of analytical methods exists in order to separate and detect alpha radioactive isotopes: α-spectrometry, mass spectrometry or ICP-MS, γ- and XRF spectrometry if applicable, etc. In case of alpha spectrometry quantitative separation of the isotopes of the certain element from the matrix elements is required. In the present paper the results from alpha spectrometry measurements of the thin sources prepared after radiochemical separation of environmental and Low-level radioactive waste samples (LL RAW) are discussed in relation to the different factors contributing to the quality and uncertainty of the activity results. Alpha spectrometry of the samples was performed by ORTEC Octete Alpha Spectrometric system equipped with 8 Ortec ULTRA-SA™ low background ion implanted detectors with 300mm^2 active area and energy resolution of 20 keV (FWHM) at the 5.486 MeV (^{241}Am peak). The calibration of the detectors was performed with certified sources, traceable to NIST for 2 geometries. If other geometry is measured most suitable was preparation of the calibration source from standardized solutions of the tracers in use. In radiochemical separation schemes ion-exchange resins, high selective chromatographic materials (TRU, TEVA and UTEVA, Eichrom Technologies) and other purification techniques were combined. In about only in 2 % of the cases the quality of the final source was considered as not useful to quantify the activity concentration.

One of the problems in increase uncertainty arises from not-complete chemical separation and peak overlapping of α-emitters of different element - the case of contaminated Pu and U eluates in complex procedure of radiochemical separation of LL RAW. The uncertainty increases is when tail of the higher energy peak is continue under the lower energy one (case of close tracer and analyte peaks for example of ^{243}Am and ^{241}Am). Tail correction is required also if 208Po tracer is used to determine 210Po activity. The other significant source of uncertainty is related to the chemical yield determination based on the tracer activity. In Series of samples the yield determination overall uncertainty is estimated as 20.5% for 241Am, 25.8% for ^{234,235,238}U isotopes and 31.5% for $^{238,\ 239/240\ 242}$Pu isotopes. In general the highest increase of uncertainty in some of the analysed RAW material is due to the unbalanced tracer activity added, due to unknown activity of specific radionuclides in the sample initially. It could contribute up to 50 percent in combined standard uncertainty.

In environmental samples the main source of uncertainty is coming from counting statistics of the low activity concentration.

COMPARISON OF TWO DIFFERENT METHODS FOR GROSS ALPHA AND GROSS BETA ACTIVITY DETERMINATION IN WATER SAMPLES

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Measurement of the gross alpha and beta activity concentrations in various matrices is suitable as a preliminary screening procedure to determine whether further analysis related to specific radionuclide is necessary. In Serbia, according to current regulations, radioactivity concentrations in drinking water for gross alpha and gross beta should be 0.5 and 1.0 Bq l^{-1}, respectively. The generally accepted methods for gross alpha and beta activity analysis of drinking water in different countries are: EPA 900.0 and ISO methods (ISO 9696, water quality - measurement of gross alpha activity in non-saline water - thick source method, and ISO 9697, water quality - measurement of gross beta activity in non-saline water). This paper describes comparison of preparations and measurement gross alpha and beta activity in bottled mineral waters produced in Serbia using two methods: EPA 900.0 with and without ashing and ISO methods. Concentration of total dissolved solids (TDS) in investigated water samples was also determined. The instrumentation used to count the gross alpha and gross beta activities for both methods was α / β low level proportional counter Thermo Eberline FHT 770 T.

ACTIVITY OF ^{210}Po IN THE BLOOD AND URINE OF THE RESIDENTS OF THE TRICITY AGGLOMERATION

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The natural radionuclide polonium is daughter of ^{238}U decay series. ^{210}Po is radionuclide with half-lives of 138.38 days. Polonium is one of the most radiotoxic natural radioactive isotopes to man due to its high specific activity and its emission of high-LET alpha radiation. Less than 0.05μg of the radionuclide is considered a lethal dose (LD50/30). Man is exposed to radioactive ^{210}Po by natural processes, mainly from the oral intake of foodstuff and drinking water. Especially large amounts of polonium are taken in during cigarette smoking as well as food of marine products. The large amounts of polonium are observed in protein-rich food, such as shellfish and crustaceans, and also observed among populations consuming large amount of reindeer and caribou meat, e. g. in Subarctic area.

The aim of this study was to establish the polonium ^{210}Po concentrations in blood samples and urine. Healthy urine and blood are not toxic. However, there contains compounds eliminated by the body as undesirable. The tested group constituted patients from Medical University of Gdansk and volunteers from Tricity agglomeration. Eating fish and cigarette smoking are factors that according to many researchers affects the amount of this radionuclide in the human body. The questions about smoking and frequency of fish eating were included in questionnaire for the patients and volunteers. This is very important because human biomonitoring of ^{210}Po has been conducted for a long time, but it is still not fully known and understood.

The human blood samples about volume 10 ml were collected from 43 patients ischaemic heart disease (IHD) from Medical University of Gdansk. The reason for choosing this particular group was purely accidental. The urine samples were collected from 37 volunteers from Tricity agglomeration (Gdansk, Sopot, Gdynia). Urine samples were collected throughout the day. The daily amount of urine excreted by volunteers ranged from 600 to 3500 ml. The research was approved by the Independent Bioethics Committee for Scientific Research of the Medical University of Gdansk.

The results of this work indicate that the activity of ^{210}Po in human blood and urine was in the wide range between 140±14 mBq and 888±36 mBq in total blood without two patients (3072±270 mBq and 2901±245 mBq in total blood) and from 1.48±0.09 mBq to 19.41±0.81 mBq in urine samples respectively. The higher activity of this radionuclide was observed for smoker and ex-smoker groups. The patients and volunteers were subdivided in groups: males and females, cigarette smokers, non-smokers and ex-smokers were taken into account. The results indicated that the ^{210}Po activity was widely distributed in the each group of analyzed patients and volunteers. The difference between ^{210}Po activities in human blood and urine of ex-smokers/smokers and eating habits is statistically significant. The obtained results of ^{210}Po activity in the human blood and urine are probably related to the consumption of fish and smoking. Human sex and age had no effect on excretion of polonium from the urine during the day.

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MCNP SIMULATION OF THE DOSE DISTRIBUTION IN LIVER CANCER TREATMENT FOR BNCT THERAPY

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The Neutron Capture Therapy (BNCT) is based on selective uptake of boron in tumor tissue compared to the surrounding normal tissue. Infusion of compounds with boron is followed by irradiation with neutrons. Thermal neutron capture on ^{10}B, which gives rise to an alpha particle and recoiled ^{7}Li ion, enables delivering therapeutic dose to tumor tissue while healthy tissue can be speared. Here, therapeutic abilities of BNCT were studied for possible treatment of liver cancer using an epithermal neutron beam. For neutron transport MCNP software was used and doses in organs of interest in ORNL phantom were evaluated. Organs of phantom were filled with voxels in order to obtain depth-dose distributions in them. The result suggests that BNCT using an epithermal neutron beam could be applied for liver cancer treatment.

BETA INDUCED BREMSSTRAHLUNG DOSE RATE IN TISSUES FROM HUMAN ORGANS

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Dosimetric studies of beta-induced bremsstrahlung in human tissues are importance in the field of radiation protection. The efficiency, Intensity and dose rate of beta-induced bremsstrahlung by 113 pure beta nuclides in different human tissues is computed. The efficiency (yield), Intensity and dose rate of Bremsstrahlung in Cortical bone is higher than that of all other studied tissues. The efficiency (yield), Intensity and dose rate of Bremsstrahlung in lower than that of all other studied tissues. These dosimetric parameters are low for ^{199}Au and high for ^{104}Tc. The efficiency, Intensity and dose rate of Bremsstrahlung increases with maximum energy of beta nuclide (E_{max}) and modified atomic number (Z_{mod}) of the target tissue. The estimated Bremsstrahlung efficiency, Intensity and dose rate are useful in the calculations photon track-length distributions. These parameters are useful to determine the quality and quantity of the radiation (known as the source term). Precise estimation of this source term is very important in planning for radiotherapy and diagnosis.

ENERGY ABSORPTION BUILDUP FACTORS, EFFECTIVE ATOMIC NUMBERS AND KERMA OF DIFFERENT HUMAN BODY PARTS, TISSUES, VITAMINS AND TISSUE SUBSTITUTES

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Gamma energy absorption buildup factor (EABF) values inside human organ and tissues; heart, kidney, liver, skin, thyroid, pancreas, retina, cortical bone, fat, nucleobases, nucleosides, nucleotides, vitamins and tissue substitutes has been computed using five parameters Geometrical Progression (G-P) method. The G-P fitting method was applied for calculation of EABF values in the energy range 0.015–15 MeV, and for penetration depths up to 40 mfp (mean free path). Kerma and effective atomic number (Z_{eff}) of the selected composites were calculated for the same gamma energy range. The computed EABF values have been studied as a function of penetration depth, incident photon energy and chemical compositions. It is observed that the EABF values and Kerma of the selected composites were dependent upon Z_{eff} values and chemical compositions due to partial photon interaction process. The photon interaction of tissue equivalent materials for selected composites was studies. The EABF values in the present work should be useful in radiation dosimetry, medical diagnostics and therapy and personnel monitoring.

Key words: Buildup factors, G-P fitting, Photon, kerma, human organ, vitamin, Z_{eff}

MONTE-CARLO SIMULATION OF BREMSSTRAHLUNG INDUCED DOSE DEPENDING ON SOURCE MATRIX

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It is well known that the radiation protection from external irradiation due to presence of pure beta emitters is simplified in comparison to the corresponding technical requirements for shielding of radioactive sources which emit, in addition, gamma radiation. This is caused by relatively strong absorption (i.e. short range) of electrons in different materials. However, specific attention should be devoted to the bremsstrahlung radiation induced in source matrix or source encapsulation, especially for emitters with relatively high beta-endpoint energy (1 MeV order of magnitude). In present work, the bremsstrahlung spectra, produced in various matrices by the following beta emitters, Sr-90, Y-90, P-32, Bi-210, Y-91 were investigated, applying Monte-Carlo simulations using GEANT-4 software. Consequently, the absorbed dose rates arising from this radiation were calculated at the surface of encapsulated sources. In simulations, as source matrix or shielding layer materials, Pb, Cu, Al, glass, and plastic were used, including the variation of absorbing layers thickness.

SIMULATION OF ALPHA DOSIMETRY FOR PREDICTING PRODUCTION OF RADIOLYTIC SPECIES AT THE SURFACE OF SPENT NUCLEAR FUEL PELLETS

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In many countries, spent nuclear fuel is considered as a waste form to be disposed of in underground host rocks. Under deep disposal conditions, a reducing environment prevails. Long-term radionuclide release from the fuel depends on dissolution processes of the UO_2 matrix. The dissolution rate of irradiated UO_2 is controlled by oxidizing species formed by radiolysis of water in contact with spent nuclear fuel [1]. To understand the effect of the radiation, the information of the dose rate at the surface of the pellets and its proximity is needed. Alpha particles contribute strongly due to their high linear energy transfer. However, their dose rate and energy deposition at the pellet surface is difficult to measure. Furthermore, a fuel pellet shows specific features, such as the rim zone, where a higher Pu concentration at a different porosity is present. Therefore the particle dose was determined by simulations with the code MCNPX [2]. The simulation data provide the basis for subsequent determination of resulting chemical effects at the fuel/water interface. The latest results including theoretical and experimental data will be presented.

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EFFECTS OF GAMMA-RAY IRRADIATION ON INTERFACE STATES AND SERIES-RESISTANCE CHARACTERISTICS OF SI_3N_4 MOS CAPACITORS

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Metal-oxide-semiconductor (MOS) capacitors have been intensively investigated because of their technological applications, such as those offered by their excellent compatibility with existing micro- and nanotechnology. The suitability and usability of MOS devices in technological applications depends on the device characteristics, which are directly related to the gate insulators and their interfaces with the underlying semiconductors. Thus, high-k systems have been used to enhance the performance of devices and to decrease their dimensions. Among high-K materials, silicon nitride (Si_3N_4) based high-k dielectric has been recognized as the promising candidate for the advanced technology. Using a high dielectric-constant gate material, a much thicker dielectric can be used to obtain the equivalent capacitance of much thinner gates. For these thicker high dielectric constant insulators, more reliable operation is expected because the electron tunneling is reduced.

Owning to several possible sources of errors, the electrical characteristics of MOS capacitors deviate from their expected ideal behaviors. These errors may be related to such parameters as the interface-state densities (D_{it}) and series resistances (R_s). Therefore, these parameters should be taken into account in relevant calculations.

It is well known that MOS devices are extremely sensitive to ionizing radiation, and the radiation response of these devices has been found to change significantly due to the variation on the D_{it} and R_s. Therefore, we aim to study possible effects of radiation on the electrical R_s and D_{it} parameters of Si_3N_4-based MOS capacitors.

Silicon nitride films with a thickness of 100 nm were deposited by plasma enhanced chemical vapor deposition (PECVD) at 13.56MHz on p-type (100) Si substrate using a gas mixture of ammonia (NH3) and silane (SiH4). To study the response of MOS devices to irradiation over a range of doses, MOS samples were irradiated using a Co-60 gamma-ray source for 5 grays and 10 grays at a dose rate of 0.015 Gy/s. Capacitance-voltage (C-V) and conductance-voltage (G/ω-V) measurements were performed at high frequency (1 MHz) before and after gamma irradiation.

The effects of the radiation were determined from analysis of the C-V and G/ω-V curves. Due to the reordering and restructuring of radiation-induced defects in the MOS capacitors, a slightly rise in the Rs values with increasing irradiation dose was observed. The calculated values Rs values were used to correct the measured G/ω-V and C-V characteristics of the devices. It is seen that the real conductance values increase with increasing the radiation dose, while the experimental conductance value decrease with increasing radiation dose. In addition, the corrected capacitance is different from experimental measurements. These results demonstrate that the series resistance is a crucial factor which can mask the real device characteristics for device behavior. Moreover, using the corrected G/ω-V and C-V characteristics, the Dit which is basic reason of negative voltage shift on C-V characteristic were calculated for given doses. The Dit is calculated as 1.44x1012 eV-1cm-2, 1.59 x1012 eV-1cm-2 and 1.62 x1012 eV-1cm-2 for 0 Gy, 5 Gy, and 10 Gy, respectively. The C-V and G/ω-V analysis demonstrate that Rs and Dit are important factors that can affect electrical characteristics of the capacitor.

SPECIFIC FEATURES OF THE INFLUENCE OF HIGH-CURRENT HIGH-ENERGY ELECTRON BEAMS ON THE LUMINESCENT PROPERTIES OF UNDOPED AND NB, FE-DOPED AL_2O_3 CRYSTALS

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The anion-defect Al_2O_3 crystals are being widely used in the personnel dosimetry, radiative monitoring of environment as well in estimating the dose load in the oncologic patient ray treatment. In this case combination of the thermoluminescent dosimetry and optically stimulated luminescence methods is often used. When applying such dosimeters for accelerated electron beam monitoring two new factors do arise necessary to be taken into account when determining doses. First, at the accelerated electron energies about 10 MeV the displaced atom type radiation defects are produced modifying the luminescent properties of dosimeters. Second, at high ionization intensity the charge carrier recombination rate is clearly increased resulting, in general case, in the decrease of sensitivity to the irradiation dose.

In this paper, the influence of 10 MeV electrons accelerated at the M-30 microtron on the luminescent properties of both undoped and Nb, Fe-doped Al_2O_3 crystals has been studied at the maximal doses about 10^{14}e/cm^2 and $2{\cdot}10^9$–$5{\cdot}10^{10}$ e/cm^{2}s fluence intensities.

We have found that, as a result of irradiation of all the crystal types, the long-term phosphorescence was observed at room temperature (with no optical thermostimulation). The phosphorescence yield appeared to depend on the crystal doping as well as on the irradiation intensity and dose. It is interesting that, unlike the case of phosphorescence, no visible difference in the thermoluminescence yields as the function of the fluence intensity was observed at the same irradiation doses.

The decrease of both phosphorescence and thermoluminescence yields was observed for undoped Al_2O_3crystals at the irradiation doses above 10^{12} e/cm^2, while for the doped Al_2O_3 crystals it was noticed at higher doses.

Appearance of phosphorescence after irradiation by a high-intensity electron beam testifies to the presence of quite small charge carrier traps with at least two levels, having the depopulation rate less than the high-intensity electron pumping rate. The decrease in the phosphorescence and thermoluminescence yields at the irradiation dose increase is, most probably, due to the introduction of radiation defects being the non-radiative recombination centers.

THE EFFECTS OF DOSE AND WATER TREATMENT ON EPR SIGNALS IN IRRADIATED FINGERNAILS

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Fast and precise retrospective dosimetry is crucial in making decisions about medical procedures and safety mesures in radiation accidents. Electron paramagnetic resonance (EPR) spectroscopy has a potential as one of available biodosimetry methods for use in victims of such incidents. So far this method was successfully applied using enamel and bones as materials retaining radiation-induced EPR signals useful for dosimetry. Recent studies suggest the possibility of using EPR signals generated by radiation in fingernails for the purpose of dosimetry. Fingernails have many advantages over the enamel or bone: easy, non-invasive sampling and quick measurement of dosimetric EPR signal, possibly also in field conditions.

The presented study demonstrates changes in time of the EPR signal in irradiated nails and the effect of water on the mechanically-induced and radiation-induced EPR signals measured ex vivo in the fingernails. A mechanical stress caused by cutting of fingernails generates a strong EPR signals (mechanically-induced signals, denoted MIS) which overlap with the radiation-induced signal (RIS), making it difficult to determine intensity of the RIS. Furthermore, the signals generated mechanically vary in time in a complex way, i.e. MIS1 is growing and MIS2 is fading. Both of those signals are significantly reduced by water treatment of fingernail clips.

In the presented work dose dependence of the EPR signals in a water-treated fingernail samples was determined. The main conclusions of the study are the following: (1) radiation-induced signal was stable over several days in ex vivo conditions (2) RIS component did not show any difference in its microwave power saturation, compared to the MIS signal remaining after water treatment, (3) RIS did not completely fade after water treatments - its component marked as RIS5 is relatively resistant to a few minutes of soaking of the fingernails in water, (4) RIS5 component saturates at the dose about 60 Gy, which may provide a basis for retrospective dosimetric measurements.

Key words: Dosimetry, fingernails, radiation, signal, MIS, RIS

THE POSSIBILITY OF USING NUCLEAR TRACK MEMBRANE FOR OPHTHALMOLOGY

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This work researches the possibility of using nuclear track membrane for ophthalmology in epitelial -endothelial corneal dystrophy treatment.

Experiments were conducted using a track membrane “TOMTREK” based on PET with pores diameters (0.2-0.8 -) m and (5 • 106 -2 • 109) pores / cm^2 density. The pores are formed by irradiating the polymer PET 40Ar +8 ions with energy 41.5 MeV. After irradiation, the membrane was chemically treated in the alkaline solution. Imparting hydrophilicity membrane was the next step.

Contact angle of wettability the surface track membrane was measured just after the chemical treatment in NaOH and after 10 hours in air.

The surface had been processed by the plasma self-sustained volume discharge to give the surface the hydrophilic properties of the membrane.

The maximum voltage on plasma discharge was 20-22 kV. The energy density in the discharge was ~ 6 • 10-4 J/cm^2 per pulse. Pulse repetition rate was 103 s^{-1}. Samples of 6x6 cm were attached in a special rotating device. Thus, the same effects were both surfaces of the membrane. After surface treatment, TM samples were placed in plastic bags. After a night contact angle of wetting was measured with these samples.

Disks treating by the plasma were cut. The disc diameter was 10-11 cm.

The edges of the discs were incised and processed with hot temperature in order to obtain the model of an appropriate shape.

It was a shape of a truncated sphere with a certain radius of curvature. Then, the membrane was sterilized and implanted into the anterior chamber of the pig’s eye. The sample was untuck and hemmied by running surgical suture. Thus, we trained the methods of barrier keratoplasty using a nuclear track membrane.

As a result of studies, the authors came to the conclusion that the membrane should have a thickness of 5-7 microns, a porosity of more than 106 pores/sm2 and resistant hydrophilic surface.

APPLICATION OF EDXRF SPECTROMETRY FOR THE ANALYSIS OF ANCIENT CERAMICS

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An analytical procedure developed for the analysis of ceramic samples using EDXRF spectrometry will be presented, together with some preliminary results from the analysis of Early Neolithic ceramic fragments excavated in different sites in Albania.

Archaeological surveys and excavations have clearly shown that all the Albanian territory have been inhabited since prehistoric period. The excavations have shown that in some sites the humans have been living without interruption throughout the Neolithic period. The archaeological materials from these sites, mostly ceramics, constitute a unique case that could give information about the technological development of those societies from Early to Late Neolithic. Characteristic ceramic fragments from four sites of this type will be investigated by various analytical techniques aiming to evidence the similarities and differences between ceramics belonging to different Neolithic stages within one site and between different sites.

EDXRF spectrometry is widely used for studying ceramic samples because apart from being nondestructive, fast and low cost, the multielemental nature of the technique allows the application of different multivariate analysis.

The samples were measured in secondary target excitation EDXRF system, using Cu and Mo secondary targets for excitation of low- and medium-Z elements, respectively. The program Corex, which uses fundamental parameters and backscattered peaks from the measurements were used for the calculation of the concentrations. EDXRF spectrometry shows acceptable values of the detection limits for most of the determined elements. Precision and accuracy of the determinations were evaluated by the measurements of a series of standard reference materials. The results show good agreement between the recommended and calculated concentrations, i.e. no evidence of systematic error. Precision, expressed as relative standard deviation of the repeated measurements of SRM, shows values in the range 5 – 8 % for major elements, and values within 10 % for most of the minor elements.

SPECIFIC ABSORBED FRACTION OF ENERGY AND RELATIVE PHOTON DOSE IN HYDROXYAPATITE

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The effective atomic numbers (Z_{eff}) and electron densities (N_{el}) of hydroxyapatite (HA) have been computed for total and partial photon interactions in the wide energy range of 1 keV–100 GeV using WinXCOM. The variations of effective atomic number and electron density with energy are shown graphically. Geometric progression (GP) fitting method has been used to compute energy absorption and exposure build-up factor of HA for wide energy range (0.015MeV-15MeV) up to the penetration depth of 40mean free path. Build up factors increases with increase of penetration depth. The computed buildup factors are used to estimate the Specific absorbed fraction of energy and relative photon dose in hydroxyapatite. The variation of specific absorbed fraction of energy and relative photon dose with penetration depth and thicknes have been studied and this variation is compared with that of cortical bone and compact bone. The computed specific absorbed fraction of energy and relative photon dose are useful in clinical dosimetry.

MUTLI-PURPOSE RESEARCH FACILITY: ^{60}CO GAMMA IRRADIATION UNIT AT RESEARCH CENTER ŘEŽ

Hygreeva Kiran Namburi[1], Ondrej Marcinka[2], Marek Miklos[2], Eva Havlova-Homzova[2]

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It is well know from 1950's till date, that the users, demand and network of gamma irradiation facility centers are growing rapidly to support industries as well as research due to its versatility. At present, its applications are in the fields of biological, chemical, solid state physics, medical, food & sterilization, etc. The Gamma Irradiation Facility of the CVREZ is a dry-storage irradiator, which reached source end of life. The facility is now under refurbishment as a multi-purpose research center, fulfilling the requirements of international standards to support primarily the research sector and industries. It is intended to perform the pilot scale studies on the materials used in the fields of basic sciences (food, pharmaceutical etc.) to industrial applications (nuclear, polymer, solar, aerospace, sterilization, etc.). Overall objective of our project is to support research activities aiming to understand the materials modification due to ionizing radiation. For instance understanding the modification of polymer/elastomer components physical structure and properties due to ionizing radiation, that are used in the nuclear reactors as gaskets, seals, electrical insulation, thermal insulation, etc. Upgraded facility will provide high-fidelity simulation of nuclear radiation environments for materials and component testing.

In the current contest, we would like to present our work by providing the information on (i) our objectives in utilizing the facility, (ii) technical description of the facility (iii) special features and equipment's that will be installed (iii) present methodology for specific experimental test set-up that will enable to perform the experimental studies at high/extreme temperatures, cryogenic temperature's and in inert environment, (iv) summarize modern material characterization tools available at CVREZ and (v) finally report about experiments intended to perform in the facility and its usefulness to society.

ANOMALOUS DESORPTION FROM PRE-IRRADIATED SOLID NITROGEN

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Electronic desorption or desorption induced by electronic transitions (DIET) is a complex process involving relaxation of electronic excitations and conversion of electronic energy into atomic motions [1,2]. Electronic desorption of solid nitrogen was studied under excitation with electrons, ions and photons. Mass spectrometry analysis of species desorbing under bombardment by 0.5 keV electrons revealed atoms, molecules and clusters ejected into vacuum: N, N_2, N_3, and N_4. The dominant component appeared to be N_2 molecules. The mechanisms of electronically induced desorption from solid nitrogen are still not well understood.

Anomalous low temperature post-desorption from the surface of nominally pure solid nitrogen preliminary irradiated by an electron beam was detected for the first time. The study was performed using a combination of activation spectroscopy methods – thermally stimulated exoelectron emission (TSEE) and spectrally resolved thermally stimulated luminescence (TSL) – with detection of the anomalous low temperature post-desorption yield. Charge recombination reactions are considered to be the stimulating factor for the desorption from pre-irradiated α-phase solid nitrogen.

The primary excitations appearing under irradiation with ionizing radiation relax by different paths producing a number of secondary excitations and involve such processes as emission of electrons and photons, charge and energy transport, electron-hole recombination, creation of neutral and charged defect centers, mass diffusion, electronic desorption, radiation-induced reactions, etc. Some of secondary excitations are stabilized in the solid storing part of energy absorbed during irradiation. During the controlled warm-up this energy can be released as photons, electrons and spent partially for desorption. Recently [3] we found anomalous low temperature post-desorption of own atoms from the surfaces of pre-irradiated atomic cryocrystals. Strong peaks of atom ejection were observed at temperatures much lower than the characteristic sublimation temperature. Here we report first results of the experiments on post-desorption of nitrogen from the surface of nominally pure solid nitrogen preliminary irradiated by an electron beam.

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EVALUATION OF THE ACCURACY OF A COMMERCIAL RADIATION TREATMENT PLANNING SYSTEM FOR EXTERNAL BEAM PARTIAL BREAST IRRADIATION WITH AN ANTHROPOMORPHIC PRESAGE® DOSIMETER AND RADIOCHROMIC FILM

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Purpose: This work presents study an investigation into the accuracy of a commercial radiation treatment planning system for external beam partial breast irradiation with an anthropomorphic PRESAGE® dosimeter and GAFCHROMIC® EBT2 film.

Methods: An anthropomorphic breast PRESAGE dosimeter was created. A three field partial breast plan was generated in the Pinnacle^3 treatment planning system and delivered to this phantom. Comparisons were performed between the Pinnacle^3 treatment planning system calculated dose distribution, PRESAGE® dosimeter and GAFCHROMIC® EBT2 film. Dose volume histograms (DVHs), gamma maps and line profiles were used to evaluate the agreement.

Results: DVHs of gross tumor volume (GTV), clinical tumor volume (CTV) and planning tumor volume (PTV) for the PRESAGE® dosimeter and Pinnacle^3 treatment planning system show that both agreed 97.8% of the prescribed dose. Gamma map comparisons showed that all three distributions agreed with greater than 97% of comparison points passing the ±3% / ±3 mm criterion. The isodose line distribution comparisons between PRESAGE® and Pinnacle^3 exhibited agreement to within 1.5%.

Conclusion: This work establishes the feasibility of the PRESAGE® to be shaped into anthropomorphic and establishes the accuracy of Pinnacle^3 for partial breast planning. Furthermore, these data have established the groundwork for future investigations into 3D dosimetry with more complex anthropomorphic phantoms.

CALCULATION OF THE CROSS SECTIONS ON ^{63}CU AND ^{176}LU TARGETS USED FOR PRODUCTION OF ^{64}CU AND ^{177}LU THERAPEUTIC RADIONUCLIDES BY USING THE TALYS AND EMPIRE CODES

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The cross sections of (n, g) reactions on ^{63}Cu and ^{176}Lu targets by using the exciton model of pre-equilibrium reaction mechanism have been compared with the experimental data. In our calculations, some free parameters of the optical model potentials, level density and the squared matrix element M^2 have been adjusted for a good agreement with the experimental data.

OPTIMIZED READOUT ELECTRONICS FOR SPM GAMMA DETECTOR

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Silicon photo-multiplier (SPM) is a promising novel technology that could replace legacy photomultiplier tubes (PMT) in scintillator based radiation detectors. SPM main advantages over PMT are ruggedness and small size, low voltage, low cost, and insensitivity to magnetic fields.

We describe the development gamma ray detector based on SPM coupled with CsI(Tl) scintillator, with and emphasis on readout electronics development. Using a novel approach we have achieved a world leading energy resolution of around 6.5%, while still meeting a low power requirement. Potential applications of the detector include security (portal and handheld monitors) and personal dosimetry.

THE LATENT EFFECTS IN DIGITAL ICS UNDER ELECTRICAL OVERSTRESS PULSES AND ARRHENIUS LAW

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The results of experiments on electrical overstresses (EOS) influence on digital IC with the amplitude below the threshold of damage are presented. The Arrhenius law may be used for results.

Introduction: The charging of spacecraft components by high energy radiation can result in spontaneous pulsed electrostatic discharges (ESD). The resulting EOS pulses can interrupt normal operation of spacecraft electronics [1]. The serious of sub threshold EOS pulses can reduce the IC reliability and tends to parametric degradation and functional malfunction due to additive mechanisms.

The Experimental Results: The series of experiments was conducted over different ICs. of Voltage pulse amplitude was chosen below the damage threshold determined previously for single EOS [2]. It is very important for practice to approximate the number of EOS pulses for IC damage versus EOS amplitude. The experiments on CMOS IC CD4007 were performed to find the appropriate function. Results of experiment are presented in fig. 1 as a dependence of 1 μs EOS output pulses needed for IC functional damage.

It was found that the best approximation function is exponent: N=exp(b(V0-V)2) (1), where N - the number of 1 μs EOS output pulses for IC functional damage; V0 – EOS amplitude under N = 1; V – EOS amplitude under test; b = 1.6833e-4 – approximation parameter.

This result was extrapolated up to operating voltages. We have found that N = 1e16 under maximum rating voltage 15 V. Under the maximum IC rating (20 MHz) it's in accordance with whole IC lifetime about 140000 hours!

As a result we have found that approximation (1) is similar to the Arrhenius law: nu=Aexp(Ea/kT) (2), where nu - lifetime reduction; A – coefficient; k - Boltzmann constant; T – temperature; Ea – activation energy.

As compared with (1) we see that N corresponds to nu-1; b to Ea and kT to (V0 – V)-2. It means that EOS IC degradation may be described by Arrhenius law where EOS voltage acts as a series of temperature stresses.

Conclusion: The results of experiment revealed that it is necessary to take into account the additive effects in ICs under sub threshold EOS pulses. Using Arrhenius law the EOS results may be applied to the whole EOS amplitude range up to operating voltages.

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APPLICATION OF OPTICALLY STIMULATED EXOELECTRON EMISSION FROM CSCL IN FAST IRRADIATION DOSE READOUTS

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Dosimeters based on the thermally- or optically stimulated luminescence (TSL, OSL) phenomena are commonly used in solid state dosimetry. However, beside them also dosimeters with the effect of low-energy electrons emission from the surface during illumination of irradiated substances – known as optically stimulated exoelectron emission (OSEE) phenomena – can be also applied in this field. In the current presentation the study results of properties of very thin CsCl detector layers deposited on the conducting surface will be given. In particular, its response to short pulses illumination after electron irradiation dose (i.e. kinetics and intensity of electron emission, dependence on light pulse length and its intensity, proportionality to dose) will be analyzed in details. Moreover, the results of dosimeter surface degradation during electron irradiation examined by electron stimulated desorption and time of flight method will be also presented.

SECONDARY ELECTRON EMISSION AND MULTIPACTOR DISCHARGES

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Development of new RF accelerating structures that are capable of producing gradients in excess of100 MV/m, and the development of compact accelerators and accelerator-based light sources that are currently expected to have numerous applications ranging from the use in medicine to the high-energy physics, require more compact accelerating cavities and components for beam control. There are many new concepts that are being explored for the compact accelerator design. While current traveling-wave electron linear accelerators use disk-loaded metal structures to reduce the phase velocity of the RF wave to match the particle velocity, other concepts are under development. One class of structures that looks particularly promising is the dielectric-loaded accelerator (DLA), in which a uniform dielectric-lined metal tube replaces the metal disk-loaded structure. Special, non-symmetrical, cavity design for compact accelerators is one of main subjects of research in the Center of Accelerator Science at Old Dominion University. It has been reported that all these concepts are inclined to support the multipactor effect that, in turn, limits their range of operation. Since the RF technology is omnipresent in accelerator industry, new skilled specialist are in permanent demand, and graduate students will have to be educated and prepared to meet the challenges of these new developments.

Multipactor discharge presents a major boulder in the development of compact accelerators and light sources. Multipactor is a resonant discharge produced by a RF field in which the growth in the electron density is sustained by secondary emission from cavity walls driven by the RF power that is used for particle acceleration. In some areas of accelerator cavities' walls, there are often stray electrons that are driven by RF waves back into the surface, and secondary electrons are produced. The secondary electron yield depends on (a) impact energy, (b) surface geometry, temperature and structure, and (c) direction of the RF field at the time of electron impact. Surface material could be dielectric, semiconductor, conductor or superconductor, whose secondary electron yield may vary by an order of magnitude. This imposes important consequences for multipactor effect. If more than one electron is emitted for each primary electron, the rate of electron density growth could become high enough to dissipate a significant fraction of the RF power inside the cavity before the saturation due to space-charge or other effects sets in. While discussing the detrimental effects of SEE and multipacting, we will also point out to some beneficial effects that could be applied to radiation detectors.

INTERPRETATION AND PREDICTION OF NUCLEAR EXPERIMENTAL RESULTS BY THE DATA-CONTAINING CODES

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One of the trends in modeling of rare isotopes production is the creation and the development of codes which, on the one hand, realize various standard theoretical approaches of the reactions producing exotic nuclei and, on the other hand, contains a large bulk of nuclear data. This development follows the direction of higher capability of the programs and, in addition, makes these codes user-friendly step by step.

Typical examples of such codes namely EMPIRE and TALYS are discussed. The results of the calculations of the reaction cross sections and isomeric ratios are presented for illustration.

It is shown that in the most cases the programs are capable to describe a complete set of reaction data and thus the results of the calculations may be considered as a reasonable prediction of yields of rare nuclides.

INTEGRAL REFLECTION COEFFICIENTS FOR OBLIQUE INCIDENCE OF PHOTONS IN THE DOMAIN OF INITIAL ENERGIES UP TO 300 KEV

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In studying radiation reflection from larger objects (such as walls, floors, etc.), the concept of radiation albedo can be used. In this case, reflection is not strictly defined as the reflection from a surface (surface backscattering), but as a complete process of radiation penetration into a target material, its scattering and absorption in the object, and finally, irradiation of a part of radiation from the boundary surface of the material, with the decreased energy and from a point on the surface dislocated regarding the point of the primary beam incidence. This concept includes several basic and quite acceptable simplifications of the physical problem, thus enabling spatial, energy, and angular distribution of reflected radiation to be determined in a simpler way than required originally by the totality of the transport task.

In the previous 10 years the authors published several papers, in which analyses of photon reflection were done and the universal behavior of the integral reflection coefficients was explored, based on the results of the Monte Carlo simulations of photon transport in a set of materials of interest. Those analyses covered the domain of incident photon energies up to 300 keV and were limited to normal photon incidence only.

In this paper we present results of the analyses of photon reflection from planar targets for oblique photon incidence and for different shielding materials (water, concrete, aluminum, iron, and cop per), in the range of initial photon energies from 20 keV to 300 keV. Photon reflection coefficients have been calculated based on the results of Monte Carlo simulations of the photon transport, performed using MCNP4C code. Integral reflection coefficients include total number and total energy albedo of photons, mean number of scatterings in the target material prior to the final reflection from the target, and the fraction of photons reflected back after only one collision in the material.

The integral photon reflection coefficients for a fixed initial photon energy have been presented as functions of the photon incidence angle. In addition, for a constant incidence angle, the total number and energy albedo of photons have been presented as functions of the incident photon energy, and as functions of the ratio of total cross-section of photons and effective atomic number of target material, a parameter which was used in our previous publications to analyze universal behavior of the photon reflection in case of normal photon incidence.

These results have been analyzed in order to check if the universal behavior of the integral reflection coefficients, demonstrated for normal photon incidence, is also valid for oblique photon incidence, and to determine the range of the incidence angles for which such universal behavior is preserved.

COMPLEX APPROACH TO MICROELECTRONICS RADIATION HARDNESS INVESTIGATION

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The paper is a revue of our microelectronics radiation hardness testing approach.

The general basis of the approach is the concept that the wide variety of radiation environments causes the limited number of dominant radiation effects in microelectronic devices and circuits that can be initiated and simulated with the use of optimal set of test facilities.

Traditionally, the main regulation is aimed to choose the correct irradiation sources from a narrow set. Almost as a law, it is Co-60 for total ionizing dose (TID) effects, flash X-ray for dose rate effects (DRE), nuclear reactor for structural damage and heavy ions cyclotron for single event effects (SEE). At the same time, there is a lack for device under test particularities and variations consideration- modes of operation, the parameters set, bias and temperature conditions, etc. And we are positive that the latter has the greatest impact on the hardness level estimation validity.

The main particularities of our approach:

1. We implement various radiation tests at all steps of IC's living cycle –design, production and employment.
2. We use wide variety of irradiation sources not only above mentioned but– lasers (nanosecond for DRE and focused picoseconds for SEE), X-rays and LINACs for TID effects simulation. We have performed thousands of comparative tests and calculations to prove the adequacy and effectiveness of additional variety of irradiation sources. Strict calibration and dosimetry procedure has been developed for each additional irradiation source.
3. In every experiment we try to check all possible modes of IC's operation and functionality, all informative parameters and tests conditions to find the real "worst case" irradiation and measurement regime.
4. All measurement lines should be as short as possible (less than 1 m).
5. We perform irradiation in full -60°C...+125°C temperature range.
6. We perform smart radiation tests trying to understand the radiation behavior, failure reasons and the ways of radiation sensitivity decrease.

We represent our approach at leading Russian radiation test center based on governmental-private partnership of National Research Nuclear University MEPhI (Institute of Extreme Applied Electronics) and JSC "Specialized Electronic Systems" (SPELS).

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF DOSE RESPONSE IN NON-HOMOGENEOUS OSL DETECTORS

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Optically stimulated luminescence (OSL) is a two-stage luminescence phenomenon. First, the material is irradiated. The metastable excited state may lasts for many years. Luminescence is triggered by optical stimulation. We can observe light emission at shorter wavelengths than the stimulation wavelength. The emitted luminescence is proportional to the dose of radiation absorbed by the material. Hence, it is frequently used in dosimetry of ionizing radiation as well as in luminescence dating applications.

Theoretical description of the OSL response is usually limited to the case of a very thin and homogeneous detector. In most applications the OSL detector is a polycrystalline (i.e. non-transparent) material with the thickness of more than 0.5 mm. In this case the stimulating light is absorbed mostly at the surface of the detector. Therefore, during readout not all charge carriers traps are emptied uniformly. This significantly changes the OSL luminescence kinetics and may affect dose determination as well. The situation is even more complex in non-homogeneous OSL detectors – e.g. hybrid organic-inorganic materials. This paper analyses OSL response in “thick OSL detectors” as well in non-homogenous materials consisting of two different media having various light absorption characteristics as well as various OSL response.

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RADIATION PROTECTION, RADIATION WASTE MANAGEMENT AND SITE MONITORING AT THE NUCLEAR SCIENTIFIC AND EXPERIMENTAL CENTRE IRT-SOFIA AT INRNE-BAS

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Radiation safety is a crucial issue during lifetime of a research reactor. The article identifies important components and describes the safe practices in implementing radiation protection and radioactive waste management programmes, and in their optimization at the Nuclear Scientific Experimental and Educational Centre (NSEEC) with research reactor IRT at INRNE-BAS. These programmes were put together in order to ensure the protection of people and the environment from the harmful effects of ionizing radiation. Described are the responsibilities of the radiation protection group, the dose limitation systems, an adequate classification of working areas, the use and maintenance of radiation protection equipment and facilities, radiation and contamination monitoring, and radiation protection procedures. The instrumentation and personal protective equipment, as well as some important issues related with the continuous site monitoring and the organizational and radiological aspects of emergencies are briefly presented. Compliance with international good practices related to the fulfillment of the relevant safety requirements will also be presented and discussed. Important issues are concerning the measures applied to zoning and working area classification, radiation monitoring of working areas, and operating procedures, including decontamination procedures and techniques.

Control of the working environment and the radiological status at the IRT area is performed through continuous measuring of gamma background and analysis of environmental samples (soils, plants, aerosols, groundwater and rainfall) collected at the protected area. Samples are collected from several control points. Aerosols are sampled using high-volume air sampler and a pump. The implementation of stringent regulations and strict radiation control in compliance with the ALARA principle ensures keeping the radiation exposure of IRT personnel below the regulation limits. The comprehensive long-term monitoring of the IRT area allows to obtain accurate information for the typical levels and concentration ranges of various parameters including radiation level in the atmosphere and to acquire an unbiased assessment of the quality of workplace environment. The results evidence the absence of anthropogenic impact on the general levels of natural radioactivity within the nuclear site boundaries; consequently residents of nearby Sofia districts are not subjected to an ionizing radiation hazard, either by irradiation or contamination due to activities on the IRT site.

DECONTAMINATION OF PROTECTIVE CLOTHING AGAINST RADIOACTIVE CONTAMINATION

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Personal protective suits against radioactive contamination are produced from material, which is intended to prevent direct personal contamination. These suits generally protect against contamination by radioactive aerosol particles or by liquid radioactive substances. Currently, a lot of companies have been offering different types of such suits.

This paper describes experimental results of external surfaces mechanical decontamination of the studied materials forming selected suits. Seven kinds of personal protective suits declaring protection against radioactive aerosols contamination in different price ranges were selected for decontamination experiments.

The square seamless samples were cut out of the suits and then fixed on metal pads. Ten samples were prepared for each type of suit. The contamination mixtures were applied onto the testing surface by spraying of radioactive contaminant through a circular template.

The radioactive contaminant was chosen La-140, which is suitable for these types of experiments due to its short half-life (1.678 days), and moreover, its decay product Ce-140 is a stable nuclide. Chemical properties of lanthanum are representative for the whole group of lanthanides. Two chemical compounds of La-140 (water-soluble and water-insoluble) were used for the contamination process.

The Colibri TTC radiometer with Alpha/Beta/Gamma detection probe SABG-15+ (produced by Canberra Industries, Inc.) was used to determine the surface contamination. The probe enables distinguishing the alpha, beta or gamma particles contribution using the iron or plastic barrier inserted between the detector and the source during the measurement.

The decontamination process was performed by wiping the contaminated area with a cotton swab dipped in the military decontamination foam mixture ODS-5™ produced by Oritest Group. The wiping was every time conducted three times in one direction and three times in the perpendicular direction. The decontamination procedure was repeated once again after the determination of residual activity.

The outcome of this paper is to compare the efficiency of double-step decontamination process of various personal protective suits against radioactive contamination. Comparison of the decontamination effectiveness for the same type of suit, but for the different chemical mixtures (lanthanum in a water-soluble or a water-insoluble compound), was performed.

RESULTS OF THE FRENCH NATIONAL WORKING GROUP GEDOC FOR OCCUPATIONAL EYE-LENS EXPOSURE IN CLINICAL AND INDUSTRY FIELDS

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Further to the recent studies on early and late effects of ionizing radiations, the International Commission on Radiological Protection (ICRP) has concluded that the radiosensitivity of the eye-lens is higher than expected before.

In 2011, the ICRP recommended to lower the dose limit of the eye-lens to 20mSv per year. This dose limit can be averaged over 5 years if 50 mSv is not exceeded over per year. The current eye-lens dose limit is 150 mSv. The main issue is to determine how the future regulations will be complied with. Medical and Nuclear Power Plant (NPP) activities are mainly questioned about this evolution. The GEDOC is compounded with 20 members, from medical and NPP industries. Interventional radiology and nuclear medicine in hospital, replacement of the heating tubes in NPP have been for instance investigated on various sites with OSL, TLD and ionizing chamber detectors .The aim of the GEDOC working group initiated by LANDAUER EUROPE is twofold. The first objective was to estimate current eye-lens doses on high hazard workstations. These estimations have been compared with the CIPR dose requirements. The second one is to study metrological, operational and ergonomic requirements in order to establish a new eye-lens dosimeter.

The practical methods, the results and the conclusion of the working group work will be consequently presented and discussed

ABSORBING MATERIALS WITH APPLICATIONS IN RADIOTHERAPY AND RADIOPROTECTION

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The radiotherapy centers are using linear accelerators equipped with multi-leaf collimators (MLC) for treatments of various types of cancer. For superficial cancers located at maximum depths of 3 cm high energy electrons are often used, but MLC cannot be used together with electron applicators. Because the tumor shape is not square (as electron applicators), searching for different absorbent materials that could be used as absorbent shields for adjacent organs with different applications in radiotherapy and radioprotection is of paramount importance.

In our paper we present an experimental study regarding the transmitted dose through some materials when subjected to electron beams of various energy values (ranging from 6 to 15 MeV). The materials have been obtained at West University of Timisoara and tested in the High Energy Radiotherapy Center from Timisoara.

The experimental results show that the transmitted dose through tested samples is ranging between 20% and 60%, depending on the electron beam energy, sample thickness and sample composition. These preliminary results suggest that the analyzed materials can be used as absorbers in different applications in radiotherapy and radioprotection.

Key words: Radiotherapy, radioprotection, absorbers, dose, electron beams

SUPERFICIAL DECONTAMINATION OF CORRODED STEEL STRUCTURES OF COMPLEX SHAPES BY MOLTEN SALT STRIPPING

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Decommissioning of old Nuclear Fuel Cycle facilities usually generates big amount of radioactive waste in the dismantling operations. Part of the waste is in the form of contaminated carbon steel structures, sometimes presenting severe corrosion or oxidation. Radioactive contamination in the structures, although mainly restricted to low and medium activity levels, constituted an important concern. It should be outstanding that the capacity of radioactive wastes stockpiling is generally limited and expensive. Then, the reduction of the radioactive waste volume has a significant impact in the reduction of the decommissioning costs and in the amount of material to be stored. The Nuclear and Energetic Research Institute – IPEN-CNEN/SP – Brazil has faced the problem of old facilities decommissioning. Basically, for the dismantling operations of the units, the main radionuclides of interest, from the radioprotection point of view, are U of natural isotopic composition and the thorium-232. Some attempts were done to reduce the volume of those wastes and traditional decontamination methods were tried, such as acid pickling, alkaline washing and ultrasonic baths. Nevertheless, the chemical available decontamination methods, such as pickling/rinsing treatments employing acid solutions (with nitric or citric acids) and alkaline solutions (sodium hydroxide have failed to reach effective decontamination and the results were not satisfactory.). Different concentrations of such solutions were tested. Nevertheless, in several situations, mainly with contaminated and corroded tubes and perforated structures those methods failed. Ultrasonic equipment available was also employed in an attempt to increase the efficiency of decontamination. The choice of a coating removal process for radioactive waste in the form of carbon steel pieces must have into account, among other factors, that it is not necessary a high quality of finishing, since the main objective is to release the material as iron scrap. In this paper are described some aspects and problems in decommissioning of IPEN's nuclear fuel cycle facilities and is presented the development of a new method for radioactive superficial decontamination of corroded and contaminated steel structures by immersion in molten salt baths of different compositions.

STATUS OF RADIATION PROTECTION AND SAFETY AT BPKM CANCER HOSPITAL, NEPAL

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Purpose: The objective of this work was to evaluate all the safety procedures toward the radiation protection for workers in the radiation oncology department.

Methods and Materials: The annul thermoluminescent dosimeters (TLDs) reports for five years of the staffs were evaluated, radiation surveys were done in the control consoles, radiotherapy machines (linear accelerators, telecobalt -60, HDR Brachytherapy) rooms and waiting areas of all machines using Aloka survey meter.

Results: The five years TLD reports shows that the whole body dose of the individual staffs is found within the annual dose limit except the accidental exposures. Radiation exposures in the working areas are also safe limits.

Conclusion: The radiation safety practices for radiation protection are satisfactory and the radiation workers of the departments are found working within safe limit.

PROTECTION OF THE PUBLIC DURING A SEVERE EMERGENCY AT A LIGHT WATER REACTOR OR ITS SPENT FUEL POOL

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Severe emergencies involving damage to the fuel in the reactor core or in a spent fuel pool, can cause deaths and severe health effects off-site, and have psychological, economic and social consequences for the public. Experience from past severe emergencies, such as the emergencies at the Three Mile Island (1979), Chernobyl (1986) and Fukushima (2011) nuclear power plants, have shown that decision makers were unable to act promptly to protect the public, due to the lack of understanding of (a) the progression of severe emergencies at a nuclear power plant, (b) their possible off-site consequences and (c) the warranted response actions to keep the public safe.

This paper provides an outline of the guidance developed by the IAEA's Incident and Emergency Centre (IEC) for off-site decision makers, regarding the off-site response during a severe emergency at a nuclear power plant. It is based on research and lessons learned from past emergencies, and takes into account the reality of a severe emergency, such as the lack of reliable information, the vast uncertainties to be expected (i.e. regarding the event progression, the release, the environmental dispersion and the exposure of the public), the effectiveness and consequences of response actions, or the heightened emotions and mistrust of the public towards officials and the scientific community.

In summary, the pre-established and comprehensive off-site response is initially triggered by emergency action levels (i.e. criteria observable by the plant operator, which are indicative of actual or projected damage to the fuel), if possible before a major release to the environment, and implemented in pre-established zones in all directions around the plant. Once a major release has occurred, the off-site response is adjusted and/or extended based on operational intervention levels, which are criteria for environmental measurements (e.g. dose rate above the ground) or laboratory analysis indicative of the projected dose to the public, that can be used directly, without further assessment. The off-site response is driven by the objective of protecting the public from the radiological health hazard resulting from a potential release, as well as from other hazards, such as the public doing more harm than good to protect itself. Tools for public communications are made available for the latter, that allow providing the public and others (e.g. decision makers and medical staff) with the information they need to put the radiological health hazard in perspective and make informed decisions concerning their welfare and the welfare of others.

FIFTEEN YEARS OF OCCUPATIONAL EXPOSURE MONITORING IN THE FEDERATION OF BOSNIA AND HERZEGOVINA

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Monitoring of exposed workers in Bosnia and Herzegovina started in 1960s. After brief interruption in 1990s, the dosimetry service resumed in 1999 after International Atomic Energy Agency (IAEA) provided first TLD reader in Bosnia and Herzegovina – Harshaw 4500. Until 2013 Radiation Protection Centre of the Institute of Public Health of Federation of Bosnia and Herzegovina (RPC) was the only institution in the country that was capable of providing this service. In December 2013 RPC covered 1,485 of exposed workers with personal dosimetry, which is more than 70% of all radiation workers in the country. Most of the TLD users work in medical institutions – 1,417. Other occupations include industry, veterinary medicine etc. Total number of evaluated annual doses is approximately 15,000. Majority of the annual doses were less than 0.99 mSv a^{-1}(96%), some users received doses 1.00–1.99 mSv a^{-1} (3.3%), and very few doses between 2.00 and 2.99 mSv a^{-1} (0.6%). In isolated cases TLD users received doses higher than 3 mSv a^{-1}. There are no registered cases of exceeding the annual limit (20 mSv a^{-1}). Exposed workers that perform interventional procedures in radiology, cardiology, cardiac surgery and gastroenterology (cca. 90 persons) are provided with 2 TLDs that are worn below and above the lead apron. In such cases Niklason's methodology is used for the estimation of effective dose. Results of the analysis show an improvement in radiation protection in the last 5 years, most likely due to active involvement of the State Regulatory Agency for Radiation and Nuclear Safety (SRARNS).

CALCULATION OF THE DOSE CONVERSION COEFFICIENTS FOR THE VOXELIZED EYE LENS FOR NEUTRONS IRRADIATION

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Calculations of the neutron conversion coefficients for the voxelized eye lens using Monte Carlo MCNP5/X code were performed in this report. ICRP recommended significant reduction of annual limit of the equivalent dose for the eye lens from 150 to 20 mSv/y. This reduction has motivated a lot of interest in eye lens dosimetry. In this paper, we describe voxelization of the eye lens, and calculation of Hp(3) equivalent dose delivered by neutrons of various energies. Results of voxelized phantoms were compared with those obtained for anthropomorphic phantoms.

AREA DOSIMETRY FOR THE NEW RADIOPHARMACEUTICAL CENTER IN IFIN-HH

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In the last years, a new center for R&D in the field of radiopharmaceutical products was set up. The main objective of the center are the researches concerning the use of F-18 in nuclear medicine. The center has a new PET Cyclotron, TR-19, with variable energy from 14 MeV to 19 MeV. Both for obtaining the licences from the Romanian authorities, but also in order to have a history of the dose rate value in different area of the building hosting the center, a monitoring program for area dosimetry was developed. The quantities selected to be measured was the ambient dose equivalent rate, H^*, both for gamma ray and neutron. The measurements were performed using a Berthold UMO LB 123 dose-rate meter with gamma and neutron probes. The first step in this program was to perform measurements of the radiation background, in the selected points before putting into operation the machine. The results of these measurements are now the reference values for H^*, for gamma and neutron ray. The next step of the program was to perform measurements of H^*, in the same points during the operation of the cyclotron. Until now, a large number of measurements were done, for several values of the current (20 μA, 50 μA, 60 μA) corresponding to the generation of 18 MeV protons. The paper deals with the measurement program and also with the results of these measurements, from the "zero moment" (before starting the operation of the cyclotron) until now (Oct. 2013). The results of these measurements (for different values of the cyclotron current), together with some comments regarding the relation between the current values and the values of H^*.

ASSESSMENT OF ANNUALWHOLE-BODY OCCUPATIONAL RADIATION EXPOSURE IN EDUCATION, RESEARCH AND INDUSTRIAL SECTORS IN GHANA (2000/09)

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Institutions in the education, research and industrial sectors in Ghana are quite few in comparison to the medical sector. Occupational exposure to radiation in the education, research and industrial sectors in Ghana have been analysed for a 10 y period between 2000 and 2009, by extracting dose data from the database of the Radiation Protection Institute, Ghana Atomic Energy Commission. Thirty-four institutions belonging to the three sectors were monitored out of which~65 % were in the industrial sector. During the 10 y study period, monitored institutions ranged from 18 to 23 while the exposed workers ranged from 246 to 156 between 2000 and 2009. Annual collective doses received by all the exposed workers reduced by a factor of 2 between 2000 and 2009. This is seen as a reduction in annual collective doses in education/research and industrial sectors by~39 and~62 %, respectively, for the 10 y period. Highest and least annual collective doses of 182.0 man mSv and 68.5 man mSv were all recorded in the industrial sector in 2000 and 2009, respectively. Annual average values for dose per institution and dose per exposed worker decreased by 49 and 42.9 %, respectively, between 2000 and 2009. Average dose per exposed worker for the 10 y period was least in the industrial sector and highest in the education/research sector with values 0.6 and 3.7 mSv, respectively. The mean of the ratio of annual occupationally exposed worker (OEW) doses for the industrial sector to the annual OEW doses for the education/research sector was 0.67, a suggestion that radiation protection practices are better in the industrial sector than they are in the education/research sector. Range of institutional average effective doses within the education/research and industrial sectors were 0.059–6.029, and 0.110–2.945 mSv, respectively. An average dose per all three sectors of 11.87 mSv and an average dose per exposed worker of 1.12 mSv were realised for the entire study period. The entire study period had 187 instances in which exposed workers received individual annual doses >1 mSv, with exposed workers in the education/research sector primarily receiving most of this individual dose.

ASSESSMENT OF ANNUALWHOLE-BODY OCCUPATIONAL RADIATION EXPOSURE IN MEDICAL PRACTICE IN GHANA (2000/09)

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Occupational exposure to radiation in medical practice in Ghana has been analysed for a 10-y period between 2000 and 2009. Monitored dose data in the medical institution in Ghana from the Radiation Protection Institute's database were extracted and analysed in terms of three categories: diagnostic radiology, radiotherapy and nuclear medicine. One hundred and eighty medical facilities were monitored for the 10-y period, out of which ~98 % were diagnostic radiology facilities. Only one nuclear medicine and two radiotherapy facilities have been operational in the country since 2000. During the 10-y study period, monitored medical facilities increased by 18.8 %, while the exposed workers decreased by 23.0 %. Average exposed worker per entire medical institution for the 10-y study period was 4.3. Annual collective dose received by all the exposed workers reduced by a factor of 4 between 2000 and 2009. This is seen as reduction in annual collective doses in diagnostic radiology, radiotherapy and nuclear medicine facilities by ~76, ~72 and ~55 %, respectively, for the 10-y period. Highest annual collective dose of 601.2 man mSv was recorded in 2002 and the least of 142.6 man mSv was recorded in 2009. Annual average values for dose per institution and dose per exposed worker decreased by 79 and 67.6 %, respectively between 2000 and 2009. Average dose per exposed worker for the 10-y period was least in radiotherapy and highest in diagnostic radiology with values 0.14 and 1.05 mSv, respectively. Nuclear medicine however recorded average dose per worker of 0.72 mSv. Correspondingly, range of average effective doses within the diagnostic radiology, radiotherapy and nuclear medicine facilities were 0.328–2.614, 0.383–0.728 and 0.448–0.695 mSv, respectively. Throughout the study period, an average dose per medical institution of 3 mSv and an average dose per exposed worker of 0.69 mSv were realised. Exposed workers in diagnostic radiology primarily received most of the individual annual doses >1 mSv. The entire study period had 705 instances in which exposed workers received individual annual doses >1 mSv. On thermoluminescent dosemeter (TLD) return rates, facilities in Volta and Eastern Regions recorded highest return rates of 94.3 % each. Ashanti Region recorded the least TLD return rate with 76.7 %.

ASSESSMENT AND BENCHMARKING OF THE IMPACT TO GAMMA DOSE RATE EMPLOYING DIFFERENT PHOTON-TO-DOSE CONVERSION FACTORS USING MCNP CODE AT THE DECOMMISSIONING STAGE OF IGNALINA NPP

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A comparative study was performed to reveal the impact of several photon-to-dose conversion factors for gamma dose rate calculations when applied to heterogeneous environment in the case of decommission of the Ignalina Nuclear Power Plant (INPP). The following set of conversion factors were investigated by employing the Monte Carlo n-particle transport code (MCNP) derived from the recommendations given in ICRP21, ICRP74, ANSI/ANS 1997 and ANSI/ANS 1999, based on the experiments performed for gamma radiation dose rate measurements inside the emergency core cooling system (ECCS) tank with surface radioactive contamination up to 54 Bq/cm^2. MCNP precise simulation and the benchmark between the conversion coefficients highlighted the impact to the results for the selected case of this investigation. The results revealed that the data from theANSI/ANS 1999 publication is reliable for various dose and shielding calculations in case of decontamination and similar applications since it showed a statistically satisfied agreement between the simulation results and experimental data. These tendencies suggest that the radiological protection system currently adopted in NPP while under decommissioning can be characterized using ANSI/ANS 1999 recommendations with respect to gamma dosimetry.

EMERGENCY RESPONSE EXERCISE OF LABORATORIES EQUIPPED WITH GAMMA SPECTROMETRY

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At present 7 laboratories equipped with semiconductor gamma spectrometry (HPGe detectors) are included in the Radiation Monitoring Network (RMN) in the Czech Republic. These laboratories have 31 spectrometric chains and approximately 20 "experts" and 70 "users" who would guarantee measurements during a radiological emergency (RE). The stress exercise (a load test) was carried out in 4 of them. The aim was to test their measuring capacity in existing technical facilities and staff in the event of a RE and identify problems (bottlenecks) in the whole process from receipt of samples to entering the results into the central database of RMN. Duration of the exercise was 8 to 14 hours. Due to lack of staff, work in one 12-hour shift during a RE is presumed, which the laboratories should be able to provide for 14 days.

Exercise samples covered a wide range of commodities that would probably come to the laboratories during RE (aerosol filters, adsorbed gaseous forms of iodine, fallout, surface and drinking waters, food chain components and soils). Some of the samples were previously spiked.

Almost 40 employees took part in the exercise and measurements were carried out at 18 spectrometric chains. An automatic gamma counter which allows automatic operation of two HPGe detectors including the analysis of the spectra with a storage for up to 180 sample containers was operating in one of the laboratories involved in the exercise. During the exercise about 700 samples were evaluated; in addition, gamma-automat measured other 80 samples in the "night shift". 700 samples, this means 40 samples per a spectrometric chain or, from another point of view, 18 samples per man. The main limiting factor of the capacity is the lack of staff. The rearrangement of the laboratories for work in emergency does not take long.

On the basis of the results the total measuring capacity of laboratories of RMN CR was estimated on more than 1000 samples per day.

The most overextended and most time-consuming areas of the whole process were identified and mistakes, errors and shortcomings of measurements were evaluated (in determination of the activities, in registration parameters of the sample, in manipulation with high activity samples) and the causes were analyzed. The relative deviation of a result and the reference value did not exceed 30% in 80% of the spiked samples.

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RADIATION DOSE IMPACT ON THE WORKERS FROM THE RADIOPHARMACEUTICAL FACILITY

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Some important indicators were determined to be useful in the evaluation of radiation occupational exposure. These indicators are analysed to identify and to correlate the main parameters that had an impact on the radiation dose of workers in a Brazilian Radiopharmaceutical Facility, during the last three years. The workers were selected from a group responsible for the production, labelling and distribution around 95% of the radiopharmaceutical material in Brazil. The data analysis took into account the number of monitored workers, the distribution of dose, the annual effective doses (above records levels), and collective effective dose, the radiation level monitoring of workplace and environmental. The conclusions from this work are used to optimize the radioprotection procedures of this installation. This optimization included operational measures such as modernization of the production lines and of hot cells, improvements in the packaging system and continuous training of the workers in specific jobs. The dose results obtained from monitoring practices, over last three years, are discussed and they are in accordance with the limits recommended by national and international regulatory authority.

MONITORING OF FOOD RADIOACTIVE CONTAMINATION AS AN TOOL FOR CONSUMER RADIATION PROTECTION

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Consumption of radioactive contaminated food is considered as one of the most important routes of radionuclide penetration into human bodies. Therefore, the Polish veterinary authority implemented a programme of radioactivity monitoring in various foodstuffs of animal origin (beef, lamb, pork, poultry, game, fish, hen eggs, and cow milk). Ten laboratories test over a thousand samples per year for their ^{137}Cs and ^{134}Cs activity concentrations. At present, only ^{137}Cs is measurable. Generally, the ^{137}Cs activity concentrations are very low and, in most of the measurements, reach values below MDA. However, in game animals fairly high levels of ^{137}Cs are still noted, especially in wild boars. In several wild boar meat samples the permitted level of 600 Bq/kg was exceeded. Ingestion of a large portion of wild boar meat in a daily diet by hunters' families may increase ^{137}Cs uptake in this group of consumers. Therefore, some precautions of consuming wild boar meat may be advised.

ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURE FROM RTG AND CT IN VETERINARY CLINICS

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Radiation protection in Poland is regulated by the Atomic Law Act which constitutes a restrictive demand for both: gaining permission for use and routine use of equipment creating ionizing radiation. The act is no so restrictive in the field of veterinary use of RTG and CT equipment. Differently from human radiography or tomography the animal study does not require inspections of radiation protection officer nor special requirements for study work-room. The only requirement for veterinary clinic is to conduct ambient measurements once a year (but still without supervision of radiation protection officer). In consequence there is no reliable data on occupational exposure of veterinary staff nor on animal owner exposure that assist the studies.

The aim of our study was to provide such data. Measurements using thermoluminescent dosimeters LiF:Mg,Cu,P were performed in few clinics to assess ambient dose equivalent H*(10), individual dose equivalent Hp(10) and Hp(0,07). Measurements were supplemented with inquiry form for clinic staff about radiological procedures and safety. Results and discussion are presented.

A NATIONAL INTERCOMPARISON PROGRAM FOR PERFORMANCE APPROVAL TESTS OF INDIVIDUAL DOSIMETERY SERVICE PROVIDERS IN IRAN

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Performance testing as part of approved procedures is carried out to demonstrate that the essential performance specifications are routinely maintained.

There are four service providers in Iran which use different luminescence techniques (e. g. TLD and RPL) with various kinds of dosimeter materials/reader instruments in the personal dosimetry services.

A national performance approval tests program has been performed in energy range of soft x-ray, 660 keV and 1.25 MeV, and dose range of recoding, investigation and annual dose limits, and different angle of incidents (0, 20, 40 and 60 degree) for the dosimeters of the service providers.

The results of this testing satisfies the overall accuracy criteria specified by the ICRP, so that all the results fall within the acceptable accuracy band defined as trumpet curves with 95% confidence levels.

INVESTIGATION OF RADIO- AND RADIATION-PROTECTIVE NANO-STRUCTURED MATERIALS

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Wide application of modern technologies, which use electric-magnetic radiation both for information communications and as power carriers, leads to significant growth of electric-magnetic background in the human surrounding. In order to minimize its impact to a safe level, it is necessary to use special radio-absorbing materials. To protect against electric-magnetic fields (EMF), there were developed and studied some radio-absorbing filler materials on base of such carbon materials (whose specific surface square is 12-26 m^2/g), as technical carbon, graphite, carbon fibers, carbon nano-pipes, thermal-expanded graphite. With these filler- and coating materials, there were developed some radio-protective materials and technologies to produce them: radio-protective building- and siding materials, radio-absorbing filler materials on base of fragmented paper, cloth, fibers, pellets, etc., radio-protecting heat-insulating foamed glass, radio-absorbing and radio-protective products for echo-free shielded chambers and rooms, etc. The obtained radio-protective materials ensure whole protection of any inhabitant building against penetration of EMF and reduce their values to permissible (safe) limits.

Human presence and application of engineering means in the space, as well as wide using radiation sources in the medical sector, have deal with impact of ionizing radiation on human bodies and relevant hardware. In order to reduce such impacts to safe levels, it is necessary to apply special radiation-protective materials. There were developed and investigated some light radiation-protective materials on a polymer base, to improve safety of medical nuclear equipment and also safety of emergency and medical personnel. The DMA analysis shows, that increase of quantity of radiation-absorbing modifiers in a polymer composite, leads to increase of the Junge module, strength, yield strength, however relative elongation decreases, but saving enough high value. Calorie-metering of the pilot specimens shows, that strengthening of the polymer composites occurs in result of re-orientation and tension of the polymer chains under reversed loads by annealing. Measurements of the reducing coefficient for mono-energy gamma-raying of ^{57}Co isotope with energy $E\gamma$ = 122 keV, shows increase of this coefficient up to 1.33–1.40.

AERO ENGINES MAINTENANCE – SPECIFIC RISKS

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Background: To meet the high demands that have been placed, aero engines of modern military aircraft are made from alloys that are added radioactive elements. One of the most significant is thorium Th-232. The presence of Th-232 imposes the need for monitoring of occupationally exposed personnel engaged in the maintenance of these engines.

The aim of this paper is to review and assess the risks present in certain aero engine maintenance.

Methods: In our study occupational exposure of 32 workers of different specialties engaged in aircraft service (aircraft and engine, electrical equipment and instruments, electronic equipment and weapons) to ionizing radiation was examined. Measurements were performed with ionization chamber model 450P-DE-SI "Victoreen" according to the Methodology given in the Regulation on the application of ionizing radiation in medicine (Official Gazette. RS 1/12 of 11.01.2012) and Regulations the conditions for obtaining a licence for performing radiation activities (Official Gazette. RS 61/11 of 19.08.2011). Results were compared with the results of adequate measurements performed by German army.

Results: The calculated values of effective doses in different working positions ranged from 0.42 μSv / h - 5.79 μSv / h. Based on results and exposure time, estimation of the doses and risks for each position were performed. According to results, all investigated positions should be considered as risky workplaces due to exposure to ionizing radiation. The obtained values are lower than the values on the same jobs in the German army, but the time commitment of each employee are significantly higher, which increases the risk of our examinees.

Conclusions: Application of statutory safeguards, professional competence and health status of persons engaged are necessary preconditions for safe operation. It is also necessary, to make a proper organization and changing modes of work in order to reduce the exposure and total risk.

Key words: Aero-engine maintenance, ionizing radiation, risk

MONTE CARLO STUDY ON THE PHOTONEUTRON SHIELDING IN A MEICAL ACCELERATOR ROOM

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Medical linear accelerators operating above 10MV require door shielding for neutron as well as photon. Thermal and epithermal neutrons are absorbed with great effectiveness by ^{10}B. Inelastic scattering or absorption may again produce potentially hazardous gamma rays. Neutron capture in hydrogen and boron releases a gamma ray. In this study, the photoneutrons and photons generated by linear accelerator of 18MeV energy electrons were simulated using radiation transport code MCNPX. Dose equivalent and fluence for neutrons and photons were calculated at various points inside treatment room and outside door. The shielding performance of borated polyethylene (BPE) and lead as shielding material was evaluated. The calculation of the reduction in neutron and photon fluence was performed for various shield thickness as well as the secondary radiation generated by the reaction with BPE and Lead. To determine an optimal arrangement of lead and BPE for neutron and photon shielding, shielding performance was evaluated considering arrangement of BPE and lead. The dose from neutrons is about one order of magnitude higher than the photon dose inside the door. In the case for the BPE thickness-40mm, the fluencies from additional photons generated by the reaction between neutrons and shielding material is about 6.58% and 29.89% of the neutron fluencies at the surface on the source side and outside, respectively. However, for lead, the ratio of additional photon fluence is much smaller than that of BPE. The obtained results suggest that an additional lead is necessary to attenuate neutron-capture gamma ray.

DEVELOPMENT OF THE APPLICATION SOFTWARE AND DESIGN OF THE HARDWARE FOR THE RADIATION SAFETY MANAGEMENT

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Introduction: The instrumentation system and safety manual of radiation facilities typically operate individually as a work process or unit system. The safety management operations in radiation facilities (radiation worker management, radiation source management, facilities management, etc.) are managed by a small number of radiation safety managers. These problems are directly or indirectly the cause of radiation accidents. Therefore, the necessity of systematic safety management guidelines and an integrated radiation safety management system for protection against radiation accidents and an effective management of radiation facilities have been constantly emerging.

Objectives and Methodology: In this study, we try to design an efficient safety management system for complex radiation facilities management and diversified radiation sources. In addition, we developed an integrated radiation safety management system for efficient radiation safety management and facilities management, which we intend to implement for improving the stability and reliability.

Results: The main communication interface (TCP/IP, RS232C, RS422, RS485) of the radiation safety management instrumentation system were analyzed. In addition, based on the design manual and field application, the hardware configuration system (access control, CCTV, movement management, radiation dose monitoring) was analyzed. We consider the scalability and efficiency of the system, and selected a high-frequency band(900MHz)system. This system was installed in the KAERI(Korea Atomic Energy Research Institute) RI-Biomics radiation area for the test operation.

The analysis information of hardware configuration and communication interface can help to optimize the radiation safety management system. In addition, the movement management using the RFID system can be used not only the workers management but also the facilities management and radiation source. We designed the integrated radiation safety management application software for efficient and reliable radiation safety management through the analysis of the hardware configuration and radiation safety management. Based on the requirements of radiation safety management work, the system requirements of application software were analyzed. And we designed the sequence and database of application software. The integrated radiation safety management application software was developed using the C# programming language. This system is able to the radiation source management, worker management, access control, movement management, radiation dose monitoring, exhaust and drain control.

Conclusion: The proposed system is to be operated efficiently in radiation management by very few radiation safety managers. In addition, it will be applicable to standardized technology systems for the safety management of radiation facilities.

RADIATION ABSORBED DOSE ASSESSMENT OF CREW MEMBERS BY MONTE CARLO METHOD

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Crew members of commercial flights always get higher amounts of radiation absorbed dose in respect to normal people which leaving on the earth. This may cause some problems such as cancer and damage to Central Nervous System (CNS) of them. So, it is necessary to calculate the amount of radiation absorbed dose due to space radiation. In this research work the exact absorbed dose rate of the crew members was calculated by online version of EPCARD, a Monte Carlo effective dose calculator, software. To find the Cosmic Rays spectra including neutrons, protons, photons, electrons, positrons and other space nucleon fluxes in different heights the FLUKA software was used. The results of this research showed, the radiation dose at supersonic flight altitudes which flies at 25000 meters is much higher (about 4 times) than the common altitude of commercial flights means 10000 meters, specially at pole latitudes. Furthermore in the next step, radiation absorbed dose rate in different altitudes between 10000 to 25000 meters was calculated in the steps of 150 meters, by fixing the latitude on 32 (Degrees) and (39) (minutes) N / 51(Degrees) 40 (minutes) E (Isfahan – Iran latitude) and also the date of experiment in order to find a simple mathematical model between the altitude and increasing of dose rate. To test this mathematical model the R square test was done and the value of R^2 was calculated for second and fifth order polynomial models. The amount of R^2 was calculated 0.979 and 0.995 respectively which shows a very good values because they are very close to one. According to this mathematical model, if the altitude increases 1m, the radiation absorbed dose rate would increase 0.0009μsv/h for the Latitude of 32 (Degrees) and (39) (minutes) N / 51(Degrees) 40 (minutes) E (Isfahan – Iran latitude). This change is because of the increased level of protons and alpha particles at higher altitudes that is the direct result of sun's solar irradiance.

COMPARATIVE ANALYSIS OF TWO METHODOLOGIES FOR RISK EVALUATION AND ASSESSMENT AT WORKPLACE WHERE PROFESSIONAL EXPOSURE OF IONIZED RADIATION EXISTS IN CONDITIONS OF CONTROLLED RADIATION ZONE

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Introduction: In the recent decades, along with the technological development and the modernization of the equipment, significant and evident progress has been reached in the field of diagnostic radiology. That leads to increase of proportional participation of the radiation coming from the medical imaging in the populational effective annual dosage *per capita*. According to this there is a possibility of increasing of annual effective dose among the radiological workers that increases the possibility of occurring of stochastic effects.

The aim: The aim of the work is to create comparative analysis of two methodologies for risk evaluation and assessment at workplace where professional exposure of ionized radiation exists in conditions of controlled radiation zone and to verify their applicability in practice. The strengths and the weaknesses of both methodologies are discussed in the paper.

Resources and Methods: Within the framework of a certain descriptively epidemiological research study, data from the conducted preventive medical checkups on an examined group of total number of 30 workers have been used, all employed in a department for x-ray diagnostics, who have been professionally exposed to ionized radiation (x-rays) in conditions of controlled zone of radiation. Data from the environmental measurements performed in the working environment and personal TL dosimetry of the people tested within period of five years have been used for identification of the harmfulness and for evaluation of the exposition.

Results: The results from the medical checkups and environmental measurements were used to estimate the risk of ionizing radiation by the method of matrix evaluation. On the other side, the results from the TLD were used to estimate the risk by the method of nominal coefficients of risk. The results received from the both risk assessments do not differ significantly, and such difference is not of essential value from aspect of professional exposition.

Conclusion: The results from the conducted research for risk assessment received by both different methodologies lead to a conclusion that the workers are exposed to risk that is being characterized as acceptable risk for professionally exposed workers. Pursuant to that, the evaluation of a risk from x-ray exposition could be made by using any of these methodologies, but as more precise and user friendly is the methodology based on nominal and total quotients of risk from ionized radiation, which we hereby recommend for further use.

Key words: Ionized radiation, professional exposition to radiation, risk assessment at workplace, stochastic effects, and nominal quotients of risk.

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A TOOL FOR ESTIMATION OF EFFECTIVE DOSES IN INTERVENTIONAL CARDIOLOGY

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The number of procedures in interventional cardiology is increasing over the past years. They contribute an important share to the over-all exposure from medical sources. Doses are usually described by kerma-area product (P_{KA}) and cumulative air-kerma at the interventional reference point (K_{IRP}). These dose descriptors are very helpful for comparison with diagnostic reference levels (DRLs) and estimation of peak skin dose (PSD). One of the indicators used to estimate risk of stochastic effects of ionizing radiation is effective dose. Its value is calculated using different techniques; they usually rely on Monte Carlo simulations of radiological examination. The approximate value of effective dose is obtained using one of the standardized mathematical phantoms and commonly used imaging technique. However, more accurate results can be obtained if calculations used patient's original examination data available from the records. This simulation would take considerable amount of time and it is not practically possible. In our paper we simulated hypothetical examination using different anode potentials (65—125 kV), field-sizes (indicators 16, 20 and 25) at 60 cm focus-skin distance, cranio-caudal angles (-45°—45°) and anterior-oblique angles (30°—150°) in PCXMC 3.0. Constant values included thickness of added filtration and P_{KA}. Obtained set of more than 1000 conversion factors were stored in Microsoft Access Database. We used simple code that was based on trilinear interpolation to obtain in-between values not covered by simulation. Later, we used real patient data to obtain effective dose using two different methodologies – simulation of real data and calculation using trilinear interpolation of conversion coefficients. The obtained results differ by less than 2%. Conversion factor between P_{KA} and effective dose is 0.268 mSv/Gycm^2. Developed software is specific to the x-ray unit used. Although establishment of initial conversion factors in time consuming, the value of effective dose is obtained instantaneously for any patient imaging protocol used.

INFLUENCE OF VARIOUS FACTORS ON THE DOSE OF PERSONNEL DURING CARDIOLOGY DIAGNOSTIC

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In cardiology diagnostic the number of coronary catheterisation is increasing constantly. It is a minimally invasive procedure to access the coronary circulation and blood filled chambers of the heart, while it causes one of the highest potential exposures of the staff.

The aim of this work was the determination of staff exposure during coronarography diagnostics and the investigation of the effect of some factors (working method, fluoroscopy time, body) on the dose of personnel. The measured doses were compared to the doses measured by the National Dosimetry Service.

The doses were measured under and over the apron on the chest, on the left eye (eyebrow), left shoulder out of the apron, and left wrist of 3 cardiology doctors. Each doctor carried out 5 diagnostic coronarography procedures. For radiation protection of the personnel 0.5 mm thick lead aprons, thyroid collar, lead glass protection hanging from the ceiling and protection between the table and the floor were applied. The doses measurements were carried out with thermoluminescence - TL (LiF:Mg,Cu,P-MCPN) and radiophotoluminescence – RPL (GD-352M) dosimetry systems.

No systematic difference between the TL and RPL dosimetry systems was found. The annual effective doses E_{eff}, calculated from the measured values as well as the equivalent doses to the eyes, were in all cases below the dose limit (20 mSv/year) as required in the new IAEA Basic Safety Standard (Interim Edition, 2011).

Significant differences of the effective doses were found among the three doctors in the recent study (15.5 mSv, 10.4 mSv, 8.7 mSv), as well as in the earlier results of the National Dosimetry Service (9.2 mSv, 4.6 mSv, 1.3 mSv), i.e. one doctor with a long experience received higher doses than the other two. From these results it can be also seen that a single dosimeter under the apron performed by the National Service underestimates the E_{eff} as compared to the double dosimetry carried out in this study. The doses depend on many factors in coronarography, such as fluoroscopy time, complexity and number of examinations, experience of the doctor, feature of the doctor (height) and patient himself. Therefore measurements with good statistics have to be carried out.

ESTIMATION OF SKIN EXPOSURE DURING RADIOGRAPHY/VERIFICATION OF EMPIRICAL FORMULA

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The knowledge of radiation output from X-ray unit plays an important role in knowing radiation dose to patient in a radiological examination. The radiation exposure of x-ray machine is a function of kV_p, mAs applied, the target to patient distance, type of rectification and the filtration of the unit. If an appropriate formula is developed incorporating the x-ray exposure and other parameters on which x-ray exposure depends, one can estimate the radiation dose before undertaking that particular radiological examination.

In present study we have measured the output of X – ray machines making use of $CaSO_4$: Dy thermoluminescence dosimeters. Pre calibrated [Chougule et al 1992] five TLD discs were placed on wax phantom, one at the center of radiation field and four discs along the circumference of 3 cms. radius from the center of radiation field. After the exposure the discs were stored in radiation free area for about 24 hours and then measured for radiation dose on Thelmador-6000 [BARC make] TL reader. One thousand such measurements were done for various set of combination of kV_p, mAs, distance of TLD from target. Edmonds I R [1984] gave an empirical formula for estimating the skin entrance dose of X – ray machine as

$$\text{Skin entrance dose}(\mu Gy) = \frac{K\,(kV_p)^n \cdot mAs}{P^n\,(TSD)^2}\left\{\frac{1}{T} + 0.14\right\}$$

where 'K' is constant of proportionality, 'P' is 2 for single phase generator and 1 for three phase generator whereas 'T' is the added filtration in mm of Al. In present study we have used the measured dose values to find out the parameters of the formula and it was observed that

$$\text{Skin entrance dose}(\mu Gy) = \frac{107\,(kV_p)^{1.985} \cdot mAs}{P^n\,(TSD)^2}\left\{\frac{1}{T} + 0.14\right\}$$

Above formula tested for various exposure factors and holds good within ± 10% accuracy. Detailed results are discussed in this communication.

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RADIATION ABSORBED DOSES ASSESSMENT OF PHYSICIAN AND PATIENT (CHILD AND ADULT) DURING RENAL ANGIOGRAPHY

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Renal angiography is one of the X-ray medical imaging methods to study inside of kidney's blood vessels. In this examination, patient and medical team receives high radiation absorbed doses due to long duration of fluoroscopy.

Staff radiation absorbed doses; mainly arise from the secondary scattered radiations from patient. Even though staff absorbed doses are not too much per examination, because they perform several surgeries every year, their total radiation absorbed doses could be remarkable. Among the staff, physicians receive the most amounts of radiation absorbed doses in renal angiography because; they stay more time near the patient. So, investigation of patient and physician absorbed doses during renal angiography is very important. In this research, radiation absorbed doses of some radiosensitive tissues of patient (adult and child) and physician during renal angiography have been calculated by using ORNL phantoms and Monte Carlo method (MCNPX code). The results of this research showed, in renal angiography of right kidney in a one year old child and adult patient, gall bladder with the amounts of 2.32 and 0.35 mSv respectively, has received the most radiation absorbed doses among other tissues. It should be noticed that, child tissues have received much more radiation absorbed doses in comparison to the same tissues in adult phantom. About the physician, left hand absorbed the most amounts of dose, means 0.036 mSv, in renal angiography of adult patient. In addition, absorbed dose of the physician's lens eye, thyroid and legs were 0.005, 0.001 and 0.006 mSv respectively in the above study. Although these values are less than the reported thresholds by ICRP 103, it is essential to note, these doses are related to one examination and since the physician usually performs more than one surgery per day and much more surgeries per year, the mentioned tissues may receive doses more than the allowed thresholds. Tuning the values of some parameters such as high voltage, current of the tube, radiation field size and time of exposure, strongly affect on radiation absorbed doses of patient and medical team. So, choosing the optimum values of these parameters are very important especially for the children. Also experience and skill of physician, calibration and fine tuning of the system, collaboration of medical team during angiography which affect directly on the duration time of angiography and using proper radiation shields such as lead apron, glasses and thyroid collar should strongly recommended to reduce the physician and patient radiation absorbed doses.

OCCUPATIONAL EXPOSURE DUE TO WORKING WITH A PORTABLE DENTAL X-RAY SYSTEM

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Portable dental x-ray systems are used for dental diagnostic radiography of the patients. Such systems are generally used in emergency situations (e.g. in natural disasters), for disable/aged peoples, in operation rooms and field-hospitals.

In this research, the occupational exposures due to the using of a Genoray dental portable x-ray system have been investigated. For this aim, the doses of some sensitive organs of operator have been measured using implanted TLD in a Rando-phantom during different situations of exposure.

The maximum total dose was measured .095 mSv per shot in closed hand-arm situation of the operator when superior maxilla of patient is exposed down. As well the eye-lens and finger doses have been measured 0.111 and 1.400 mSv per shot respectively.

Thus considering the geometry of this imaging system as well as annual organ dose limits, the main limitation in number of its using is determined by results of the hand dose.

SCATTER FRACTION WITH SIMULATIONS. REVISITING RADIATION SCATTER IN X-RAY IMAGING.

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Current methodologies in shielding design of x-ray imaging facilities assume that the scattered air kerma is proportional to the primary air kerma, field-of-view (FOV) and scatter fraction. The later quantity was determined through measurements made by Trout and Kelley, using a phantom made of Masonite sheets representative of a human torso. Later, Simpkin and Dixon pointed out several problems in these data, namely that the model assumed all workloads at a single (maximum) operating potential, and that the voltage (kV) waveform and filtration used by Trout and Kelley for the low operating potentials was outdated. To correct the data for low kV they took measurements of the scatter fraction made by Dixon at 90°, using up-to-date equipments with a higher filtration and using a more sophisticated phantom. The current data is, therefore, based on measurements done in different times, with different generations of equipments and very different phantoms. In this work we revisit, by means of Monte Carlo simulations, these studies. We present a series of simulations that address the following questions: What are the limits for the assumption that the scattered air kerma is proportional to the FOV? Does the choice of phantom material affects the results of Trout and Kelley? Is the extrapolation for higher filtrations valid to other scattering angles? How does the grid, cassette, supporting structures and a realistic anthropomorphic model of the patient affects the transmitted and scattered radiation? Furthermore, what is the influence of these structures and materials in the image quality? Simulations provide a faster and cheaper way to take measurements with a constant controlled setup, covering all possibilities and variables with unlimited data and no risk to overload the x- ray tube. The code package PENELOPE was used with a geomtery that replicates the phantom of Trout and Kelley and another, a more realistic phantom, including internal organs. The primary beam was taken from the IPEM database with kV=50-150 for a tungsten anode. Four FOV were considered for each centered and edge aligned incidences. The dependence of the scatter fraction on the FOV, incidence, materials and complexity of the phantom will be discussed.

RADIATION DOSES IN ADULTS CT PRACTICE IN SERBIA: INITIAL RESULTS

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There are around 120 CT units operating in Serbian hospitals. Data on patient doses have been collected on 6 of them and results are presented in this work. To present the typical practice in the country, data collection was performed on different types of CT units including different vendors (Siemens, GE and Toshiba) and units with different number of detector rows (4, 16 and 64). Data were collected in terms of $CTDI_{vol}$ and DLP values for head, chest and abdomen examnination for adult patients. Dose values are estimated as a mean value of at least 10 patients per examination type. Results show a wide range of dose values even on the same models of CT scanners. Protocols on CT units are created by vendors and usually are not changed while patients are examined.Compairing 3 Siemens models (4, 16 and 64-rows CT units) general conclusions about relation between doses and number of rows can not be made. The relation differs depending on body part examined. In head examination, on the same models of GE units, CTDI values differ for factor 2. The highest values for chest are on 64-row Toshiba CT unit, 34 mGy for CTDI. In abdomen examination, doses on this unit are 10 times higher than on others, 227 mGy for CTDI and 3078 mGy×cm for DLP. In 16-rows CT units, doses are higher on GE compared to Siemens' unit, while in 64-rows doses are higher on Toshiba compared to Siemens' unit. For abdomen, CTDI is 20 times higher on Toshiba. The assessed patients' doses in terms of CTDI and DLP were below or slightly above the reference levels and in accordance with surveys from other countries, although the scope for dose reduction trough optimisation of the examination protocol was observed.

REDUCING RADIATION EXPOSURE: OUR EXPERIENCE REVIEW AND FURTHER STEPS

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Background: Even though yearly quantitative measures of radiation exposure have never been performed in Macedonia, we are witnessing a spectacular rise in all imaging modalities, particularly CT and MRI. In our last yearly report (unpublished data) we have noted an increase of 22% for CT and 32% for MRI examinations. Regarding the biological effects of elevated radiation dose exposure and the potential risks of cancer development, we consider the appropriate use of radiation in medical purpose as a matter of public health care and a priority in our health institution.

Aim: The aim is to evaluate the adequacy and performance of our current Low-Dose approach in medical imaging against the ALARA principles.

Method and Materials: We will review the radiation exposure reduction measures undertaken so far, and detect systematically their insufficiencies against the ALARA principles. We will use our internal records and reports of performed examinations.

Discussion: The basic principles for reducing radiation exposure could be grouped as followed*:* reducing the overall radiation exposure to any kind of medical investigations involving X-rays and lowering radiation exposure during CT examinations.

Results: So far, our delivered low-dose efforts succeeded in rising, but only partially, the awareness of radiation exposure, the best results, as expected, being achieved among radiologists and staff at the radiology department.

Our current Low-Dose approach as we assessed it, has proven to be insufficient in monitoring and recording patients radiation exposure during their treatment in our hospital. We need to monitor cumulative radiation doses. We lack insight in the appropriateness of certain imaging investigations involving radiation exposure induced by our multidisciplinary clinical practice. We aim to go one step beyond optimizing current CT protocols and evaluate the overall radiation exposure per patient, generated by teams of physicians when treating one pathology as a resultant of their multidisciplinary approach. Simultaneously, an individual radiation exposure report for each patient will be issued in order to record their cumulative radiation dose. We need to implement a Continuous Quality Improvement Approach. Namely, the cumulative dose report not only per patient but per treated medical condition is a key quality indicator allowing in the same time to assess the pertinence of our clinical practices.

Conclusion: The result of our review, clearly demonstrated that, in order to fully implement a Low-Dose approach according ALARA principles, we need to undertake the following next steps:

-raising awareness among all physicians to radiation exposure
-standardize key CT protocols in our daily practice
-recording cumulative radiation dose per patient

-elaborate a performance evaluation tool, allowing review and assessment of daily clinical practices as key steps in a Continuous Quality Improvement Approach.

COMPARISON OF PATIENT RADIATION DOSE FROM CHEST AND LUMBAR SPINE X-RAY EXAMINATIONS IN 10 HOSPITALS IN GHANA

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This study estimated the patient dose in chest and lumbar spine radiographic examinations in 10 hospitals in Ghana. Dose estimations were done on 1045 patients (aged, 39.6 + 10.6 y; range 18–85 y) involving 501 (47.9 %) males and 544 (52.1%) females for a total of 1495 individual projections. The entrance surface dose (ESD) for the patients was assessed by an indirect method, using the patient's anatomical data and exposure parameters utilised for the specific examination and Quality Assurance Dose Database software developed by Integrated Radiological Services Ltd in Liverpool, UK. The study showed variations in the ESDs for chest examinations with five of the hospitals having values above the internationally recommended levels. ESDs for lumbar spine anterior–posterior and lateral projections were within acceptable limits. Diagnostic reference levels proposed by the International Commission on Radiological Protection based on patient dose data are imperative to the current Ghanaian situation and will lead to a reduction of the radiation dose.

Key words: Patient dose, chest and lumbar spine examinations

OPTIMIZATION OF PATIENT RADIATION PROTECTION IN PELVIC X-RAY EXAMINATION IN GHANA

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Pelvis X-ray examinations inevitably involve exposure of the gonads to ionizing radiation. In line with the principle of keeping doses as low as reasonably practicable (ALARP), accurate patient dose measurement is vital if we are to ascertain that these exposures are fully optimized. The study aimed to provide patient dose estimates for pelvis examination being undertaken at 10 separate hospitals in Ghana in order to provide an initial quantitative indication of each site's typically achievable radiation safety and quality standards. The method employed was adapted from established methods and peer reviewed literature, such as the International Atomic Energy Agency (IAEA) publications on optimization of the radiological protection of patients undergoing radiography, fluoroscopy, and computed tomography examinations in some countries in Africa, Asia, and Eastern Europe. Dose measurements were calculated on 323 patients (137 (42%) male, 186 (58%) female, ages, 38.56yr ± 9.0; range 20–68). The entrance surface dose (ESD) was determined by an indirect method, using the patient's anatomical data and exposure parameters utilized for the specific examination. The Quality Assurance Dose Database software (QADDs) developed by Integrated Radiological Services Ltd. in Liverpool, UK was used to generate the ESD values. The study identified variations in the technique factors used compared with the recommendations in the European Commission (EC) quality criteria. Eighty percent of the hospitals recorded lower ESD values below IAEA recommended diagnostic reference levels (10 mGy) and 40% of the hospitals exceeded the UK national reference value (4 mGy). However, one hospital consistently recorded higher ESDs than the other hospitals. The variations in the data recorded demonstrate the importance of creating awareness by the radiographic staff on quality assurance and standardization of protocols to ensure satisfactory standards and optimized radiation dose to patients and staff.

Key words: Patient radiation protection, gonadal dose, patient dose audit

INFLUENCE OF COMPUTED TOMOGRAPHY ANGULAR TUBE CURRENT MODULATION ON PATIENT SKIN DOSE

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Angular tube current modulation in computed tomography (CT) is a feature of CT scanners that allows change of tube current in real time to achieve an optimum distribution of x-ray intensity for every viewing angle. This is just one of the options that is used to reduce patient dose. New imaging techniques, such as CT perfusion or CT fluoroscopy, could cause patient skin doses to approach deterministic levels. In this study we have used thermoluminescent dosimeters (TLD) to determine how local patient skin dose depends on angular tube current modulation. 8 dosimeters were placed on an elastic band around the patient body (abdomen area) and positioned at 45° from each other. Prior to exposure they were calibrated (in clinical conditions) using RTI's Piranha dosimeter that was calibrated in a Secondary Standard Dosimetry Laboratory. 18 patients were included in the study. Obtained results differ from patient to patient due to their different size and number of scan series. Values were normalized for different tube current. The highest doses were received in the area of umbilicus (100%), than doses to left and right lateral side (76% and 81%), following by spine area of posterior side (55%) and anterior side ±45° from umbilicus (54% and 60%), while the lowest doses were received on posterior side, ±45° from spine area (43% and 41%). It is most likely that the highest dose is in the area of umbilicus was due to additional exposure during topogram (scout). Other results correspond to expectations; highest doses are received in the areas where more exposure is needed to penetrate the patient.

ROMANIAN PEDIATRIC EXPOSURE TO IONIZING RADIATION FROM DIAGNOSTIC MEDICAL PROCEDURES

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Medical exposure to ionizing radiation is the main source of artificial exposure, especially for children. Taking into account that children have a higher sensitivity to the ionizing radiation and thus a higher risk of developing certain cancers in adulthood, it is necessary to monitor all exposures performed with the purpose of estimating of the radiation dose received by each child.

According to the legally binding provisions, the recording system at the hospital level shall include at least the information concerning: patient data, data on individual exposure parameters used and data for patient dose assessment, as appropriate (DAP-meter values, skin absorbed dose, DLP/CTDI indication).

Based on data recorded in some state pediatric hospitals in Romania, estimations were made for the frequency of X-ray examinations and the mean dose received by patients for major conventional radiological and CT examinations performed during the years 2011-2013.

In our study, the available data for patient doses assessment were DAP and DLP indications and conversion coefficients for relating measured values of DAP/DLP indications to effective doses are estimated by the NRPB Report 262.

The obtained data suggest the necessity to introduce, at the national level, the health cards with a special section for the registration of all medical exposures to ionizing radiation and the estimated dose received by each pediatric patient. Prescribing other radiological examinations to the pediatric patient should be done by raising awareness of the higher risks of exposure to ionizing radiation, taking into account the dose received until the prescribing time and the choice use of other non-irradiated imaging techniques.

CALCULATED DOSES TO FAMILY MEMBERS OF PATIENT TREATED WITH RADIOIODINE 131

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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 aim of this study was to evaluate effective dose to family members of patients treated with radioiodine 131 and to compare with dose constraints proposed by International Commission on Radiological Protection (ICRP) and International Agency of Atomic Energy IAEA. The Thermoluminiscent dosimeters (TLD 100) and RADAR (Radiation Dose Assessment Resource) software were used for assessment of effective doses to sixty family members of the same number of hyperthyroid and thyroid carcinoma patients. Estimated effective doses were well below recommended dose limits except in some cases. RADAR calculated doses were higher than estimated doses than 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. After three days of hospitalization thyroid cancer patients represent minimal radiation hazard to their family members.

ASSESSMENT OF ABSORBED AND EFFECTIVE DOSE FOR PATIENTS AFTER PARATHYROID GLAND SCINTIGRAPHY USING ^{99m}TC-MIBI

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This paper shows results of dose assessment for most irradiated organs and effective dose following application of radiopharmaceutical ^{99m}Tc-MIBI for parathyroid gland scintigraphy. Study included minimum 10 male adult patients, and applied activity was 370 MBq.

Methods: Data used for dose estimation were taken from Publication ICRP No 80, and the assessment is based on MIRD internal dosimetry model. Using available biodistribution of ^{99m}Tc-MIBI data, 7 organs were considered to be significant sources of radiation. S-values for those organs and their combinations were singled out and absorbed doses in these organs and effective dose were calculated (Method 1). The absorbed doses for the same 7 organs, as well as the effective dose, were also calculated using available data of absorbed and effective doses per unit of injected radioactivity (Method 2).

Results: The most irradiated organs were kidneys with the absorbed dose of 12 mGy (M1), and 13.3 mGy (M2). The following organs, with respect to level of irradiation, were upper large intestine, lower large intestine, liver, bladder, small intestine and muscles. When assessed by Method 2, the only difference was for small intestine, which is in fourth place. The difference between two methods was lowest for most irradiated organ, about 10%, while it was highest for the small intestine, about 60%. For the rest of the organs the differences were between 13% and 37%. Calculated values for effective dose were 3.8 mSv (M1) and 5.5 mSv (M2), with difference of 32%.

Discussion: Method 1 takes into consideration only 7 organs and their mutual irradiation. Even though the accumulation of radiopharmaceutical is not significant in none of the remaining organs, all of them contribute, to some extent, the irradiation of considered 7 organs and effective dose, so it can be assumed that the real value of effective dose is higher than the one assessed using Method 1. Variations among the patients in the group (weight, organ mass, presence and the extent of pathology etc.) most likely exceed the variations in the assessed doses.

Conclusion: Due to large number of factors affecting the accuracy of dose assessment, it can be said that the agreement of the two methods, with the average difference in estimated dose values of 27 %, is satisfying, and both methods can be equitably used in routine dose assessment for patients in nuclear medicine.

UNCERTAINTY OF DOSE ASSESSMENT IN CONVENTIONAL RADIOGRAPHY

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Dose assessment is performed in diagnostic and interventional radiology to evaluate the equipment performance, for the optimization of practice or to assess the risk emerging from use of ionizing radiation in medicine. The dose values result from measurements, computations or a combination of both. Results of dose assessment depend strongly on the assumptions made and methodology and procedures used. Such results are only acceptable if they are presented together with uncertainty that allows for their reliability. According to Guide to the expression of uncertainty in measurements (GUM), the assessment of uncertainty is based on the combination of uncertainties of statistical nature (Type A) and other information (Type B). This is achieved by assigning the probability density function to the each input quantity. There are numerous influencing quantities that contribute to the uncertainty of the dose. For each of these exposure-related quantities, the applicable error sources and their magnitudes vary, depending on the equipment used to make the measurement, whether or not relevant corrections have been applied and how computations are performed. This study has identified and quantified a range of influencing quantities that may be used to estimate the combined uncertainty of patient dose assessment in the simple radiographic examination – chest radiography. Examples of how these uncertainty sources combine to give the uncertainty of the patient dose-related quantity - entrance surface air kerma (ESAK) are presented. The ESAK was calculated from measured x-ray tube output and known exposure parameters. The study is based on exposure factors collected from 40 chest radiography examination of adult patients obtained at one conventional radiography unit. Influencing quantities were divided in three groups. First group is related to physical and technical factors as tube voltage and tube current reading, radiation output, geometry and patient positioning indication. Second group is related to air kerme measurement (intrinsic error of dosemeter, difference in beam quality, irradiation geometry, air density correction, electromagnetic compatibility, beam size and homogeneity, tube voltage accuracy and repeatability, scattered radiation, dosemeter positioning and its long term stability), while third group of influencing quantities is related to patient characteristics as backscatter radiation, geometry and positioning and accuracy of applied tube voltage. Depending on the size of the sample, the assessed expanded and combined uncertainty ranged from 23 to 31%, with dominant influence of uncertainty of B type. Uncertainty of type A was significant only when patient samples are small. Uncertainty is a quantitative indication of the quality of assessed dose, obtained by measurements, computations or combination of both. It supports optimization of dose assessment. Knowledge of influencing quantities that significantly contribute to the total uncertainty of dose assessment enables implementation of method for their reduction in order to improve accuracy of dose assessment.

MEASUREMENT OF PATIENT DOSE IN VASCULAR INTERVENTIAL RADIOGRAPHY

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Cardiac catheterizations have contributed greatly to the treatment of heart diseases. However the radiation exposure to the patient is significantly higher compared with other radiological examinations. The objectives of this study are to evaluate the level of radiation dose received by the patients in order to introduce local diagnostic reference levels. A total of 108 consecutive patients who underwent cardiac catheterization using Dose-area product (DAP) were measured.

The mean of DAP ± SD of therapeutic and diagnostic cardiac catheterization procedure was (80.84 ± 25.09) mGy.cm^2 and (67.04 ± 26.65) mGy.cm^2 respectively and for; male, female and total was (74.87± 41.33, 72.52± 27.91 and 73.84± 35.75) mGy.cm^2 respectively. The mean of fluoroscopic time ± SD of therapeutic and diagnostic cardiac catheterization procedure was (6.10 ± 4.51 and 5.31 ± 2.96) minutes respectively and for male, female and total was (7.6±6.67, 5.90±3.70 and 6.89±6.26) minutes respectively. The mean of entrance surface dose ± SD of Therapeutic and diagnostic cardiac catheterization procedure was (80.8384± 25.08, 67.0351± 26.649) mGy respectively, and for male, female and total was (74.87 ± 41.33, 72.52 ± 27.91 and 73.84 ± 35.74) mGy respectively.

The study concluded to the fact that the patients received relatively high dose but the dose is necessary to enable the diagnosis or treatment and there are still minor differences with global standards.

STAFF DOSIMETRY IN INTERVENTIONAL CARDIOLOGY USING ELECTRONIC PERSONAL DOSIMETRY

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Study was performed to measure radiation dose to staff involved in fluoroscopically guided interventional cardiology (IC) procedure. 33 staffs were monitored 39 IC procedures performed during 4 week period in two most occupied cardiology centers in Khartoum, Sudan. Staffs were 15 cadiologist, 13 nurses and 5 radiographers. Radiation doses were measured using electronic personal dosimeters (EPD) type RAD-60 with Energy compensated si-Diode detectors (RADOS, Finland). Perior to experimental measurements, EPDs were calibrated in three X-ray qualities described in the ISO 4037 narrow spectrum series a viable at the secondary standard dosimetry laboratory. EPDs were calibrated to measure personal dose equivalent, using ICRU slab phantom.

For occupational dose assessments, each staff was provided one EPD worn on chest above the lead apron and read immediately after the procedure. Effective doses were estimated from the measured personal dose equivalent Hp(10) using single dosimetry algorithm [1]. Based on the calibration resulted, the selected EPDs performed satisfactorily in X-ray qualities indicated. Cardiologist received the highest doses, followed by nurses and then technologists.

Estimated median and maximum effective doses per year presented in fig. 1. maximum effective doses up to 1.4 mSv per year was estimated. The calculated effective doses were well below the annual dose limits of 20 mSv per year recommended by ICRP [2]. However, the absent of continuous radiation surveillance is the major of concern since individual doses may vary according to the length, type and complexity of these procedures.

The study could encourage staffs to acquire electronic dosimeters as way for individual dose measurements in the absent of legal dosimetry service in the county. EPDs could replace passive dosimeters owing to direct reading and alarm features however, it is not practical for double dosimetry as more than one EPDs will be required for each staff and also owing to difficulties in their use in some organs such as neck and at the extremities.

OPTIMIZATION OF RADIOLOGICAL DOSES TO PATIENTS UNDERGOING INTRAVENOUS UROGRAPHY (IVU) EXAMINATIONS IN ADDIS ABABA, ETHIOPIA

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Background: The effects of ionizing radiation should be a permanent concern in radiological practice, especially in exams with long duration and high exposure, like Intravenous Urography (IVU).

Objective: To calculate entrance surface dose (ESD) and dose area product (DAP) as the result of radiation exposure of patients due to Intravenous Urography examinations.

Methods: A cross-sectional study was conducted on 145 adult patients above 16 years of age. Two government and two private hospitals were included in the study period from February 2012 - March 2012 in Addis Ababa, Ethiopia. The characteristics of the radiographic equipment and the exposure data of each patient were recorded using designed format. The radiation output of the x-ray machines was measured using unfors RaySafeXI R/F detector. Doses delivered to patients were determined using appropriate equation. The obtained data were analyzed using statistical software.

Results: An average of 6.0 radiographs was obtained per patient. The mean ESAK,ESD, Cumulative ESAK, Cumulative ESD ranges from 3.9 to 7.6 mGy, 5.5- 10.1 mGy, 21.5 to 53.5 mGy and 29.9 - 74.3 mGy respectively.

Conclusion: The mean ESD recorded in this study (8.6mGy) was less than the diagnostic reference levels (DRLs) recommended by Commission for European Community (10mGy) and International Atomic Energy Agency (10mGy). These insure that the IVU examination performed in Addis Ababa was capable of achieving acceptable dose levels for patient safety.

Key words: Intravenous Urography, ionization radiation, patient dose

OPTIMISATION MEDICAL EXPOSURES IN INTERVETION RADIOLOGY USED IN MOTHER TERESA HOSPITAL, TIRANA, ALBANIA

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Ionizing radiation nowadays have become powerful tool in diagnostic, radiotherapy and nuclear medicine, so at the same time significantly is increasing the population's medical exposures, as result a large number of people always need training for the above purposes. Under these conditions, the immediate task to arise is the optimization of these exposures, so to avoid the possible detrimental effects of different radiation, 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 even less that the rates allowed. This allows on the other hand a significant reduction of doses received even by persons exposed professionally.

In diagnostic radiology is needed a periodical check of the physical and geometrical characteristics of X ray beam, and uses of screens which are used to divide areas which are not related to the examination. In all the cabinets, in general, related with use of ionizing radiation or radioactivity materials for medical purposes a periodical quality control check of equipments is needed.

Always we have to 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 which are working in different cabinets of "Mother Teresa" Hospital.

EVALUATION OF PATIENT AND STAFF DOSE DURING PACEMAKER PROCEDURES

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A pacemaker is a device that helps regulate the rhythm of the heart as well as the rate at which it beats, the process of installing the pacemaker conducted under high dose of x-ray; this is a result of the complexity of process and the length of their time, so the patient and staff are exposed to high radiation doses, But the proportion of the benefit of the process is greater than the ratio of rays damage. This research studies the dose of pacemaker procedure to 193 patients for three types of pacemakers under fluoroscopic control, and found that the dose calculation (mGy cm^2) had high variation from the standard value. The mean value of DAP (mGy cm^2), ESD (mGy) and FT (min) for male were (447.21±0.07), (4.47±0.02) and (11.68 ± 0.02) respectively. The mean value of DAP (mGy cm^2), ESD (mGy) and FT (min) for female were (403.59±1.4), (4.03±0.01) and (11.38±0.12) respectively. The mean value of flouro time (min) for (VVI), (VDD) and (DDD) are (07.30), (12.24) and (27.50) respectively. The mean value of DAP (mGy cm^2) for (VVI), (VDD) and (DDD) are (240.09±1.03), (614.05±0.07) and (643.50±2.01) respectively. The mean value of ESD (mGy) for (VVI), (VDD) and (DDD) are (18.45±0.07), (40.31±0.12) and (42.24±0.01) respectively.

EVALUATION OF PATIENT AND STAFF DOSE IN BRAIN INTERVENTIAL RADIOGRAPHY

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Interventional Radiology (IR) refers to a range of techniques which rely on the use radiological image guidance (X-ray fluoroscopy, ultrasound, computed tomography [CT] or magnetic resonance imaging [MRI]) to precisely target therapy. IR improved the diagnosis many of the diseases. This study aimed to Evaluation of Patient and staff dose in brain interventional Radiography. A total of 100 patients were examined in royal care hospital.

Effective doses, and the corresponding risks of radiation-induced cancers, are presented for patients undergoing many IR procedures. The dose–area product (DAP) was used to quantify the amount of radiation used to perform IR procedures. The results were tabulated in the Tables (mean ± standard deviation (sd)) and the range of the readings in parenthesis. The dose values in diagnostic radiology are small, therefore the dose were presented in milli-Gray. For dose calculation, this result spatial for male and female respectively. Patient individual exposure parameters were recorded (tube voltage (kV=70±0), tube current and exposure time product (mAs=10.25±7.55686±597.20) and source to image distance (SID=97.20±1.64, 97.82±8.384), age=(41.00±11.74744.70±17.44) and ESD (11.53±9.5022411.53±9.50224) and DAP (1238.8±1123.06, 1153.3±950.22413) and f.t (4.22±.86,5.73±1.60) and D.O.P (32.75±1.893, 34.50±6.05).

The correlation coefficient which is defined as a measure of the degree of linear relationship between two variables, usually labeled X and Y used in this study to describe the relation between two variables affect patient dose ESD(mGy) against tube current time product(mAs) and floro time(f.t) and dose area product (DAP) . And (DAP) against duration of procedure(D.O.P) Positive correlation coefficients were obtained between these values. This means if the value of mAs or kV increases the value of the ESD increases.

THE PATIENT AS A RADIOACTIVE SOURCE - AN INTERCOMPARISON OF SURVEY-METERS FOR MEASUREMENTS IN NUCLEAR MEDICINE

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Aim: In nuclear medicine the patient himself becomes a radioactive source after application of a radiopharmaceutical. The aim of this study was to show the exposure of staff during preparation and application of the most commom nuclides (Tc-99m, F-18, I-131, Y-90) and while supporting patients. Being aware of a possibly elevated radiation exposure is necessary for individual radiation protection in the daily routine.

Methods: Dose rate measurements in the ambiance of 31 patients chosen at random in our hospital department took place directly after treatment with Tc-99m (HDP), F-18 (FDG) and I-131 (Nal). All measurements were performed close to the patient's sternum and at a distance of 0.5, 1 and 2m. Additionally, dose rates of radioactive sources (capsule, syringe, tubing with Tc-99m, F-18, I-131 and Y-90) were measured at distances of 0, 0.1, 0.2, 0.3, 0.5 and 1m. Readings were taken with different survey-meters and active personal dosimeters (APD).

Results: Results of readings are exemplarily discussed for a distance of two meters to patients and for average activities. For Tc-99m-HDP dose rates of 3 - 4 μSv/h were received (N = 10, A = 715 MBq), for F-18-FDG 7 - 12 μSv/h (N = 10, A = 343 MBq), and for I-131 12 - 20 μSv/h (N = 14, A = 1253 MBq). Measurements of sources are exemplarily shown for one radioiodine capsule measured in a typical thin plastic shielding (I-131, d = 0.1m, A = 166 MBq). Photon dose rates were in the region of 0.8 - 1 mSv/h whereas three devices capable of measuring mixed fields (beta and gamma) gave dose rates between 1 - 1.2 mSv/h. High-energy beta emitters like Y-90 gave substantially higher dose rates. For older devices the reading of dose rate Hx yielded similiar results compared to recent devices after conversion into the ambient equivalent dose rate H*(10). In one case comparatively high readings of dose rate H*(10) had to be corrected for the detectors' response. Dose rate measurements using APD are appropriate but they aberrated especially for low dose rates (< 10 μSv/h). Furthermore, APD needed longer to get to a realistic measured value display (ca. 2 min.).

Conclusions: After diagnostic procedures even in close contact to the patient dose rates do not exceed 1 mSv/h. In very close contact to patients treated with high activities of I-131 dose rates of 15 mSv/h may be reached (treatment of thyroid carcinoma, A = 7.5 GBq). For a close contact to radioactive sources very high dose rates may be found expecially for unshielded beta-emitters or for high-energy emitters with insufficient shielding. This emphasizes the imperative principle of keeping distance to the source and reducing the time of close contact. Readings of various survey-meters give comparable results after taking conversion factors and different efficiencies into account. The APDs used in our study are also capable of measuring dose rates when the count rate of the device is high enough.

REDUCTION OF PATIENT'S DOSE OF I-131 THERAPY BY USED LOCAL DIURETIC JUICE

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The aim of the study is to compare the results of the external exposure and the range of the dose spread by the patients, hospitalized in two different groups of 3-5 d receiving radioiodine therapy because of thyroid cancer, and one of group were giving the local diuretic plant (Barley) as local juice. The control group was 28 patients they were isolated as international precautions after taken I-131 capsule 100 mCi, and their external exposure was recorded day by day after first 24 hrs and the distance for external measurement was 1 m at the abdominal level. The mean of external exposure values of patients at forth day were 30.24±12.92 μSv h−1. The second group after taken I-131 capsule 100 mCi we were gave the patients Barley juice (250 mL) after every meal three times on day and their external exposure was recorded day by day after first 24 hrs. The mean of external exposure values of patients of this group at third day was 26.92±9.89 μSv h−1. We are observed that the external exposure from the second group is clearly decreased to low levels which that is contribute to decrease the patient dose and it is also decrease the exposure from the patient to his/her family.

SUGGESTED DIAGNOSTIC REFERENCE LEVELS FOR MAMMOGRAPHY X-RAY EXAMINATION IN ETHIOPIA

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Background: A diagnostic reference levels (DRLs) form an efficient, concise, and powerful standard for optimizing the radiation protection of a patient.

Objectives: To establish the first Ethiopian mammography diagnostic reference level (DRL) as a part of ongoing dose reduction program.

Materials and Methods: A cross-sectional study was conducted on breast patients having compressed breast thickness (CBT) between 3.7 cm to 5.3 cm in Addis Ababa, Ethiopia. Five mammographic units and 755 mammograms were included in the study period. The mean glandular dose (MGD) was assessed for standard size breast substituted by different polymethyl methacrylate (PMMA) phantoms and imaged under typical clinical conditions in two mammography units. Peak kilo voltage (kVp) and entrance surface air kerma (ESAK) were measured using calibrated digital dosimeter Mult-O-Meter Unfors, model 535L, Sweden. The data were analyzed statistically.

Results: The 3rd quartile value of all mammography units and that of private mammography units were found to be 2.37 and 1.73 milligray (mGy), respectively. Hospitals 3rd quartile values of MGD ranges between 1.57 to 7.21 mGy. The MDG based on 4.0 cm polymethyl methacrylate (PMMA) measurements was found to be 1.5 mGy.

Conclusion: Both phantom and patient dose values indicated unnecessary high doses in one government mammography unit. For this mammography unit, urgent dose-reduction measures and follow-up actions were recommended.

Keywords: Diagnostic reference level, mammography, mean glandular dose, polymethyl methacrylate (PMMA) phantoms

WHICH IS MORE DOMINANT PARAMETER IN DAP VALUE: FLUOROSCOPIC TIME OR PATIENT SIZE?

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Interventional cardiology procedures usually delivered the highest radiation dose to the patients in comparison to other procedures. It is therefore important to know which parameter has the highest impact on patient dose.

From September to December 2013 at the University Clinic of Cardiology, Skopje a study was conducted about the relevance of different factors on Dose Area Product (DAP) value as an indicative parameter for patient dose.

For 90 patients were collected data for chest perimeter, type of procedure, fluoroscopic time, DAP value and medical team which perform the procedure. It was made correlations between type of procedure and fluoroscopic time; Between DAP value and fluoroscopic time; DAP – type of procedure; DAP – Anterior Posterior (AP) patient dimension and DAP – Body Mass Index (BMI). For stenting and coronarography procedures it was done analysis of average fluoroscopic time for six medical teams.

The results indicate that fluoroscopic time has higher impact on DAP values than BMI or AP patients dimension. However, comprehensive analysis should be done about influence of tube angulations on exposure parameters, as well as about the dynamically changing of SID (Source Image Distance).

For the same type of procedure performed on the same angiography system, it was found a variation in fluoroscopic time among medical teams.

In conclusion, the relationship between patient size, type of procedure, fluoroscopic time and the DAP value, is very complex and depends on many clinical and technical factors.

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CONTRIBUTION OF NON-CODING GENOME TO SUSCEPTIBILITY AT LOW DOSES OF RADIATION (STUDIES ON A COHORT OF SERBIAN CHILDREN EXPOSED TO X-IRRADIATION)

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on behalf of the Dark.risk consortium

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The Dark.Risk group consists of 5 participating institutions (HMGU, ROSA, ENEA, UAB and SERGAS) based in 4 different EU member states. In the Dark.Risk project we will work with the Serbian Registry of Tinaea Capitis Children (SRTCC) to prepare the way for the study long-term health effects in a large cohort of almost 24 000 individuals exposed to a highly uniform dose of radiation during childhood. As the effects of low doses of radiation are still uncertain a series of biomarkers are needed to distinguish between radiation-associated and radiation-independent cases (*i.e.* biomarkers of causality).

The past five years has seen an explosion in knowledge of the structure and function of the human genome, forcing a paradigm shift in the way we look at the information encoded in our DNA. Less than 5% of the human genome is transcribed into protein coding messenger RNA. It now turns out that 90% of the genome is actively transcribed into RNA in a regulated manner. A number of different functional classes of non-coding RNA transcripts are recognized, two classes of which (microRNAs and long non-coding RNAs) have distinct functions ascribed to the different components of the non-coding transcriptome.

Differentially expressed lncRNAs were identified following quantile normalization, fold change filter processing (GeneSpring) with sample and control (sham irradiated) comparison in defined cell culture approach. Of the seven regulated lncRNAs that we subsequently selected for validation, all exhibited the same up- or down-regulation following irradiation in each of the three analysed cell lines. This is the first indication that a given radiation-regulated lncRNA has a defined role across different cell lines during the radiation response. Such a result is a strong contrast to the situation observed for miRNAs, which exhibit highly cell-type specific changes in expression.

In particular the non-coding microRNAs appear to be highly stable in biological materials having a high potential to be used as effective biomarkers in the future. Dark.Risk will prepare the way to use SRTCC biomaterials to evaluate the potential of the non-coding genome to deliver information on disease outcome and association with radiation.

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ZEOCIN-INDUCED ADAPTIVE RESPONSE IN YEAST *SACCHAROMYCES CEREVISIAE*

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Adaptive response as a nonspecific phenomenon is a defense mechanism whereby cells exposed to a low dose of radiation become more resistant when curtain intertreatment time is given before the subsequent higher dose. One already known inductor of adaptive response in plant cells is the radiomimetic zeocin. A suitable model for studying the mechanism of adaptive response is yeast *Saccharomyces cerevisiae* as most of the genes responsible for the DNA double strand breaks repair have human homologues.

The aim of this study is to test the potential of zeocin to induce adaptive response to zeocin in yeast cells *Saccharomyces cerevisiae* and to clarify experimental conditions in which the most pronounced adaptive response is observed.

Materials and Methods: *Saccharomyces cerevisiae* D7ts1 diploid strain was used as a test system. The following endpoints were studied: survival, gene conversion, reverse mutation and mitotic crossing-over when different intertreatment times were given- 45 minutes, 1, 2, 3 or 4 hours. Our preliminary results showed that 10μg/ml zeocin is a suitable concentration to be used as a priming dose and 100μg/ml zeocin- as a test dose. Constant-field gel electrophoresis was applied for measuring DNA double strand breaks repair capacity. The effect of different recovery times were studied- 1, 2, 3 and 4 hours.

Results: The results obtained by the D7 mutagenicity test show that when 45 minutes intertreatment time between the priming dose and the test dose is given the cells survival is the highest in comparison with this of cells treated only with the test dose. This corresponds to the decreased levels of gene conversion, reverse mutations and mitotic crossing- over. They are comparable with the control non-treated cells.

In order to test the acceleration of DNA double-strand breaks rejoining caused by zeocin, 45 minutes intertreatment time was used. The best adaptive response was induced when up to 1 hour recovery time was given after the treatment with the test dose.

Discussion: We demonstrate for the first time that zeocin may induce adaptive response to zeocin in yeast cells *Saccharomyces cerevisiae*. The most pronounced adaptive response is observed when cells are given 45 minutes intertreatment time and up to 1 hour recovery time. In these conditions cells can undergo the damaging activity of the radiomimetic Zeocin.

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MECHANISMS OF RADIATION HORMESIS ON *DROSOPHILA* MODEL

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Long-term studies of radiation hormesis, made in our research group have identified several key mechanisms. As cells with weakened protection will accumulate damages and will be exposed to ageing with the greater speed, than steady cells, their radio-induced elimination at early development stages will result in delay of age-dependent changes and will lower speed of ageing (Moskalev 2007). The use of genome-wide transcriptome sequencing has allowed us to identify new molecular mechanisms of radiation hormesis associated with changes in gene expression of signaling pathways Hedgehog, Jak-STAT, mTOR, Notch, TFG-beta, Hippo, genes proteasomal degradation of the basal transcription factors, nucleotide excision repair and mismatch repair, circadian rhythms, ribosomal transcription, DNA synthesis and metabolism of xenobiotics (Moskalev *et al*., 2014).

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DISPLAY OF GENETIC INSTABILITY OF CELLS IN THE POPULATION OF CHLORELLA VULGARIS AFTER SPARSELY AND DENSELY RADIATION EXPOSURE

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This article represents the data on the laws of action of sparsely and densely ionizing radiation on the culture of green unicellular alga Chlorella vulgaris. The article gives the values of RBE of alpha radiation (^{239}Pu, LET = 125 keV / m) for chlorella. As a part of this research the survivalship curves were obtained for Chlorella cells, pre-irradiated with rare and densely radiation at equivalent doses of 50, 150, 300, 400 Gy. Different types of cell inactivation caused by ionizing radiation along with the delayed effects of colony-formation of Chlorella cells that characterize the genetic instability of the population have been discovered here for the first time. It is shown that under densely radiation cells are able to form colonies in later periods in comparison with the cells subjected to sparsely ionizing radiation. It has been found that the RBE of densely irradiation of chlorella is equal to 3. Delayed effects of colonies formation, characterizing genetic instability, are observed both after sparsely and densely irradiation, but with different doses that induce the greatest damage: It is within the range of 50 - 100 Gy for gamma-irradiation and 20 - 50 Gy for alpha-irradiation. Minimal duration of the cell recovery is the same and requires around 48 hours. At the same time densely radiation causes more injuries per dose unit, so the cells which are capable of restoring demonstrate the colony-formation within 48 hours after irradiation.

Key words: Gamma-irradiation, alpha-particles, chlorella, RBE, delayed effects of colonies formation

IN VITRO RADIOSENSITIVITY AND ADAPTTATIVE RESPONSE TO GAMMA-IRRADIATION OF BLOOD LYMPHOCYTES OF CHILDREN LIVING IN THE ARAL SEA BASIN (ZONE OF ECOLOGICAL DISASTER)

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Process of the Aral Sea drying during last 50 years creates ecological disaster in the whole region. Moreover, the Sea was the main source of food and employment for people living around. Many people went away and for those who stayed to live in the region (adults and children), the disaster led to increased problems with health, including oncological diseases. So, in frames of INTAS project we carried out the complex comparative study aimed to analyze state of health of children, living in the Aral Sea Basin (Aralsk town) and in Central Kazakhstan (settlement Akchi). In this communication its part, connected with analysis of children's genomic instability and in vitro radiosensitivity, will be present.

Materials and Methods: Groups of boys and girls of 5-8 years old, living in Aralsk (44 persons) and Akchi (34 persons), were formed from randomized excerpts of the data of the previous medical and psychological examination. Samples of venal blood (1.0 ml) were cultivated in the Cytochalasin B micronucleus assay.

For each child 3 parallel blood cultures were analyzed for the detection of background level of genomic instability, effects of 1.0 Gy gamma-irradiation (Co^{60} source "Cirus", dose rate 0.2 Gy/min) after 24 hours of culture, and adaptive response to gamma-irradiation: one culture was irradiated twice – first with an adaptive dose of 0.05 Gy 24-th hours after the beginning of cultivation, and 5 hours later with a challenge dose of 1.0 Gy. Microscopic analysis included the detection of differences in the spectrum of cellular populations (cells with 1-4 and more nuclei), estimation of the frequency of micronuclei (MN) in all types of dividing cells, frequency of apoptotic as well as mitotic cells. Altogether, about 1500 cells, including 1000 binuclear cells were analyzed per slide. Statistical analysis was performed by applying the standard statistic computer programs.

Results: Frequency of cells with MN as well as radiosensitivity, determined by frequency of cells with MN, were very high in both settlements and did not differ between Aralsk and Akchi. At the same time the fraction of children with positive adaptive response in Akchi (36.6%) was significantly lager than in Aralsk (12.8%). The fraction of children with negative adaptative response was higher in Aralsk then in Akchi – 64.1% and 23.3%, respectively.

Correlation analysis had shown that the radiosensitivity of children's blood lymphocytes is connected with different parameters as: state of mother's health during her pregnancy ($r> 0.9$), child gender ($r> 0.6$-0.8), a child's state of health: weight / height index ($r> 0.9$); microanomalies of development ($r> 0.5$); anxiety expression ($r> -0.4$) and several past diseases ($r> - 0.4$): cardiovascular, chronic respiratory and infectious, as well as group of indicators of family social status: income and father's social status ($r> 0.9$), housing conditions ($r> 0.5$ -0.7). Furthermore, it has been found many weak but significant correlations.

DIRECT VERSUS INDIRECT RADIATION ACTION IN IRRADIATED VEGETAL EMBRYOS

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Experimental study on the biological effects of X-rays and accelerated electrons on the maize embryos with focus on the influence of water content at the moment of irradiation. X-ray photon beam as well as accelerated electrons were generated by the linear particle accelerator VARIAN CLINAC 2100SC of University Hospital "Sf. Spiridon", Iasi, Romania, with a dose rate of 2.24 Gy/min. As known, the water radiolysis release free radicals that attack biomolecules in addition to the directly absorbed radiation energy. Thus, watered versus dry maize caryopses were irradiated (0.5-3.0-6.0 Gy) and analyzed in identical conditions. Biochemical assay of nucleic acids and cytogenetic investigations of mitosis phases, mitotic index and aberration index were carried out.

Spectral measurement of ultraviolet light absorption underlined the estimation of relative content of nucleic acids. Then the cell chromosomes were colored using Fuelgen rapid staining method. After coloring, the top of the roots were cut and crushed through the squash method onto microscope slides. For cell visualization was used an optic microscope – NIKON Y-FL eclipse e600 to which was attached a photo camera – NIKON e950. Increased water content resulted in the nucleic acid biosynthesis inhibition in irradiated samples in contrast with low dose radiations that tend to stimulate the nucleic acid biosynthesis. The mitotic index measuring the percentage of dividing cells in the root apical meristem tissues was found diminished in watered samples indicating the negative influence of indirect effects of water radicals. Chromosomal aberrations were identified like: expelled chromosomes, C-metaphases, picnotic chromosomes, chromatin bridges, retard chromosomes with no specific correspondence with the irradiation dose or radiation nature. General tendency of aberrant mitoses enhancing was recorded in watered samples – with up to the 100% for 6.0 Gy radiation dose. The most radiosensitive mitosis phase was found to be the metaphase where not only simple chromosomal aberrations like those already mentioned were recorded but also complex ones like multiple chromatin bridges and expelled chromosomes. Slight positive influence on the cell division either at the level of nucleic acid biosynthesis or mitotic index of the 0.5 Gy radiation dose was discussed in the term of hormesis. The general conclusion was related to the dominancy of indirect radiation action by means of the radicals from the water radiolysis.

GDF-15 OVEREXPRESSION INCREASE RADIOSENSITIVITY OF BREAST CANCER CELLS

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Purpose: The GDF15 gene (Growth Differentiation Factor-15) is a member of TGF-b superfamily. They are involved in many cellular processes in both physiological and pathological conditions including cell growth, cell differentiation, apoptosis and radiation altered cellular homeostasis. The purpose of this study is to investigate the effect of GDF15 gene overexpression on proliferation and radiosensitivity of breast cancer cells in vitro and in vivo.

Materials and Methods: A mouse breast cancer LM-2 cell line with stable transfection of full-length mouse GDF15 cDNA was established. Cell growth and proliferation was observed using WST assay. Radiation induced GDF15 and TGF-b1 expression was determined by qRT-PCR. Radiosensitivity was determined by colony formation assay in vitro and by tumor growth delay assay in vivo. Radiation induced plasma cytokine profile was measured by cytokine array (R&D system)

Results: In mouse breast cell line LM2 stably expressing GDF15 gene, cell proliferation was slight increased and sensitivity to ionizing radiation was decreased.

The LM-2-GDF15 cells were more resistant to radiation-caused apoptosis, with the decrease of TGF-b1 mRNA expression. In the in vivo model the plasma level of IL-10 and TNFa were elevated and CXCL-12 and IL-2 were decreased in tumor bearing 2Gy exposed animals. Overexpression of GDF15 in syngenic mice less suppresses the growth of breast cancer cells and decreased radiosensitivity in vivo.

Conclusions: GDF-15 may improve the radioresistance of breast cancer cells via effecting cell survival, inhibiting of radiation-induced apoptosis and inhibiting TGF-b1 related cytotoxic action.

SYNERGISM MODEL FOR THE COMBINED ACTION OF RADIATION AND HEAT

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Several factors can exert their influence on biological objects at the same time. Among others, the combination of high temperature and ionizing radiation has been widely used in cancer treatment. In many cases, the combined exposure results in a higher effect than expected, which is commonly called synergism. This study has been carried out to reveal regularities of the synergism due to the combined action of radiation with another factor such as heat, chemical and physical one on the biological objects. Theoretical approach was done on the basis of hypothesis that synergism may be related to an additional lethal or potentially lethal damage arisen from the interaction of the two different types of sub-lesions induced by both agents. The sub-lesions were considered ineffective when each agent was applied separately. The additional damage responsible for the synergistic effect seems to be irreversible. Experimental results as well as data published by others were used for model validation. A mathematical model was developed and tested upon the available data. The model predictions were in a good agreement with experimental data. The versatility of the model was proven by successful applications to combined effect of ionizing radiation with various factors such as ultrasound, cigarette smoking, and chemicals. For a constant dose rate, synergistic interaction of radiation and heat at low intensity was realized only within a certain range of temperature, independently of the target organism analyzed. Decreases in radiation dose resulted in an increase in the duration of thermo-radiation action to achieve the same absorbed dose. Therefore, the number of thermal sub-lesions would also be increased resulting in the disruption of the condition at which the highest synergy should be observed. To preserve an optimal ratio of heat-induced damage to radiation-induced damage with any decrease in the dose rate, the exposure temperature should be decreased. In this regard, a long duration of interaction of ionizing radiation with environmental heat is of importance for radiation protection, and risk assessment as low intensities of deleterious factors can, in principle, synergistically interact with each other.

MOLECULAR MARKERS FOR THE ASSESSMENT OF RADIATION-INDUCED OXIDATIVE STRESS IN OCCUPATIONALLY IRRADIATED INDIVIDUALS

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Occupational exposure of nuclear workers is mainly due to gamma rays, which belong to low linear energy transfer (LET) radiation, occurs at low-dose rates and may accumulate effective doses of up to 0.5 Gy. Biological effects of low dose low dose rate radiation are mainly due to highly reactive, oxygen containing free radicals and molecules known as reactive oxygen species (ROS). Elevated levels of ROS may cause chronic oxidative stress that can permanently disrupt cellular redox homeostasis, leading to persisting elevated levels of DNA lesions, such as double strand breaks. Thus chronic oxidative stress increases the risk of oncogenic, neurodegenerative, cardiovascular and other diseases and predetermines the necessity for systematic biomonitoring of persons employed in the nuclear industry. The present work is part of an ongoing molecular epidemiology study on radiation workers and is focused on antioxidant status, DNA damage and repair capacity of blood components.

Mononuclear cells and plasma were collected from 40 occupationally exposed individuals from the "Kozloduy" Nuclear Power Plant in Bulgaria (cumulative radiation dose from 0.1 to 588.1 mSv) and 20 unexposed controls within a similar age range. The level of DNA damage was analyzed by Comet assay (gel electrophoresis of single cells) under neutral conditions. The cell capacity to repair DNA damage was determined after additional *in vitro* exposure of the cells to 3 Gy γ-rays. Spectral tests based on absorption and fluorescence measurements were employed for the assessment of redox status markers, such as ROS levels, antioxidant activity of blood plasma and mitochondrial electrochemical potential in lymphocytes.

Statistical analysis of the data revealed that occupational chronic exposure to low doses did not lead to significant changes in ROS levels or mitochondrial membrane potential. The total antioxidant status of plasma showed a tendency towards decrease with increasing radiation dose, as well as with increasing age. The cumulative effect of these two factors – radiation dose and age, is statistically significant. DNA damage levels increased with age as expected, and age seemed to have a bigger effect than radiation dose. However, in the group of subjects with radiation doses below 200 mSv, DNA damage levels slightly decreased with age, allowing us to assume the presence of some adaptive response in the low dose range. Although a significant effect of radiation dose on DNA damage and repair capacity was not found, it should be noted that the data in the exposed group was widely dispersed in comparison to the controls, emphasizing the importance of individual radiosensitivity.

USE OF PROTEOMICS IN SEARCH FOR BIOMARKERS OF RADIATION EXPOSURE

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Different organs respond to radiation by altering the level of protein expression and their post-translational modification status. Therefore, it is reasonable to believe that protein expression profiling can be used to successfully find radiation-associated protein biomarkers in biological samples such as urine, blood/serum or even tissue. However, only three serum and plasma proteins have been defined as potential bio-indicators of radiation exposure so far, namely amylase, citrulline and the Flt3-ligand. However, these biomarkers do not seem to be sensitive enough for dose estimations long after the exposure. Thus, the discovery of radiation-associated protein biomarkers remains an enormous challenge within radiobiological research because of the time- and dose-dependent variation of protein expression. Animal and cellular studies have been used as a tool to identify potential biomarkers that then may be tested in molecular epidemiological studies.

This presentation will describe novel applications of proteomics that will facilitate the search for biomarkers in clinical samples. It will also highlight methods used in tissue-based biomarker research. Some biomarkers that have been associated with radiation-induced heart disease will be discussed in detail.

INVESTIGATION OF MICRO RNA (MIR) EXPRESSION IN ARCHIVAL ANIMAL SAMPLES

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Investigation of the micro RNA (miR) profiles of spleen samples from archival samples from Janus tissue archive (http://janus.northwestern.edu) pointed out a differential expression of several miRs in animals exposed to high doses of radiation delivered as a single fraction v.s. controls and mice exposed to fractionated radiation. A set of 47 micro RNAs (miRs) and control mRNAs was selected based on these data and used for preparation of a custom 96 well plate microarray with 47 miR targets in each well. This microarray was used to screen additional formalin fixed, paraffin embedded spleen samples selected from among thousands of mouse samples deposited in the mouse tissue archive Janus (janus.northwestern.edu) housed in Department of Radiation Oncology at Northwestern University. These spleen samples came from non-irradiated mice and animals exposed to 21 different radiation treatments. These mice were exposed to different qualities and doses of radiation (total doses ranged from 0.01-50cGy for neutrons and from 0.1 to 20 Gy for gamma rays), delivered as acute, fractionated or daily exposures, with different dose rates. Following irradiation, animals lived out their full lifespan. The spleen samples used for miR microarray analysis came from a total of 135 mice. Of these, 17 mice were non-irradiated controls. While spleen samples from great majority of animals were healthy, 16 animals had developed a spleen cancer. A set of nineteen miRNAs (out of possible 47) showed robust expression in all 135 samples. Of these, five mi RNAs (miR 665, miR 503, miR503, miR 690, miR 1195 and miR 511) also showed differential expression in mouse lymphoma cell lines with different radiosensitivity status. Our results suggest that the expression of these five miRs increases more in the radioresistant cell line LYR than in the radiosensitive cell line LYS following irradiation. Expression of messenger RNAs and proteins implicated in apoptotic response of LYS and LYR cell lines was evaluated as well, using Q-PCR arrays and Western blots.

TRISOMY 21 AND CONGENITAL MALFORMATIONS AFTER CHERNOBYL: CONFIRMATION OF MICROCEPHALY IN BIRDS BY HUMAN MICROCEPHALY. NON DISJUNCTION OF CHROMOSOMES DURING MEIOSIS, INDUCED BY IRRADIATION, IS RESPONSIBLE OF TRISOMIES (21, 13, 18) NINE MONTHS AFTER CHERNOBYL.

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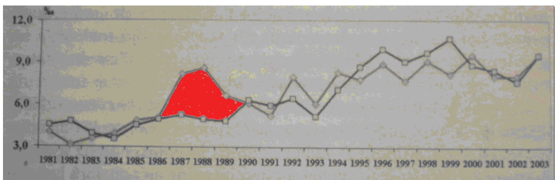
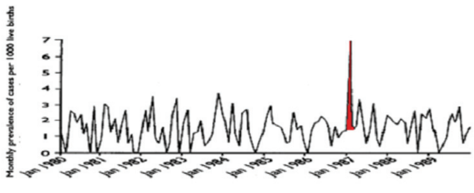
Nine months after Chernobyl (April 26, 1986), there were 4 peaks of mongolism, in Belarus *(Lazjuk G, 2008)*, in Berlin (Germany) *(Sperling K, 1994),* in Scotland *(Ramsay CN, 1991)* and in Sweden *(Ericson A, 1994)* in January 1987. Irradiation from monazite soil containing Thorium at the time of conception can be followed by Mongolism, in Kerala (India) *(Kochupillaia N, 1976)* and Yangjiang (China) *(Science, 1980: 877).* In Belarus, a multitude of congenital malformations were found in a survey of 70 000 births (polydactyly, spina bifida, labial clefts, intestinal and esophageal stenosis, limbs, digestive, anal, cerebral and uretral malformations, mongolism, etc...), with a striking peak 9 months after Chernobyl (curve: In red). Malformations can be classified in trisomy 21 (intestinal and esophageal stenosis), trisomy 13 (Patau syndrome) (polydactyly, cleft lip/palate, microcephaly, microphtalmy) and trisomy 18 (spina bifida). In Ukraine (Polissia), 96 000 births were analysed: The incidence of spina bifida was 22/10,000 (18-27/10,000) versus 9/10,000 in Europe *(Wertelecki W, 2010)*; interestingly, there were microcephaly and microphtalmy, and teratomas. This is coherent with microcephaly, deformed eyes and becks detected in a study of 500 birds by *Moller AP (2011)*, in the Chernobyl area. Cataracts in birds *(Mousseau TA, 2013)* were also found in humans *(Bandajevsky YI, 1997)*: The culprit is Cesium 137, a photosensitizer used in solar industry. Curiously there is also a case of human hepatic Wilson's disease described after irradiation (Uranium can be extracted from copper mines). Concerning the mechanism of Trisomy (13, 18 and 21), there are experimental proofs that irradiation induces a non disjunction of chromosomes during meiosis in drosophila, mouse and hamster (*Nicolaidis P, 1998; Grell RF, 1999; Salvontaus M-L, 1975; Hansmann I, 1990).* Mongolism has 2 other irradiation markers: Translocations (of oncogene ets) and leukemia. Thus malformations/trisomies are direct consequences of irradiation from Nuclear accidents and/or Atomic Bomb explosions. Birds are excellent predictive models for human abnomalies (cutaneous tumor, microcephaly, cleft lip/palate and cataract). In conclusion, Nuclear energy is too dangerous for newborns and must be abandoned and replaced by safe alternatives (solar and wind energies) as did Germany after Fukushima. Mongolism is not caused only by age in itself (because age cannot induce translocations and leukemia), but also by accumulation of irradiation effects with ageing.



Source: Lazjuk G. I., Lazyuk D. G., Possible teratogenic and mutagenic effects at population of Bélarus as the consequences of the Chernobyl catastrophe, colloque AFCN Bruxelles, avril 2006.



Sperling K, BMJ 1994: *Trisomy 21 in West Berlin from January 1980 to December 1989.*

IONISING RADIATION INDUCES PERSISTENT CHANGE IN CARDIAC MITOCHONDRIAL FUNCTION OF C57BL/6 AND APOE$^{-/-}$ MICE

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Excess risk of heart disease occurs a long time after exposure to lower doses of radiation. The aim of the study was to elucidate pathological changes occurring in heart mitochondria in a long term after the exposure. Atherosclerosis-prone ApoE$^{-/-}$ and C57BL/6 mice were exposed to local cardiac irradiation using two doses (X-ray; 2 and 0.2 Gy). Using quantitative proteomic approach we found alterations in the levels of proteins of mitochondria-associated cytoskeleton, respiratory chain, ion transport and lipid metabolism. The respiratory capacity of irradiated C57BL/6 cardiac mitochondria was significantly reduced at 4 and 40 weeks. In parallel, protein oxidation was increased, suggesting enhanced oxidative stress. Radiation had no effect on respiration or oxidative stress in the ApoE$^{-/-}$ mitochondria but alterations were observed in the lipid metabolism. In conclusion, our data show that irradiation causes persistent proteomic and functional alterations in heart mitochondria which may lead to malfunctioning of the heart muscle.

PRECLINICAL DEVELOPMENT OF A BRIDGING THERAPY FOR RADIATION CASUALTIES

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Victims of a terrorist attack presenting with the hematopoietic or gastrointestinal syndromes resulting from exposure to excessive levels of ionizing radiation will succumb to sepsis if not adequately treated. The probability of survival is increased substantially if the victim's immune system is allowed to recover before sepsis sets in. We report here preclinical development of a new bridging therapy which will allow the victim's immune system to recover from damage caused by ionizing radiation.

CD2F1 mice were irradiated with lethal, whole-body doses of cobalt-60 gamma-radiation and then transfused intravenously (retro-orbital sinus) with whole blood, peripheral blood mononuclear cells (PBMC) or plasma from tocopherol succinate (TS)- and AMD3100-injected mice after irradiation. Survival was monitored for 30 days after transfusion of whole blood, PBMC or plasma. Intestinal and splenic tissues were harvested after irradiation and cells of those tissues were analyzed for markers of apoptosis and mitosis. Bacterial translocation from gut to heart, spleen, and liver in TS-mobilized PBMC-treated and irradiated mice was evaluated by bacterial culture. Efficacy of such cells was also tested against combined injury (radiation plus wound).

The infusion of PBMC from TS- and AMD3100-injected mice significantly enhanced survival after high radiation doses causing hematopoietic and gastrointestinal syndromes, inhibited apoptosis, increased cell proliferation in tissues, and inhibited bacterial translocation to various organs compared to mice receiving vehicle-mobilized cells. TS-mobilized progenitors also mitigated radiation combined injury in mice. TS and AMD3100 mobilized progenitors into peripheral circulation and the infusion of mobilized progenitor-containing blood or PBMC acted as a bridging therapy for immune-system recovery in mice exposed to high, potentially fatal doses of ionizing radiation. We suggest this novel bridging therapeutic approach that involves the infusion of TS-mobilized hematopoietic progenitors following acute radiation injury might be applicable to humans as well.

Note: The views expressed do not necessarily represent the Armed Forces Radiobiology Research Institute, the Uniformed Services University of the Health Sciences, or the Department of Defense.

DEVELOPMENT OF STATE REGISTER OF PERSONS EXPOSED TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT IN BELARUS

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Background: Creation and development of the state information resource in health care, monitor health status affected by the Chernobyl catastrophe population of Belarus is an important and actual problem, which allows an objective evaluation of health status.

Purpose: The article presents data on the creation, stages of development, goals, objectives and problems of functioning of the State Register of persons exposed to radiation as a result of the Chernobyl catastrophe, other radiation accidents at this stage.

Material and Methods: The analysis of the system of collection and processing of information collected in the State Register of persons exposed to radiation as a result of the Chernobyl catastrophe, other radiation accidents, planned the main ways to improve it, defined the strategic objectives of its functioning, provides a definition of the categories affected by the Chernobyl accident.

Results: At present the State Register of persons exposed to radiation as a result of the Chernobyl catastrophe, other radiation accidents is a unique medical information system in terms of volume (registered more than 200,000 people), and on the territorial scope (the whole territory of Belarus).

Conclusion: Experience working the State Register of persons exposed to radiation as a result of the Chernobyl catastrophe, other radiation accidents can hope that a personalized and a long-term registration changes in state observed contingent can provide the information basis for an objective answer to the question of the real damages the health of the population of Belarus affected by the disaster at Chernobyl nuclear power plant.

EFFECTS OF THE CHRONIC LOW DOSES ON AQUATIC SPECIES WITHIN THE CHERNOBYL EXCLUSION ZONE

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During 1998-2013 we studied the rate of chromosomal aberrations in embryo tissues of the pond snails and root meristems of higher aquatic plants, and also hematologic indexes of mantle liquid of the snails and peripheral blood of fishes in water bodies with different levels of radioactive contamination within the Chernobyl exclusion zone (ChEZ). The absorbed dose rate for hydrobionts from water bodies of the ChEZ during the period of researches registered in a range of $4.6 \cdot 10^{-3}$-3.4 Gy year^{-1}, and in the control water bodies - up to $1.7 \cdot 10^{-3}$ Gy year^{-1}. Cytogenetic analysis of embryos of the pond snails testifies the increased level of chromosomal aberrations in the mollusks from stagnant water bodies of the ChEZ in comparison with control reservoirs. During the period of studies the highest values were registered for the snails of closed reservoirs of the ChEZ where the rate of chromosomal aberrations was registered within range of 18-27%, that on the average more than in 10 times exceeds the spontaneous mutagenesis level for aquatic species. The snails of river ecosystems were characterized by the low level of aberrant cells - 2.5-3.5%. For the mollusks from the control lakes this index was reached on the average 1.5% with the maximal values 2.3%. The positive correlation between chromosomal aberration rate and absorbed dose rate in the pond snails' embryos in water bodies of the ChEZ was registered. The rate of chromosomal aberrations in root meristematic cells of different higher aquatic plants from the most contaminated lakes of the ChEZ was in range of 7-17%. In the plants of rivers this index was on the average 3.5-5.0%, and was not exceed 2.6% in control water bodies. Thus, the rate of chromosomal aberrations in hydrobionts of the stagnant water bodies in the ChEZ repeatedly exceeds the level of spontaneous mutagenesis, inherent to the aquatic species (2.0-2.5%) and can be display of radiation-induced genetic instability. In fish dwelling in lakes of the ChEZ a considerable qualitative and quantitative changes in hematopoietic system were registered. In water bodies with high level of radioactive contamination the content of leucocytes in blood of fish was substantially below than their level in fish of the control reservoirs. At that the total amount of thrombocytes in fish from contaminated lakes was higher than control indexes. In blood of the perch from Glubokoye Lake the decreased content of oval forms of thrombocytes was determined. The erythrocytes of the crucian carp and perch from Glubokoye Lake were the most susceptible to pathological changes of both nucleus and cell wall. The total amount of cell abnormality in this water body was registered at following level: for the crucian carp 59.5‰, and for the perch 22.6‰, that considerably exceeds the indexes of violations for fish from control reservoirs (1.9-4.1‰).

LATE CANCER AND NON-CANCER EFFECTS OF CHRONIC RADIATION EXPOSURE OF BONE MARROW

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Accident at former soviet plutonium production plant “Mayak” in 1957 resulted in emission of considerable amount of radioactive substances to the atmosphere. Radioactive fallouts caused contamination of the environment by Sr-90 and short-lived radionuclides (East-Ural Radioactive Trace, EURT). Due to consumption of contaminated food and milk, population was affected to relatively high radiation exposure. Analysis of cancer and late non-cancer effects of radiation exposure was conducted using registered data on causes of deaths of rural population of EURT northern part for period 1957-2000. Exposed (4 844 persons) and unexposed (6 158 persons) groups of the study relate to the settlements where initial surface contamination by Sr-90 was above and below 3.7 kBq/m^2 respectively. By estimating proportionate mortality ratios statistically significant excess mortality was observed in exposed population due to the groups of causes of death as follow: stomach, liver and cervix cancers; group consisted only of stomach cancer alone; non-cancer deceases of infectious etiology. Nonsignificant but remarkably high risk was observed for the following groups of causes of death: bone cancer; leukemia; liver cancer; cervix cancer. Insignificant, virtually zero risk was found for: non-gastrointestinal solid cancers; colon and lung cancers; non-infectious non-cancer deceases. At the same time, considerable radiation doses were absorbed in bone (mean bone surface dose about 0.1 Gy) and colon (mean dose about 0.07 Gy). Doses absorbed in other organs and tissues were negligible, <0.01 Gy for most tissues. To analyze obtained results, recent findings on strong attributability of stomach, liver and cervix cancers to bacterial and viral infections were taken into account. According to IARC, stomach cancer relative risk associated with helicobacter pillory is 5.6, liver cancer relative risks associated with HBV and HCV are 23 and 17 respectively, cervix cancer relative risk associated with HPV is >100. At the same time association of lung cancer, colon cancer and some other common malignancies with infections is either not established or of low significance. We suggested that excess mortality due to cancer and non-cancer diseases of infectious etiology is associated with radiation exposure of bone marrow due to Sr-90. Irradiation of hematopoietic stem cells and progenitor cells damages hematopoiesis and suppresses the immune response. Secondary immune deficiency induced by chronic radiation increases susceptibility to the bacterial and viral infections. Such late effect of radiation exposure can be considered within the concept of deterministic tissue reactions.

Acknowledgements:
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THE STUDY OF HYPERMETHYLATION IN IRRADIATED PARENTS AND THEIR CHILDREN BLOOD LEUKOCYTES

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Earlier we demonstrated elevated levels of chromosome aberrations and TCR mutations both in irradiated parents (liquidators of the Chernobyl accident and residents of the territories with radionuclide pollution, 135 - 688 kBq/m^2, ^{137}Cs) and in their children. Individual variability of genome destabilization was observed by all criteria used and manifested both in the diverse spectrum of transgenerational mutational effects and in different levels of their expression. Intensive accumulation of knowledge about the epigenetic regulation of genome function leads to the necessity to explore new aspects of genotoxic action of radiation on the human body. The study of aberrant methylation of CpG islands in the promoter regions of genes (*P16/CDKN2A, P14/ARF, RASSF1A, GSTP1*) in blood leukocytes of liquidators of the Chernobyl accident (n=83, 38-76 years) and control subject of two groups (n=48, age ≤ 35 and n=65, age > 35 years) was carried out using methylation-sensitive restriction endonuclease analysis followed by PCR. The duration of the works of liquidators ranged from 2 weeks to 6 months. The individual doses ranged from 50 to 480 mSv. The total number of AciI sites (5'…C↓C GC…3') in the analyzed fragments ranged from 2 to 7 for different genes. Only 1 subject (2,1%) of control group (the healthy young individuals, age ≤ 35) has the methylation of the studied CpG - dinucleotides of *RASSF1A* gene. The cases of aberrant methylation of all genes were revealed both in liquidators of the Chernobyl accident and in the control group (age > 35 years). Promoter methylation of at least one of the genes analyzed was observed in 28,92 % liquidators and significantly exceeded (p = 0,016) such rate in an one-age (> 35 years) control group (12,31%). Significantly elevated frequency (p = 0.023) of individuals with abnormal methylation of *GSTP1* gene in group of liquidators as compared to control group was revealed. The frequency of individuals with abnormal methylation of *P16/CDKN2A* gene promoter was also higher (the tendency) in exposed people than that in the control group (p = 0.078) The occurrence of promoter methylation of *RASSF1A* gene was significantly correlated with aging both in the control group (r = 0, 214; p = 0.023), and in liquidators of the Chernobyl accident (r = 0, 230; p = 0,036). Similar trend was not found for other genes. Multiple regression analysis showed that the growth in the number of methylated loci of a set of genes *p16, p14 and GSTP1* is due to the fact of exposure (OR = 7.32, 95% CI = 2.49 - 25.83, p-value = 2.7×10^{-5}), exclusively. At present the study of these epigenetic abnormalities in children born from irradiated parents is conducted. The results obtained for the first time demonstrate the reality of the radiation-induced aberrant methylation of CpG islands in promoters of genes involved in the basic protective functions of cells, in the human body in remote period after radiation exposure. Taking into account accumulated knowledge in the field of molecular oncology, identified epigenetic changes may be markers of increased risk of carcinogenesis in the future that requires further study.

RETROSPECTIVE DOSE EVALUATION BY MEANS OF CLASSIC CYTOGENETIC METHOD

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One from a problem of biological dosimetry is the dose evaluation in remote time after irradiation. This takes place in certain percent of cases of acute irradiation, for example, when patient entrance in hospital is delayed. Also the retrospective dose evaluation is necessary for confirmation of irradiation fact and determination of quantity of possible absorbed dose in aims of medical social examination and potential judicial trials which are associated with requirements of a compensation of damage caused by health. The biological dose indication is produced by average dicentric frequency in peripheral blood lymphocyte culture. However dicentrics and certain other chromosome aberrations put into unstable type. Their frequencies are decreased in course of time. A special computer program was developed to use the results of classical cytogenetic analysis for retrospective dose estimation. It processes the distributions of cells by the number of dicentrics and all unstable aberrations in peripheral blood lymphocyte cultures when sampling is produced in remote period after irradiation. This computer program is a modification of the main program originally proposed to recover the dose distribution of lymphocytes from dicentric distribution of lymphocytes. The version proceeds from likening of chromosome aberration elimination to the appearance of some non-irradiated fraction in the pool of peripheral blood lymphocytes in the course of time after irradiation even if the initial exposure was uniform. This computer program has been used for retrospective dose estimations received Chernobyl patients. Changes of registered levels of chromosome aberrations were studied in the peripheral blood lymphocyte cultures of 74 patients with a different frequency during a quarter of a century after irradiation by the instrumentality of routine method. The capital body mass of majority of these patients was irradiated relatively uniformly. The initial dose estimations by average dicentrics frequency varied from 0.2 to 9.8 Gy. Strong correlation was observed between the recovered by means of the computer and initial estimates of doses. However there was some displacement of the recovered estimations in comparison with initial estimations towards smaller dose values. Also the ratios of recovered dose estimations to initial dose estimations in certain degree depended on time after irradiation. On the average practical non-bias of retrospective dose estimations was achieved only after production of the equations of multiple linear regression which take into account not only recovered computer dose estimations, but also time elapsed after exposure or frequencies of the atypical chromosomes registered in remote terms. Simultaneous increase of the time between irradiation and moment of repeated cytogenetic examination resulted in widening 95%-confidence interval of individual values.

USING NANOTECHNOLOGY AND A BIOPHYSICAL APPROACH FOR THE ANALYSIS OF THE DNA BIOPOLYMER DEGRADATION AND REPAIR BY IONIZING RADIATION

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The analysis of the **DNA biopolymer degradation** especially at low environmentally relevant doses of ionizing radiation is often challenging. We have applied an adaptation of number average length analysis (NALA) and DNA electrophoresis in agarose gels with the use of DNA repair enzymes as damage probes to calculate the levels of clustered DNA damage in human cells and under a variety of radiations. We have found the optimum conditions for the **DNA-agarose nanocomposites** to doses as low as 0.5 Gy. Latest improvements in nanotechnology and drug discovery has led to the discovery of some very unique, highly specific and innovative small chemical moleculestargeting key DNA repair pathways like base excision repair (BER) and double strand break repair (DSBR). The idea of synthetic lethality gains more ground towards effective treatment of **radiation** or chemo-resistant tumors by inhibiting for example BER in DSB repair deficient BRCA1/BRCA1 breast cancer tumors. DNA-PK is a key DSB repair protein involved also in BER. We have used DNA-PK inhibition in varioustumor cell lines and we show that DNA-PK inhibition by highly specific drugs results in accumulation of DSBs and other types of clustered DNA damage. For the detection of non-DSB clustered DNA lesions we have used human DNA repair enzymes as DNA damage probesoptimizing previous incubation conditions of **temperature**, **hydration, lysis,** etc. We show that inhibiting DNA-PK results also in the accumulation of non-DSB lesions in human tumor cells suggesting another type of 'synthetic lethality' towards cancer treatment.

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ANALYSIS OF THE EFFECT OF RADIATION ON HUMAN BLOOD BY EPR

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In the present work we report results of investigations of methemoglobin in human blood after irradiation during radio-isotopes Tc^{99m} diagnosis of by electron paramagnetic resonance (EPR). Blood was donated by consenting patients before and after diagnosis and collected under air in glass tubes containing a small amount of the anticoagulant. Additionally, the blood of regular human was directly mixed with Tc^{99m} radionuclide and measured by EPR. Methemoglobin or (ferric form of hemoglobin) is the form of hemoglobin, which is oxidized to the 3+ ferric state. This form of haemoglobin is not able to bind oxygen This compound is unable to deliver oxygen to tissues; therefore, it is advantageous to convert this 3+ form of hemoglobin into the 2+ ferrous state so that tissues can get the oxygen that they need. Each of these ions of iron can exist in two different spin states which reflect the distribution of electrons within the d orbital - high-spin and low-spin configuration.

The EPR spectra of blood have been studied at 80K temperature. It is shown that EPR spectra of blood of patients after diagnosis has signal of the ion Fe^{3+} of methemaglobin in low-spin state with g = 2.003 and in the high spin state with g=6. We can also detect EPR signals from the metal-protein transferrin (g= 4.3) that contains the non-haem rhombic iron. The EPR signal of human blood mixed with Tc^{99m} has signal Fe^{3+} of methemaglobin in low-spin state with g = 2.003 only. The results received from double integral values of the individual lines, gives us information about concentration of all the paramagnetic centers present.

HSP70B – EARLY WARNING MARKER FOR OXIDATIVE STRESS OR GENOTYPE RESISTANCE?

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Organisms isolated from habitats with extreme environmental conditions could be used as models for cell resistance to various stress stimuli.

The aim of this study was to compare genotype resistance of *Chlorella* species, isolated from different habitats to oxidative stress.

Three *Chlorella* species were used: *Chlorella vulgaris* (isolated from soil in island Livingston, Antarctic), *Chlorella vulgaris 8/1* (isolated from thermal springs in region of Rupite, Bulgaria) and *Chlorella кesslery* (mesophilic from the Trebon collection).

Two inductors of oxidative stress were used - UV-B and temperature. Cell response of *Chlorella* species was examined on the basis of heat shock proteins (HSP70B). Cells were irradiated in BLX-254 (Life Technology, UV crosslinker) as a source of UV-B irradiation (λ= 312nm) and three temperature regimes were used: 39^{o}C/30min., 42^{o}C/5min, 45^{o}C/5min and recovery time of 2 and 4 hours was given.

Our results show that HSP70B could be used as a marker of oxidative stress in these organisms. Higher constitutive content and overproduction of HSP70B could be considered among of the factors that allow *Chlorella vulgaris* to survive in the extreme Antarctic environment.

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[6]-GINGEROL PROTECTS HEPG2 CELLS AGAINST IONIZING RADIATION (IR)-INDUCED APOPTOSIS

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Ionizing radiation (IR) has many practical applications such as medicine, food, agriculture, industry, environment and research laboratory. However, high exposure of IR is associated with harmful effects on human health. It is well known that IR can induce genomic alterations, mutagenesis, and cell death in many living organisms. Therefore, the development of effective and nontoxic radioprotective agents is of considerable interest. Ginger has been widely used as medicine (common cold, fever, digestive order and arthritis) and food (flavoring agent, spice, condiment, beverage and tea) for a long time. It contains bioactive polyphenols such as gingerol, shogaol, paradol and zingerone. In particular, 6-ginerol has been reported to have many pharmacological effects. [6]-gingerol is a major non-volatile pungent compound in the rhizome of ginger (*Zingiber officinale*). It is known to have various biological effects such as antioxidant, anti-inflammatory and anticancer properties. However, there is no report on the radioprotective effect of [6]-gingerol in human hepatoma cell line (HepG 2). In this study, we investigated ionizing radiation (IR)-induced apoptosis of HepG2 cells and evaluated the radioprotective effects of [6]-gingerol against IR-induced apoptosis in HepG2 cells. HepG2 cells were pretreated with 5 μM [6]-gingerol for 1 h before irradiation (0-10 Gy). Cell morphological change was determined by microscope and cell viability was estimated by trypan blue assay. Antioxidant activity was measured by superoxide dismutase (SOD) and catalase (CAT) kit. Apoptosis-related proteins, Bax, Bcl-2, and p53 were detected by western blotting. The results demonstrated that IR induced apoptosis features (cell morphological change, cell viability loss, increased SOD and CAT activity). IR also upregulated the expression of Bax and p53 in a dose-dependent manner, whereas the expression of Bcl-2 was downregulated. This indicated that IR-induced apoptosis of HepG2 cells was p53-dependent mitochondria apoptosis pathway. [6]-gingerol pretreated cells in combination with IR attenuated apoptosis of HepG cells when compared to IR treated cells with 5 Gy (LD_{50} of HepG2 cells) alone. This indicated that [6]-gingerol exhibited radioprotecitve effects by reducing cell cytotoxicity, oxidative stress, and upregulation of apoptosis-related proteins (Bax/Bcl-2 ratio and p53) against IR-induced apoptosis in HepG 2 cells. These findings suggest that [6]-gingerol could be useful as a radioprotective agent.

GENOTYPE RESISTANCE OF *CHLORELLA* SPECIES TO UV-B INDUCED STRESS

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Different mechanisms of adaptation to environmental stress have been developed by organisms during the evolution.

Here we hypothesize that algal species isolated from habitats with extreme environmental conditions would have more efficient cellular defense mechanisms to various types of stress.

Unicellular green algae are a robust model because of the following reasons: Photosynthetic eukaryotic organisms with typical for plants cell structure and genome organization; Cell - organism with short life cycle - the response of a single cell is equivalent to the response of an individual organism.

The aim of this study is to assay the genotype resistance to UV-B induced stress of algae from genus *Chlorella* isolated from different habitats.

Chlorella vulgaris (Antarctic) is isolated from soil in island Livingston, Antarctic, *Chlorella vulgaris 8/*1 (Thermophilic) is isolated from thermal springs in region of Rupite, Bulgaria and *Chlorella kesslery* (Mesophilic) is from the Trebon collection.

Chlorella species are cultivated on TAP medium under standard conditions 23ºC ± 0.3 and 5000-5500lx in a growth chamber Phytotron GC 40. Cell suspensions in the end of the exponential/ beginning of the stationary phase are used.

UV-B is used as inductor of oxidative stress. The cells are irradiated in BLX-254 (Life Technology, UV crosslinker) as a source of UV-B irradiation (λ= 312nm).

The cell resistance of *Chlorella* species is examined on the basis of spot - test, micro-colonies assay, sector of photo-reactivation, growth rate, induction and repair efficiency of double - strand breaks (DSBs).

Our results show that doses higher than 250 J/m^2 UV-B are bioactive. Based on the complex of used methods, it is established that according their resistance to UV-B induced stress, the different species can be arranged in the following order: *Chlorella vulgaris* > *Chlorella vulgaris 8/1* > *Chlorella kessery*.

In short we can summarize that *Chlorella vulgaris* (Antarctic) and *Chlorella vulgaris* 8/1 (Thermophilic) express similar photo resistance to UV-B irradiation. To clarify mechanisms of this genotype resistance to UV-B induced stress further experiments must be done.

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FREQUENCY OF CHROMOSOMAL ABERRATIONS IN COWS FROM AREA CONTAMINATED BY DEPLETED URANIUM DURING NATO AIR STRIKES IN 1999

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This paper presents the results of cytogenetic studies in cows from the region of Bujanovac, which was contaminated by depleted uranium (DU) during the NATO air strikes in 1999. The study was conducted on peripheral blood lymphocytes, with the aim to determine the frequency of chromosomal aberrations and to assess the presence of genetic risk as a result of the possible action of DU. Blood samples for lymphocyte cultures were taken at random from the 20 animals of the households in Borovc, village near Bujanovac, and the animals were chosen because they driven to pasture, feeding and water-drinking in the NATO bombing area. For comparison the results, were cytogenetically analyzed two control groups of 20 cows from two northern localities: from Zemun and Ovča, which were not contaminated with DU. Established structural chromosomal changes were of breaks and gap types, and their frequencies in cows of all surveyed localities were within the range of basic level values that are commonly found in controls of lymphocyte cultures. Elevated values of polyploid and aneuploid cells which may indicate to presence of carcinogenic agents were not detected. In comparisons the values of frequencies of structural chromosome changes as and in the comparisons values of numerical changes that were obtained in cows from different localities, statistically significant differences were not found. According to earlier data, depleted uranium was below the limit of detection the method applied in the soil and feed that were given to cytogenetically analyzed animals. Based on the low-level chromosomal changes that are in the range of the level of basic changes, which were commonly observed in control lymphocyte cultures of cows, cannot be said with confidence that DU caused established changes, nor that is widespread in the region of Bujanovac.

Key words: Depleted uranium, cows, chromosomal aberrations, breaks and gaps, NATO air strike in 1999, Bujanovac

INCIDENCE OF A THYROID CANCER IN THE GOMEL REGION OF BELARUS AFTER CHERNOBYL ACCIDENT

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Objectives: To estimate levels and dynamics of incidence of a thyroid cancer (ThC) of the population of the Gomel area after Chernobyl accident (ChA).

Methods: Research is lead to the personal data of the State register of the persons, undergone to influence of radiation owing to ChA, the Belarus cancer-register for the period of 1986-2011.

Age-sexual parameters of incidence on 100000 population for every year investigated period on 5-years age intervals paid off. Standardization of parameters was carried out by a direct method with use of the World standard. The truncated standardized parameters for children (0-14 years) and teenagers and adult (15 years and are more senior) the standard methods paid off.

Results: The standardized parameter of incidence has grown in 9,3 times (with 1,4 in 1986 up to 13,0 in 2011). By 1995 achieve peak of incidence of children in the Gomel area, the standardized parameter of incidence has grown in 48 times (with 0,2 in 1986 up to 9,6 in 1995). The next years decrease in incidence was marked in connection with transition of children in a category of teenagers and adults.

By 2011 among children do not achieve before accident and early after accident a level of incidence. Children who were fallen ill after 2001, of year have not been subject to an emergency irradiation ^{131}I, among them 20 cases of a ThC are revealed, that in 2,5 times exceeds number of cases in 1986-1989.

The basic group of risk were persons in the age of 1-6 years at the moment of ChA, on their share 53,2 % of all cases of disease by a ThC (604 cases) among irradiated in the age of 0-18 years (1135 cases) were necessary.

By 2011 incidence of adult population has grown in 10,9 times in comparison with 1986 having reached the maximal value.

Conclusions: In the Gomel area steady growth of incidence by a ThC, both among children's, and among adult population after four years after ChA, a spontaneous level of incidence by a ThC at children, not undergone to an irradiation radioactive iodine was marked, remains high and has not reached before accident a level that demands the further is profound scientific research with an estimation of dependence doze - effect.

THE ELEVATED LEVEL OF REACTIVE NITROGEN SPECIES PRODUCTION IN BONE MARROW CELLS IN RATS EXPOSED TO LOW DOSE OF IONIZING RADIATION COULD BE HEREDITABLE

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Objectives: The rodents exposed to low doses of ionizing radiation (IR) for prolonged period as well as their progeny demonstrates elevated level of immunological alteration, susceptibility to infection and invasions, genomic instability and neoplasms in comparisson to matched control. Known that these disturbances in exposed animals are accompanied with increased reactive oxygen (ROS) and nitrogen species (RNS) production in bone marrow (BM) stroma and are genotype dependent. No data available about RNS production in BM cells in their offspring. The aim of our study was to characterize oxidative metabolism of BM cells in rats exposed to low doses of IR and their progeny.

Methods: All experiments were conducted under approval of local ethics committee in concordance with international guidance of animal handling. Both male and female rats were kept for 4 month (May-September) in Chernobyl exlusion zone (r.p. Masany). Total adsorbed dose of external exposure was 14.5 mGy (expositional dose 5 uGy*hr^{-1}) and measured activity of Cs^{137} accumulated in corps was 143.4±22.9 Bq*kg^{-1}. Later animals were moved to vivarium and progeny of generation F1 and F2 was sequentially obtained by panmixia. The generation F2 was exposed to IR as described previously and progeny F3 and F4 obtained. Male rats of 5-7 month old (generations F1-F4) were taken in experiment. The BM cells were isolated and subcultured *ex vivo* for estimation of overall metabolic activity and reactive oxygen spices (ROS) production by MTT and XTT reduction. The 24-hr nitrite accumulation in culture media was used as surrogate marker of RNS production.

Results: An increased level of spontaneous (non-stimulated) RNS production (1.5-3 fold of control) was observed in BM cell isolated from animals exposed to low doses of ionizing radiation as well as in their offspring. No significant changes in overall metabolic activity and spontaneous ROS production were found.

An altered BM cell's reactivity was identified. An oxidative burst was enhanced in response to phorbol ester but not to opsonized zimosan. The nitrosative burst to opsonized zymosan was slightly depressed while response to endotoxin was nearly equal to control level. These facts taken together indicate alterations in ballance of intracellular signaling cascades mediated by receptor-dependent pathways (TLR 2, TLR 4, Dectin 1, CR3).

Conclusions: Mentioned above alteration could underlies such delayed adverse effects of exposure to IR as increased morbidity, cancer rate as well as decreased fertility and resistance to infection and invasions. An increased RNS production in bone marrow cells persists at least during four generations of rat repeatedly exposed to low doses of ionizing radiation. The intensity of this effect decay with the number of generations. Taking into account pathophysiological significance of increased RNS production and design of experiment (panmixia), found phenomena could be recognized as a one of the evolutionary mechanism of selection of genotypes most adaptable and resistant to action of low doses.

BIOLOGICAL EVALUATION OF ^{68}GA-DOTA-NT FOR PET IMAGING AND THERAPY FOLLOW-UP

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Due to overexpression of neurotensin receptors which was demonstrated in several human cancer cells, a new marker based on neurotensin (NT) for positron emission tomography (PET) imaging and therapy follow-up has been proposed. The aim of the present study was to radiolabel and to bioevaluate DOTA-NT for (PET) imaging with ^{68}Ga. ^{68}Ga is a positron emitter radionuclide, with high potential in PET imaging, due to its short half-life, 67.6 min and its 89% β^{+} emission and 11% EC. The radiolabelling process was automatized, minimizing the labeling time and operator exposure. The gallium eluate was passed through an anion exchange column to separate Ga from metallic impurities and the final product was purified with a C18 Sepak column. The obtained radiochemical yield was higher than 80% and the radiochemical purity tested with an HPLC system was higher than 95%. The biological behaviour of the proposed radiopharmaceutical was tested through *in vivo* and *in vitro* studies. The *in vivo* studies were made on healthy and tumors bearing rats and the *in vitro* on different tumor cell lines. The preliminary results obtained showed that the ^{68}Ga-DOTA-NT agent has a great potential for pet imaging and therapy follow-up.

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MICRONUCLEI AND 8OHDG IN HOSPITAL WORKERS PROFESSIONALLY EXPOSED TO IONIZING RADIATION

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Purpose: Medical use of radiation represent a health risk of professionally exposed persons, since ionizing radiation can damage DNA either directly or indirectly. Therefore, the aim of this study was to determine the level of DNA damage in blood and urine from hospital workers professionally exposed to low-doses of ionizing radiation.

Patients and Methods: The exposed group consisted of 20 people working in radiotherapy and 10 in bronchoscopic unit. For the control group we used material from 10 unexposed healthy volunteers. The frequency of micronuclei (MN) were analyzed by cytokinesis-block peripheral blood lymphocytes and the level of urinary 8-oxo-7,8-dihydro-2'-deoxyguanosine (8-OHdG) by ELISA.

Results: We found increased frequency of micronuclei ($p<0.05$) and the level of 8-OHdG in the exposed group compared to the control group. In relation to the working conditions, number of micronuclei in the group of workers in bronchoscopic unit was higher ($p<0.05$) in comparison to the radiology unit, while the level of 8-OHdG was lower, without statistical significance.

Conclusion: Obtained results have shown that hospital workers professionally exposed to low-dose of ionizing radiation had increased incidence of MN and level of 8-OHdG. The health risk depends of working conditions. Combining results of DNA damage in blood by MN test and 8-OHdG in urine within genetic monitoring studies can contribute to a more complete conclusion about assessing the risk associated with low-level radiation exposure.

Key words: Occupational exposure; Ionizing radiation; Micronuclei; 8-oxo-7,8-dihydro-2'-deoxyguanosine

IMMUNOCYTOGENETICS INVESTIGATION OF THE PATIENTS WITH CHRONIC LYMPHOCYTIC LEUKEMIA, WHO HAD CONTACT WITH RADIATION

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Chronic lymphocytic leukemia (CLL) is a lymphoma, consisting of small B lymphocytes. This disease comprises about 25% of all leukemia's. In classical form of the disease expressing antigens are CD19+CD20dimCD23+CD5+FMC7-CD22-CD79b-Smlgk+ or λ+, sometimes expression of CD22. Recurrent cytogenetic aberrations in CLL are well known: deletion in (13q), in (17p), in (11q) and trisomy 12. CLL is the only hematological disease with an unproved participation of radiation mutagenesis in its pathogenesis. In the last years some papers appeared, discussing high risk of CLL in irradiated persons. Maybe, this discrepancy is caused by long time between the debute of the illness and the beginning of treatment. In this work we had analysed the radiation-specific chromosome aberrations in patients with CLL before beginning treatment. Fluorescent in situ hibridisation (FISH) was used for detection of CLL-specific aberrations. DNA-sonds (ABBOT) for ATM, P53, 13(q), trisomy 12 and of differential chromosome staining (DS) was used. We detected dicentric chromosomes (dic) in 6 of 21 patients, and 2 of these 6 had dic and chromosomes translocations (t). The content of dic was from 0.67 to 2.9%, and one patient had 1% of dic and 5 t/100 metaphases. Usually dic and t were seen in different chromosomes with different locus broken. This confirms the participation of lymphocytes irradiation into mechanism of CLL origin. Another 15 patients had only t, with the content from 0.46 to 1,67%. CLL patients had increased number of aberrant cells (AC); in the group of 15 subjects without participation of radiation in CLL pathogenesis the content of AC was 3,70±1,20%, in the group of subjects with aberrations, specific for radiation, or stable aberrations, the content of AC was 7,11±1,00%. Donors (n=40) had 1,34±0,40% of AC. Elevated content of AC, which is pointing to unstable lymphoid cells genomes, may be the consequence of the previous irradiation in CLL. The lymphocytes of CLL patients with dic are characterized by expression CD79b (dim to mod) and CD38 of 70-90% of malignant cells. One of CLL patients had previously a long-time contact with ionizing radiation. Additionally dic(13,20), dic(3,12) and trisomy 12 in 52-hour lymphocyte culture were identified with the aid of DS. Isochromosome i(17q)x2 and several cells with chromosomes endoredubublications, also characteristic for irradiation. Immunophenotyping had shown positive mutual expression of CD22(dim) and CD79b (dim to mod). CD38 antigen, indicator of bad prognosis, was present on the surface of 99.3% malignant cells. In this case we see the absolute correlation between immunological and cytogenetic indexes. Both methods determined: 1. Bad prognosis (CD38 expression and chromosome 12 trisomy); 2. Deviation from the classic CLL (Injuries, specific for irradiation (dicentrics), CD38 and CD79b expression on the surface of majority of the cells). Our results show that ionizing radiation may participate in CLL pathogenesis.

TRANSGENIC LINES OF DROSOPHILA MELANOGASTER AS POSSIBLE BIOSENSORS OF LOW DOSES OF IONIZING RADIATION

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Despite the mutagenic effect of ionizing radiation was found in the first half of the 20th century, the biological test-system for rapid detection of this mutagen in the environment has not established yet. The aim of this work was to design a new effective biosensor system to detect low doses of ionizing radiation in the environment.

The *Drosophila melanogaster* imagoes of wild-type strain *Canton-S* were gamma-irradiated from the ^{226}Ra source (5.5 h at dose rate of 36 μGy/h, the absorbed dose - 20 cGy). RNASeq was carried out by Illumina GAIIx. In total, it was studied the expression of 15222 transcripts in each variant of the irradiated and control samples (Moskalev *et al.*, 2013).

The transcriptome analyzes revealed that ionizing radiation up-regulates the genes that are favorable to longevity (*Sugarbabe*), but down-regulates the genes associated with aging (*Keap1*, *Hormone receptor-like in 38*, *Relish*, CG6188, *Peptidoglycan recognition protein LB*).

We suggest using the green fluorescent protein (GFP) as a reporter, which expression will be directed by the promoter of radiation inducible genes. This will allow detecting of low-dose irradiation in the *in vivo* experiments, without additional methods of genetic analysis.

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FEATURES OF SOCIAL AND PHYCHOPHYSIOLOGICAL ADAPTATION OF THREE PATIENTS, WHICH HAVE TRANSFERRED ACUTE RADIATION DISEASE OF III-IV DEGREE

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Three patients are examined, the former workers of emergency change of the Chernobyl Nuclear Power Station. One of them carried out duties of the operator of the 4th block (G.O.I., The 1960th year of birth), the second – duties of the engineer (Yu.A.P., 1961), the third – the driver inspector (T.A.M., 1962). All of them 26.04.1986 underwent sharp external rather uniform gamma-beta radiation owing to Chernobyl Nuclear Power Station accident. The radiation dose, according to cytogenetic research, made 3,5 Gr (G.O.I.), 4,3 Gr (Yu.A.P.), 9,8 Gr (T.A.M.) . A consequence of local radiation injuries were multiple teleangioektaziya, fibrous atrophic cicatricial changes of skin. They transferred over 15 repeated plastic surgeries concerning late beam ulcers. Average profile of multilateral research of the personality (MMPI) patient T.A.M., transferred ARD IV of the heaviest degree of severity and multiple local radiation injuries of the I-IV degree, and the loudspeaker of indicators on years of supervision (1999, 2000, 2002) exceed borders of population statistical norm (<70>30) on a scale of T-points and testify to an overstrain of mental adaptation with the advent of personal lines in the form of an apathetic depression (1999), with transition to a disturbing depression (2000) with somatization alarm and to manifestation of lines of the classical disturbing and depressive personality (2002), with a low energy potential. Average profile of multilateral research of the personality (MMPI) of the patient Yu.A.P., transferred ARD III of heaviest degree of severity and multiple local radiation injuries of the I-IV degree, and the loudspeaker of indicators on years of supervision (1999, 2001) exceed borders of population statistical norm (<70>30) on a scale of T-points and testify to an overstrain of mental adaptation with the advent of personal lines with domination of ipochondrical tendencies, with bent to a depression, to conversion hysteria and an asocial psychopathy, with lines of affective excitability, irritability, fieriness and neglect to social norms. Average profile of multilateral research of the personality (MMPI) of the patient G.O.I., transferred ARD III degree of severity and multiple local radiation injuries of the I-II degree (80 %), and dynamics of indicators on years of supervision (1999-2011) are registered in borders of populational statistical norm (<70>30) on a scale of T-points and testify to efficiency of psychophysiological adaptation, with a tendency to hypertimny type of the personality which is not falling outside the limits normal indicators, with characteristic optimism for this condition, sociability, high activity, energy of behavior, with ease to communication, with a social extraversion. Efficiency of psychophysiological adaptation depends not only on a dose of radiation and weight of the suffered disease, but in a bigger measure from premorbid properties of the identity of the victim, genetic features which are essential for providing not only the biological properties underlying physiological aspects of adaptation, but also features of socialization on which depends both actually mental, and social and psychological adaptation and social labor installation.

CHROMOSOME ABERRATIONS IN CANCER PATIENTS WITH DIFFERENT TUMOUR LOCALIZATIONS UNDERGONE CO^{60} RADIOTHERAPY

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The investigation of the radiation effects in peripheral blood lymphocytes of cancer patients is the actual tasks in the development of radiobiological basis of radiotherapy. In order to improve biological dosimetry in radiotherapy and to estimate the risk to health resulting from medical irradiation with time after exposure, it is necessary to evaluate the underlying mechanisms of partial-body radiation action at chromosome level.

Cytogenetic effects were studied in lymphocytes of 21 radiotherapy patients divided on three groups depending on tumour localization: with uterine body cancer, with lung cancer and with head and neck cancer. Blood sampling was performed before treatment, at the middle and at the end of external Co^{60} radiotherapy course, reaching the dose of 40-45 Gy. Both chromosome and chromatid types of aberrations were analyzed in patients' lymphocytes cultivated by conventional technique according to IAEA recommendations. FPG-staining control of cell division was applied.

It was shown the excess of chromosomal damages (both chromosome and chromatid type) before treatment over spontaneous level in all groups of patients, regardless on tumour localization The different pace of chromosome and chromatid type aberrations accumulation during radiotherapy course in groups of patients was observed. The distribution of the dicentrics and whole chromosome type aberrations among cells was found to be over-dispersed according to Poisson statistic both at the middle and at the end of radiotherapy course in all groups The almost monotonic increase of radiation-induced aberrations from start to the end of treatment in patients with uterine cancer and lung cancer and less pronounced changes in these parameters in patients with head and neck cancers were demonstrated. Immediately after radiotherapy the mean yield of unstable chromosome type aberrations was increased above pre-treatment levels 25-30-fold in groups with uterine cancer and with lung cancer, and 7-8-fold in groups with head and neck cancers.

The quantitative yield and quality range of cytogenetic damage in lymphocytes of patients with various tumour localizations and the importance of these studies for correct assessing the impact of therapeutic irradiation on the chromosomal level will be discussed.

BIOLOGICAL EFFICIENCY OF SLOW HEAVY CHARGED PARTICLES

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The biological efficiency of slow heavy charged particles (SHCP) with ranges in tissue comparable to that of a mammalian cell diameter (<10 μm) was investigated on two Chinese hamster cell lines, CHO-K1 and B11d-ii-FAF28 (strain 237). Plateau phase cultures were irradiated with fission neutrons from the reactor BR-10 (E_{av}=0.85 MeV) and ^{252}Cf source (E_{av}=2.15 MeV), three quasi monoenergetic neutron beams (0.85, 6.0, 14.5 MeV), ^{239}Pu α-particles, and ^{60}Co gamma-rays. Cell monolayers in Carrel flasks were irradiated with neutrons either through a layer of Hank's solution under conditions of secondary charged-particle equilibrium (CPE) or through a flask glass bottom (absence of CPE). The irradiation with α-particles was carried out through a 10 μm thick Melinex bottom of specially constructed flasks. The neutron dose under conditions of CPE was measured with a pair of thimble ionization chambers (UNIDOS system). Doses, particle energy and LET spectra with and without CPE were estimated with GEANT4. The biological effects studied were cell survival (CHO-K1) and chromosome aberrations (CA) production (B11d-ii-FAF28).

The results obtained showed that the RBE of neutrons under CPE conditions and ^{239}Pu α-particles for both cell lines/effects agreed reasonably with data published by other authors. The maximum RBE values were observed for α-particles (LET=115 keV/ μm) and 0.85 MeV neutrons. When dose-effect curves for neutrons with and without CPE were plotted against kerma the cell killing and CA yield were less under conditions of CPE absence clearly indicating that a smaller amount of energy was absorbed in the cells in this situation, the difference between curves increasing with neutron energy increase. However, when non-equilibrium data were plotted against the estimated absorbed doses, dose curves became steeper than those under "normal" conditions of CPE. The difference indicates the increased RBE of slow heavy recoils C,N,O (and partially, α-particles) producing the biological effect in a mammalian cell monolayer (≈5 μm) because proton component of the neutron dose is missing near the glass-tissue interface. On the assumption of independent biological action of all secondaries in the cell one can estimate the biological efficiency of SHCP. It was maximum and minimum for SHCP produced by 0.85 MeV reactor neutrons and 14.5 MeV neutrons, 4.5 Gy^{-1} and 1.2 Gy^{-1}, respectively, exceeding that of α-particles at the peak of RBE-LET dependence and of fast particles with the same Z. High RBE values account for 30-60% partial contributions of SHCP to the total biological effects of neutrons studied (0.85-14.5 MeV) despite their dose fraction of ≈10% thus emphasizing necessity of further investigations.

IN VITRO TESTING OF RADIOPROTECTIVE EFFECT OF DIFFERENT COPPER CHELATORS ON HEPG2 CELLS AND PRIMARY HUMAN LYMPHOCYTES

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One of the mechanisms of irradiation effect is the liberation of free radicals. The major components of the free radical system are reactive oxygen species (ROS) and reactive nitrogen species. Free radical formation mechanisms also involve atomic hydrogen, many heavy transition metals, such as iron, copper, and manganese.

The aim of the present study was to investigate the effect of 3 copper chelators (Neocuproine, Bathocuproine, and Tetrathiomolybdate) on the end points of cellular survival and damage following gamma radiation with 0.5, 1, 3, 5, 7, and 9 Gy in hepatocellular carcinoma (HepG2) cells and primary human lymphocytes (PHL). Clonogenic assay, CBMN assay, COMET, FACS, cell cycle analysis and immunofluorescence were used to investigate the changes in cyto- and genotoxicity.

Colonogenic assay of HepG2 and PHL cells showed that gamma irradiation caused cell dead with LD50 = 0.8 Gy. Pretreatment with copper chelators in the range of 100 uM to 500 uM for 24 h have a radioprotective effects – LD50 =2.75 Gy and 4.75 Gy respectively. When HepG2 cells were subsequently exposed to the 4Gy challenge dose, the copper chelators showed reduction in micronucleus frequency in binucleate cells. These chelators also caused about a twofold reduction in neoplastic transformation frequency per viable cell of PHL. The results correlate ($R=0.979$, $p<0.05$) with the decrease of inter- and intracellular free radical levels determined by 2′,7′-dichlorofluorescein diacetate (DCFH-DA) probe staining or malondialdehyde. Our results suggest that a low dose (0.5Gy) pre-exposure to ionizing radiation induces an adaptive response in PHL cells. This response enhances DNA double-strand break repair when cells are subsequently pretreated with copper chelators and exposed to a second radiation dose. Our results show that low dose copper chelators (up to 250 uM) do not influence HepG2 cell viability.

The further changes of MN frequency indicate that the reduction of DNA damage was connected with the alteration of ROS.

In conclusion, we demonstrate that copper chelators may protect cells against irradiative damage by mechanism of ROS clearance.

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NEW APPROACHES IN THE PREPARATION OF PROCESS SOLUTIONS FOR THE DETERMINATION OF NATURAL RADIONUCLIDES

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Naturally occurring radionuclides are present at varying concentrations in the Earth's crust and can be concentrated and enhanced by processes associated with the recovery of oil and gas.

Radioactive materials such as Uranium and Thorium were incorporated in the Earth's crust when it was formed; these normally exist at trace (parts per million – ppm) concentrations in rock formations. Decay of these unstable radioactive elements produces other radionuclides that, under certain conditions (dependent upon pressure, temperature, acidity *etc*) in the subsurface environment are mobile and can be transported from the reservoir to the surface with the oil and gas products being recovered. It is very difficult to determine the radionuclides in the backdrop of significant salt content without the use of long-term methods of separation and subsequent concentration. The sources of tritium are underground nuclear explosions, which took place in the second half of the last century. Dilution method in this case does not help. The purpose of the study was developed testing systems for the determination of uranium, thorium, and tritium in drilling fluids that contain large amounts of salts, as well as oil and polymers.

The objects of study were drilling water of the Vankor's oil field and drilling water from the fields of the Yakutia. We have been used to determine the tritium by liquid scintillation spectrometry and to detecting elements - mass spectrometry with inductively coupled plasma.

We have developed equipment that allows managed with little or no change in physical properties of the fluids separate the main salt matrix (inorganic salts, trace of oil and polymers) of determined elements (gross of uranium, thorium) and radionuclides (isotopes of uranium, tritium).

When we developed the use of the equipment has been significantly improved detection limit of uranium 20 ng/L, thorium 10 ng/L, tritium - 1 Bq/L (with efficiency of 34%).

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PHYSICOCHEMICAL CHARASTERISTIC OF URBAN AEROSOL OF CONTINENTAL PART OF BALKANS

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The composition of atmospheric aerosols impacts on aerosol toxicity and human health, the hygroscopic and optical properties of the aerosol, the earth's radiation budget, the global climate and the effect of aerosols on the planet energy balance and yet their mass size distributions and chemical characteristics are still inadequately understood. As a result of the various atmospheric lifetimes arising from the variety of the particle sizes and the complex chemical compositions of atmospheric aerosols, their global distribution shows large regional differences and their properties are poorly known. The size-distribution of trace elements and metals bonded to atmospheric particles is crucial in understanding the health effects by inhalation, in evaluation their sources and assessing their lifetime in the atmosphere. Urban areas are rich in anthropogenic sources of fine particles containing harmful metals and trace elements.

Within the SIMCA project (INTERREG/CARDS-PHARE Adriatic New Neighborhood Program) size-segregated urban aerosol of Belgrade center (44°49'14"N, 20°27'44"E) was studied during the 2008th (summer-autumn). Six stages High Volume Cascade Impactor was used for samples collection. Particle size distribution in the next ranges: $Dp \leq 0.49$ µm, $0.49 < Dp \leq 0.95$ µm, $0.95 < Dp \leq 1.5$ µm, $1.5 < Dp \leq 3.0$ µm, $3.0 < Dp \leq 7.2$ µm and $7.2 < Dp \leq 10.0$ µm were collected. The particle mass distributions, trace elements and water-soluble ions were measured. The aerosol mass concentrations were determined by gravimetric measurements (m_{GM}), trace elements analyzed by ICP/MS for Li, Na, Mg, K, Ca, Al, V, Cr, Fe, Mn, Co, Ni, Cu, Zn, Ga, As, Mo, Cd, Sb, Tl, Pb Bi and U and, water soluble ions analyzed by ion chromatography for Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, PO_4^{3-} and SO_4^{2-}. The shape, size and chemical composition of the fine and coarse particles were analyzed. The imaging was carried out by SEM that is also used for the EDX measurements. Size segregated water-soluble ions showed a domination of ions formed from gas precursors (SO_4^{2-} and NH_4^+) in the fine mode, while ions originating from mechanical processes (Ca^{2+}, Mg^{2+}, Na^+) dominated in the coarse particles.

Size segregated trace elements showed a domination of K, V, Ni, Zn, Pb, As and Cd in the fine mode, while crustal elements Al, Fe, Cu, Mn, Sb, Cr, Ga, Co dominated in the coarse particles.

The morphological and chemical composition suggested that the most abundant particles were carbonaceous soot but also microbes and natural and anthropogenic inorganic mineral materials were found.

RADIOACTIVITY OF THERMAL WATERS IN SOUTH-EAST PART OF SERBIA

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There are a lot of thermal waters in South-East part of Serbia, which are originating from igneous and metamorphic rocks. These waters are mainly used in balneology, but some of them are used for drinking purposes and in water supply to heat buildings, greenhouses and lend. It is very important to determine the gross alpha and beta activity in those waters in order to use them safely. According to the regulations in Serbia, the upper limit for gross alpha activity in drinking water is 0.5 $Bq \cdot l^{-1}$ and for gross beta activity concentration it is 1 $Bq \cdot l^{-1}$. Waters with higher levels of gross alpha or beta activity are subjected to additional measurements, in order to determine activity concentrations of specific radionuclides. We used gamma spectroscopy method for additional measurements of all water samples. From hydrogeological point of view, activity concentrations of radioactive isotope ^{3}H is also very important in determination of the age of measured waters and in determination of how long water stays in the area of its flow. For the "younger" waters ^{3}H is well known as a good tracer.

ISOTOPE ANALYSES OF THE LAKE SEDIMENTS IN THE PLITVICE LAKES AREA

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The analyses of radioactive isotopes ^{14}C, ^{137}Cs, ^{210}Pb, ^{214}Pb and ^{214}Bi and stable isotope ^{13}C were performed in the Plitvice Lakes sediments. Sediment cores, top 40 cm, were taken from four lakes: two big lakes Prošće and Kozjak and two small lakes Gradinsko and Kaluđerovac. Frozen sediment cores were cut into 1-2 cm thick layers, dried and then analyzed. ^{14}C activity in carbonate fraction was measured using liquid scintillation counter technique with benzene synthesis and in organic fraction using accelerator mass spectrometry technique with graphite synthesis. ^{137}Cs, ^{210}Pb, ^{214}Pb and ^{214}Bi were measured by low level gamma spectrometry method on ORTEC HPGe detector with the efficiency of 32%.

Distribution of ^{14}C activity in all sediment profiles showed increase of the ^{14}C activity in the top ~15 cm as a response to thermonuclear bomb-produced ^{14}C in the atmosphere in the sixties of the last century. This is also reflected in increased^{137}Cs concentration in all sediment profiles.

Steady increase of the ^{14}C activity and □^{13}C of the carbonate fraction of the sediments from the uppermost lake Prošće to the lowermost lake Kaluđerovacis the results of CO_2 degassing and carbon isotope exchange process between atmospheric CO_2 and dissolved inorganic carbon (DIC) in water and photosynthetic activity.

Different ^{14}C activity of the carbonate fraction (65 – 85 pMC, percent of modern carbon) and organic fraction (77 – 95 pMC) is the result of geochemical and biological processes of the calcite precipitation in the lake waters. The □^{13}C values of both fractions (-10 to -6‰ for carbonate and -34 to -30‰ for organic) are good indicator of origin of carbonand processes involved in lake sediment precipitation.

Radioactive fallout^{137}Cs deposited across the landscape from atmospheric nuclear tests is strongly absorbed on soil particles limiting its movement by chemical and biological processes. Most ^{137}Cs movement in the environment is by physical processes; therefore, ^{137}Cs is a tracer for studying erosion and sedimentation. The ^{137}Cs technique is used to determine sediment accumulation rates in PlitviceLakes. The approximately 22 y half-life of ^{210}Pb makes it an ideal indicator of modern sedimentation rates. The analysis of sedimentation rates by the ^{210}Pb method is based on the radioactive decay of unsupported^{210}Pb with depth in a column of sediment. In lake sediments, unsupported ^{210}Pb can originate from two sources: atmospheric deposition to the lake surface and subsequent scavenging by the depositing sediments or mobilization of sediment from the surrounding watershed. ^{137}Cs is derived from a different source than ^{210}Pb and thus provides a valuable cross-check of the ^{210}Pb results.

The presented isotope study of lake sediments from four karst lakes in the Plitvice Lakes formed during the last ~100 year showed that sediments reflect global atmospheric changes in ^{14}C and ^{137}Cs activities caused by anthropogenic influence Differences in isotope composition of sediments from four lakes, particularly between big and small lakes, indicate the influence of geochemical and biological processes on the lake sediment precipitation.

The work was performed within the project with National Park Plitvice Lakes and Bilateral scientific project between Croatia and Serbia.

RADIONUCLIDE RATIO IN TENORM STUDIES

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In our presentation, we demonstrate the approach to identify contamination by TENORM of environmental surface. This approach consists of analysis of ratio between activities of radionuclides from different natural radioactive series (method of radionuclides ratio). Approach includes investigation of correlations of ^{226}Ra, ^{232}Th, ^{238}U and ^{40}K activity concentrations in the soil samples. Distortion of naturally formed radionuclide ratio is considered as an evidence of soil contamination and can be utilized for assessment of man-made contribution of natural radionuclides. The soil contamination investigation using the approach based on radionuclide ratio analysis was performed at three sites: oil producing company, thorium storage facility and uranium processing facility. Activity concentrations of ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K in soil samples were measured by gamma spectrometry in Marinelli geometry. The results of gamma-spectrometry analysis of these samples demonstrated:

– excess of ^{226}Ra in the soil samples taken at the oil-producing company site;

– excess of ^{232}Th in the soil samples taken near the monazite concentrate storage site;

– excess of ^{238}U in the soil samples taken around the uranium processing site.

All measured soil samples at oil-producing site technological processes lead to a shift of balance in the chains of natural radionuclides. Out of 49 samples gathered at oil producing company sites 8 were contaminated by ^{226}Ra. Contamination is below 92 Bq/kg. At monazite concentrate storage site, ^{232}Th soil contamination is associated with spillage of monazite with high content of the radionuclide. Contamination of soil by ^{232}Th at the territory of monazite storage facility was determined for 6 samples out of 32 gathered. Uranium processing gives an additional contribution of ^{238}U and ^{235}U in natural soil samples. The data demonstrate excess of ^{238}U and ^{235}U concentrations in 6 samples. In found contaminated soil samples, additional ^{238}U content is up to 78% of the natural concentration. Results of our study demonstrate that the radionuclide ratios in uncontaminated soils samples are normally distributed. Deviation from normal distribution arose due to increased concentration of ^{226}Ra for oil producing site, ^{232}Th for thorium monazite storage facility and ^{238}U for uranium processing facility.

RADIUM IN MINE WATERS IN POLAND

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Underground exploitation of raw materials and fuels waters usually leads to the dewatering of strata and inflows of waters into mine workings. To allow exploitation these waters must be pumped out onto the surface. Unfortunately, these waters are often contaminated and its release causes the contamination of the natural environment, mostly surface waters. In underground coal mines in Poland inflowing waters are sometimes very salty and contain natural radioactive isotopes, mainly ^{226}Ra from the uranium decay series and ^{228}Ra from the thorium series. More than 70% of the total amount of radium remains underground as radioactive deposits due to spontaneous co-precipitation or water treatment technologies, but several tens of MBq of ^{226}Ra and even higher activity of ^{228}Ra are released daily into the rivers along with the other mine effluents from all Polish coal mines. Mine waters can have a severe impact on the natural environment, mainly due to its salinity. Additionally high levels of radium concentration in river waters, bottom sediments and vegetation were also observed. The investigations described here were carried out for all coal mines and on this basis the total radium balance in effluents has been calculated. Measurements in the vicinity of mine settling ponds and in rivers have given us an opportunity to study radium behaviour in river waters and to assess the degree of contamination. Since early 90's till last decade a significant decrease of radium activity in discharge waters has been clearly seen. Unfortunately, during last few years, we observe an increase of radioactivity in mine waters, released to the environment. Therefore improvement of the environmental monitoring frequency and application of mitigation measures to decrease the radioactive contamination is an important issue for the mining industry in Poland.

GAMMASPECTROMETRIC DETERMINATION U-238 IN ROOT PLANT SPECIES

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Migration and accumulation of contaminants in soil is complex and involves different processes such as leaching, capillary movement, sorption, nutrient resuspension roots and into the atmosphere.

The concept of biological usability of radioecological sense implies the availability of radionuclides in the soil to enter the plant through roots system. The aim of this paper is to examine whether there is a transfer of uranium from the biomass in the soil, i.e., whether the uranium is incorporated in the surface layer of the land transferred to the root part of the plant. For this purpose, selected wheat and accompanied by the transfer of uranium from the soil in wheat root portion was used for seeding the soil with locations Hadžići. Gamma spectrometric method using the vertical coaxial HPGe detector POP-TOP p-type model "GEM 30P4", it was found that the highest activity of radionuclides U-238 at the highest concentration of contaminants, that is, the transfer of radionuclides from the ground to the root part of plant species.

Key words: Soil, uranium, gamma spectrometric method, wheat

SOME RESULTS ON NATURAL AND ARTIFICIAL RADIOACTIVITY IN COVASNA COUNTY (ROMANIA)

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Covasna County is situated in the central part of Romania. Some parts of the county present post-vulcanic activity, such as mineral water and mofetta. Our samples were collected in Baile Balvanyos and Covasna town.

Ra was measured in mineral water springs from the Cardiological Hospital in Covasna town and in spring and drilling water Balvanyos area. The applied methodology was Lucas cell method for Rn-Ra equilibrium established in these samples (one month) after initial degassing of samples.

Rn was measured in 10 mofettas in the mentioned county. The applied methodologies were integrated track detectors and Radon-Scout monitor in the case of two moffetas. In situ radon exposure for a person taking a normal cure was also measured during a complete procedure (10 days). From radon concentration at nose level was estimated the exposure dose received by pacient. Maximum radon concentration of 14000 Bq/mc was registered in Bene mofeta.

Cs from Chernobyl uptake was measured in barks of oak and spruce in Baile Balvanyos. The applied methodology was gamma spectrometry using HP Ge detector. The results are compared with other data from Romania and other countries.

Our results contribute to the assessment of natural and artificial radioactivity not juts in Covasna county but also in Romania and Eastern Europe. These data provide basis for the protection and marketing of mofettas and mineral water springs.

SYNERGY OF CHEMICAL AND ISOTOPIC SIGNATURES DATA FOR ENVIRONMENTAL FATE STUDIES

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Here are presented results and possibilities of specific physico-chemical methods applications for environmental fate studies as well as for nuclear forensic investigations. In both cases, samples are analyzed to connect correlating characteristics such as isotopic ratios and chemical composition and forms (e.g. signatures) with knowledge on the processes from which the sample is derived. While methods for obtaining and using isotopic signatures in nuclear forensics are well-known, development of methods to reveal chemical form represent a relatively new approach. Sequential extractions used for examinations of chemical forms and binding conditions of contaminants and their potential supstrates are suitable for application in nuclear forensics. The exact identification of a specific process or event based on isotopic, chemical, and physical information seems unimportant, but correlations of these characteristics may be quite useful in determining whether or not an unknown material is or is not consistent with a certain process.

In the case of depleted uranium occurrence in the environment, the contamination and uranium environmental fate were studied using different analytical methods and techniques. The source of contamination was analyzed for composition and purity by gamma- and alpha-spectrometric technique revealing the U-238, U-234 and U-235 activities and mass ratios and the traces of U-236, Pu-239,240 and Np-237 in material. Obtained data were used for interpretation of results of analytical determinations of these isotopes in environmental samples of air, drinking water, soil, bio-indicators, etc. collected repeatedly and analyzed mostly by radiometric methods. Soil samples of different soil-type and level of contamination underwent 5-step sequential extraction procedure and analysis of isotopic signatures as well as stable elements. The correlations were derived and supstrates determined or indicated. Coupling these correlations with process knowledge and other information existing in a nuclear forensics library enhances the ability to assess whether material (in the case of nuclear forensics) or an environmental sample (in the case of environmental fate study) is or is not consistent with a given process or activity.

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ALPHA-, BETA- RADIOACTIVE AEROSOLS BEHAVIOR IN THE GROUND ATMOSPHERE

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Investigation of behavior of environmental background radioactivity (aerosols and gases) is one of the main tasks when solving problems of low dose effects. It also useful for investigation of electrical properties of atmosphere and climate global change forecasting, because of air radioactive aerosols and gases and their balance regulate the surface layer of atmospheric plasma. The main purpose of this work was to investigate temporal and spatial dynamics of α-radioactive and β-radioactive aerosols in the ground atmosphere. The general distinctions of this investigation are: 1) synchronous measurements of characteristics of α- and β-radiation fields and volumetric activity of atmospheric radionuclides (radon isotopes and their aerosol decay products (DPs)) at one point; 2) parallel measurements at different heights up to 35 m; and 3) high time resolution of data series. Such approach allowed getting more informative data to reach the purpose of the work. The long-term experiment was performed at Tomsk Observatory of Radioactivity and Ionizing Radiation (TORIR). Instrumental equipment included: scintillation detectors of α- and β-radiation (ATOMTEX, Republic of Belarus) installed at series of heights (0.1; 1; 5; 10; 25 and 35 m); radon isotopes and DPs radiometers (EQF 3200, SARAD, Germany; RRA-01-03, Russia; Ramon-01, Kazakhstan) and automated devices for radon (RFD) and thoron (TFD) flux densities measurements. In order to determine the degree of external factors influence the monitoring of meteorological, actinometrical and atmospheric-electrical values was performed via automated information measuring system. In accordance with simplify radon and PDs transport model (only turbulent diffusion) in air the vertical distribution of their concentrations follows exponential law and decrease with height. Results of experiment with help of scintillation α- and β-detectors showed dependence, i.e. influence on α-, β- radioactive aerosols concentration of height. The results of numerical simulation of radonisotopes and their DPs transport in ground atmosphere with using complex model (turbulent diffusion, moving under the influence of vertical wind, removal by gravity and precipitation) showed that turbulent diffusion coefficient and vertical component of wind velocity are the most important factors, which influence vertical aerosols distribution. But only when wind blows upwards (from ground surface) we can observe such inverse situation in vertical distribution of radioactive aerosols. Because of α-active aerosol (radon isotopes and DPs) concentration is direct (by radioactive complex decay low) related with β-active aerosol concentration (DPs), the experimental check of vertical distribution for β-radioactivity in air was also applied. The results revealed different dependences of flux density from height for α- and β-radioactivity in air. Detail discussion of behavior of α-radioactive aerosols in ground atmosphere during 2011–2013 and influencing factors are presented in the report.

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GAMMA SPECTROSCOPY STUDY OF NATURAL RADIOACTIVITY IN SOIL, SEDIMENT, DRINKING AND BRINE WATERS IN COMMUNITIES OF THE OIL RICH NIGER DELTA REGION OF NIGERIA

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Activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the soil, sediment and water of oil producing communities in Delta and Rivers States were determined using HpGe γ-ray spectrometry. The mean soil/ sediment activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in onshore west in Delta state is 40.2±5.1Bqkg^{-1}, 29.9±4.2Bqkg^{-1} and 361.5±20.0Bqkg^{-1} respectively; the corresponding values obtained in onshore east1 of Rivers state is 20.9±2.8Bqkg^{-1}, 19.4±2.5Bqkg^{-1} and 260.0±14.1Bqkg^{-1} respectively. While the mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in onshore east2 of Rivers state is 29.3±3.5Bqkg^{-1}, 21.6±2.6Bqkg^{-1} and 262.1±14.6Bqkg^{-1} respectively. These values obtained show enhanced NORMs but are well within the world range. All the radiation hazard indices examined have mean values lower than their maximum permissible limits. In drinking water, the obtained average values of ^{226}Ra, ^{228}Ra and ^{40}K is 8.4±0.9, 7.3±0.7 and 29.9±2.2Bql^{-1} respectively for well water, 4.5±0.6, 5.1±0.4 and 20.9±2.0Bql^{-1} respectively for borehole water and 11.3±1.2, 8.5±0.7 and 32.4±3.7Bql^{-1} respectively for river water in onshore west. For onshore east1, average activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K is 8.3±1.0, 8.6±1.1 and 39.6±3.3Bql^{-1} respectively for well water, 3.8±0.8, 4.9±0.6 and 35.7±4.1Bql^{-1} respectively for borehole water and 5.5±0.8, 5.4±0.7 and 36.9±3.8Bql^{-1} respectively for river water. While in onshore east2 average value of ^{226}Ra, ^{228}Ra and ^{40}K is 10.1±1.1, 8.3±1.0 and 50.0±3.9Bql^{-1} respectively for well water, 4.7±0.9, 4.0±0.4 and 28.8±3.0Bql^{-1} respectively for borehole water and 7.7±0.9, 6.1±0.8 and 27.1±2.9Bql^{-1} respectively for river water and the average activity concentrations in the produced water ^{226}Ra, ^{228}Ra and ^{40}K is 5.18±2.14Bql^{-1}, 6.04±2.48Bql^{-1} and 48.78±13.67Bql^{-1} respectively. These values obtained are well above world average values of 1.0, 0.1 and 10 Bql^{-1} for ^{226}Ra, ^{228}Ra and ^{40}K respectively, those of the control site values and most reported values around the world. Though the hazard indices (Raeq, H_{ex}, H_{in}) examined in water is still within tolerable level, the committed effective dose estimated are above ICPR 0.1 mSvy^{-1} permissible limits. The overall results show that soil and sediment in the area are safe radiologically but the result indicates some level of water pollution in the studied area.

Key words: Radioactivity study, Soil, sediment and water, Niger Delta, HpGe detectors

THE NATURAL RADIONUCLIDE DISTRIBUTION IN COMMERCIAL TURKISH NATURAL STONES

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The Turkey has very important natural stones potential with over 5 billion m^3 marble reserves. According to 2002 giving data the number of Turkish stones export is 303 million US Dollars. In this regards, the present study deals with 90 Turkish natural stones. The studied samples were analyzed and the concentrations in Bq/kg dry weight of radioisotopes were determined by gamma-ray spectrometry using HPGe detector. The radium equivalent activity varied from 183 Bq/kg to 522 Bq/kg for granite samples while the 1 Bq/kg to 37 Bq/kg for marble samples. The total absorbed dose rates in air ranged from 22 to 61 nGy h^{-1} for one quarter utilization of the granite samples. The annual effective dose rates per person indoors were determined to be between 108 and 298 μSv y^{-1} for of for one quarter utilization of the materials.

Applying the dose criteria recently recommended by UNSCEAR for building materials, the natural stones meet the upper dose limit of 1mSvy^{-1}. Thus, there are not restrictions for use of any Turkish commercial marble as covering materials, including Turkish granites.

Key words: Commercial Turkish natural stones; marble, granite; natural radioactivity; dose rate

INFLUENCE OF SOIL PROPERTIES ON SOIL-TO-PLANT TRANSFER FACTORS OF NATURAL RADIONUCLIDES IN THE VICINITY OF COAL FIRED POWER PLANTS IN SERBIA

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In the vicinity of active coal combustion facilities and coal ash disposal sites natural background gamma radiation can be modified by redistribution of radionuclides in the surrounding soil environment and biomaterial (IAEA, 2010). Study of coal fired power plants (CFPPs) environmental impact have been performed analyzing activity concentrations of natural radionuclides ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in the samples of soil and native vegetation collected in the vicinity of TE "Kolubara"; TE "Morava" and TE "Nikola Tesla" A and B power plants.

Investigated soils were Fluvisols distributed along the river valleys where power plants are situated. Soil characteristics like particle size distribution, soil pH, organic matter and carbonate content were determined in order to examine their influence on soil-to-plant uptake of natural radionuclides via plant roots. Plants were collected at the same time as soil samples but, because of the large crop diversity, depending on the sampling location, they were composed differently from several types of grass species taken at the same growth period.

For determination of activity concentrations gamma spectrometry method was applied with the HPGe detector (CANBERRA) with 20% relative efficiency and energy resolution of 1.8 keV at the 1332 keV. Results of activity concentration (kg Bq^{-1} dry mass) of radionuclides determined in grass samples ranged from 3.2 - 8.1 for ^{238}U; 1.3 - 8.3 for ^{226}Ra; 0.6 - 3.5 for ^{232}Th; 180 - 940 for ^{40}K.

The IAEA (2010) adopted the transfer factor to describe soil-to-plant uptake of a radionuclide defined as the ratio of the dry weight concentration in the plants to the dry weight concentration in a specified soil layer (0 - 10 cm for pasture crops). Soil-to-grass transfer factor values (kg kg^{-1} dry mass) in the vicinity of CFFPs were in the range: 0.068 - 0.279 for ^{238}U; 0.031 - 0.319 for ^{226}Ra; 0.015-0.117 for ^{232}Th and 0.321-1.958 for ^{40}K. Those TFs were comparable with the values given by IAEA (2010) obtained for the grass samples growing in loamy soils with similar texture as Fluvisols.

At the 95% level of confidence, a few correlations were found between soil-to-plant transfer factor values and soil characteristics. Positive correlations ($p<0.05$) were obtained for TFs of ^{238}U and ^{232}Th with corse silt, TFs of ^{226}Ra with fine silt, and TFs of ^{40}K with silt+clay fractions. Correlations of soil carbonate content with TFs of each natural radionuclide were strong but not significant probably because of data scattering due to difference in plant samples composition.

References:

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NATURAL AND ARTIFICAL RADIONUCLIDES IN THREE WILD MUSHROOM SPECIES FROM SERBIA

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Fungi represent ubiquitous organisms in natural environments, including unpolluted habitats such as forest ecosystems as well as polluted urban areas. Over the last century it was proven that fungi play important role in uptake and accumulation of toxic substances, such as heavy metals and radionuclides, by physicochemical and biological mechanisms.

We measured activity concentration of three natural (^{40}K, ^{226}Ra, ^{232}Th) and one artificial radionuclide (^{137}Cs) in three wild mushroom species: *Hypholoma fasciculare*, *Megacollybia platyphylla*, *Gyroporus cyanescens*, as well as their substrate. Selected species are representatives of fungal groups with different life strategies (wood saprotroph, terrestrial saprotroph and symbiont). Fungal fruiting bodies, wood and soil were sampled in Jun 2012 from mountain forest ecosystems at two sites (Vzganica-Vidlič and Metođe-Kopaonik). Samples were dried at 100°C until constant weight and grinded. Activity concentrations of gamma emitting radionuclides were determined by low-level gamma spectrometry. Transfer factors (ratio of radionuclide concentration in mushroom sporocarps and their substrate) were calculated for each species. Identified concentration ranges were as follows: ^{40}K (1180 – 1770), ^{226}Ra (5.1 - 45), ^{232}Th (10.7 - 23), ^{137}Cs (9.0 - 268). All investigated mushrooms had similar values of activity concentrations and transfer factors for ^{40}K, radionuclide which is normally involved in metabolic processes of living organisms. *Gyroporus cyanescens*showed highest levels of natural radionuclides, while *Hypholoma fasciculare* had significantly higher level of radiocaesium comparing with two other species.

Further investigations of radionuclide content in different wild fungal species will give us a better insight of their accumulation patterns and enable selection of species with good bioindicating potential.

THE INFLUENCE OF MINERALS, FOSSILS AND ROCKS DISPLAYED IN GEOLOGICAL COLLECTIONS ON INDOOR RADON LEVELS

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The National Museum of Geology hosts collections which including over 80.000 samples of rocks, fossils and minerals, and from this point of view represent an ideal location for the study of relationship between primary source of radon and its variation levels in the indoor air. Because Rn-222 is a decay product of Ra-226 in natural decay series of U-238 and Rn-220 is a natural product of the most stable thorium isotope Th-232, the thorium and uranium minerals displayed in showcases may contribute considerably to elevated Rn levels in the indoor air. Important are minerals with U and Th as major constituents, such as: *uraninite, thorite, betafite, uranothorianite*, well as common accessory rock forming minerals, like: *zircon, xenotime, monazite, allanite, apatite, titanite, epidote,* etc. Also, some fossil bones (ex. *Anancus arvernensis*) exposed may concentrate important radium content which produce Rn-222, radium is chemically similar to calcium and can to substitute it in the bones.

Radon activity concentration in indoor air was measured using a portable alpha radon monitor Pylon AB-5 with Continuous Passive Radon Detector. The system was set to operate in *continuous mode* with the calibration factors of 0.060 ± 3.58% cpm/Bq/m^3 (1.664±4%). The indoor radon concentration was measured at a height of 1.5 cm above ground level and radon exhalation rate was continuously measured for 24 hours with a counting time of 1 hour /interval in each measurement point. The measurement points are representing by the interface between glass case and air, the center of collection rooms and the halls without exhibits.

Since the radioactive half-life of thoron ($t_{1/2}$=55.6 s) is much shorter comparing with radon half-life ($t_{1/2}$=3.82d) and the distance it can travel before undergoing radioactive decay is also much shorter than the distance that radon can travel in the same medium, was chosen *Continuous method*- this is a flexible method which measures together radon and thoron as radon concentration.

The preliminary statistical analysis of our data confirms that the level of indoor radon concentration depends primarily of the types of the minerals, rocks and fossils exposed in showcases and secondly of building characteristics and environmental conditions.

Variations in these measurements can generally be correlated with distance from the minerals, rocks and fossil with concentrations of uranium, thorium and their progeny, especially radium.

CHARACTERIZATION OF ^{241}PU OCCURRENCE, DISTRIBUTION AND BIOACCUMULATION IN SEABIRDS

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The paper presents unique data of plutonium ^{241}Pu study in seabirds from northern Eurasia, permanently or temporally living at the southern Baltic Sea coast. Together 10 marine birds species were examined: 3 species of permanently residing at the southern Baltic, 4 species of wintering birds and 3 species of migrating birds; about 150 samples were analyzed.

The obtained results indicated plutonium is non-uniformly distributed in organs and tissues of analyzed seabirds. Generally the highest plutonium concentrations were found in the digestion organs and feathers, next in skeleton, and the lowest in muscles. Among analyzed birds the highest ^{241}Pu concentration was found in viscera, its activities in the digestive organs ranged from 9.7±2.5 $\mu Bq \times g^{-1}$ ww (13.0% of total ^{241}Pu) in great cormorant (*P. carbo*) to 228±39 $\mu Bq \times g^{-1}$ ww (79.6% of total ^{241}Pu) in velvet scoter (*M. fusca*). High ^{241}Pu concentrations were also found in liver where ranged from 21±4 $\mu Bq \times g^{-1}$ ww in velvet scoter (*M. fusca*) (2.2% of total ^{241}Pu) to 159±31 $\mu Bq \times g^{-1}$ ww in tufted duck (*A. fuligula*) and feathers where ranged from 15±4 $\mu Bq \times g^{-1}$ ww in great cormorant (*P. carbo*) (11.6% of total ^{241}Pu) to 132±59 $\mu Bq \times g^{-1}$ ww (34.2% of total ^{241}Pu) in common eider (*S. mollissima*). The main source of plutonium in analyzed marine birds was global atmospheric fallout as well as the Chernobyl accident, which was confirmed by plutonium activity ratios of ^{241}Pu/$^{239+240}$Pu as well as ^{238}Pu/$^{239+240}$Pu.

On the basis of the average ^{241}Pu concentrations in the southern Baltic Sea biocenosis components the plutonium content in marine organisms increases as: seabirds < fish < phytobenthos < phytoplankton < zooplankton < zoobenthos.

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^{241}Pu IN THE SOUTHERN BALTIC SEA

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Most contamination studies have focused on alpha emitting plutonium isotopes so far. ^{241}Pu isless important in terms of its radiotoxicity than the α-emitting plutonium radionuclides

^{238,239,240}Pu but is quite significant because of its huge contribution to the whole plutonium fallout. Our previous experiments on air samples indicated extreme increase of ^{241}Pu amount in atmospheric dust in April 1986. The available information about the bioaccumulation and distribution of ^{241}Pu in the Baltic Sea ecosystem and Poland territory is still very limited. The main purpose of the present work was to complete the present knowledge and estimate the further levels of the Baltic Sea environment contamination.

The highest total ^{241}Pu concentration in seawater was found in the Słupsk Bank (3.35±0.17 mBq·dm^{-3}) and this area had the highest concentration of ^{241}Pu connected to suspended matter as well (1.94±0.12 mBq·dm^{-3}). High concentrations of ^{241}Pu in the central part of the southern Baltic Sea can be a result of Baltic water circulation.

The ^{241}Pu activity in phytoplankton sample from the Pomeranian Bay was 1.06±0.09 mBq·g^{-1} dw. Within zooplankton samples the highest ^{241}Pu activity was found in samples from the central part of the southern Baltic (2.66±0.16 mBq·g^{-1} dw) and from the Gdańsk Deep (2.64±0.70 mBq·g^{-1} dw). In zooplankton samples, similar situation to seawater samples was noticed – the highest concentrations of ^{241}Pu were found in the central part of the southern Baltic Sea, and similarly to seawater it could be a result of Baltic water circulation.

Generally the data show significant differences in ^{241}Pu concentrations among all the species examined. The highest values of ^{241}Pu activities for whole organism were found in fish from *Perciformes:* benthic round goby (0.863±0.066 mBq·g^{-1} ww) and pelagic perch (0.666±0.001 mBq·g^{-1} ww). The lowest ^{241}Pu activity was found in flounder (0.104±0.009 mBq·g^{-1} ww). The plutonium was also non-uniformly distributed between the organs and tissues of the analyzed fish, especially pelagic herring and cod as well as benthic flounder.

In sediments, the highest amount of plutonium was found in the middle parts of all analyzed sediments and came from the global atmospheric fallout from nuclear tests in 1958-61. The distribution of ^{241}Pu in analyzed sediments samples was not uniform and depended on the sediment geomorphology and depth as well as on its location.

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POLONIUM ^{210}PO AND RADIOLEAD ^{210}PB IN HAIR OD DOMESTIC ANIMALS

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The aim of the study was polonium ^{210}Po and radiolead ^{210}Pb determination in hair samples taken from chosen domestic animals, namely dogs *Canis familiaris*. The research covered 15 breeds of different hair type living in the northern Poland.

The average values of analyzed radionuclides in analyzed dog hair were from 0.46±0.02 mBq·g^{-1} to 15.05±1.13 mBq·g^{-1} for ^{210}Po while for ^{210}Pb its activity values were measured from 0.31±0.03 mBq·g^{-1} to 9.82±0.53 mBq·g^{-1}. The values of the ^{210}Po/^{210}Pb activity ratio were calculated from 0.82±0.09 for Yorkshire terrier to 5.16±0.45 for Bolognese. The highest activities of ^{210}Po and ^{210}Pb were measured for small long-haired dog Maltese while the lowest in small long-haired Yorkshire terrier and Poodle toy.

Generally, both ^{210}Po and ^{210}Pb radioisotopes accumulation does not depend on dog sex. Higher values of ^{210}Po and ^{210}Pb were found in long and rough-haired dogs. Further, our experiments showed the hair from dogs living in villages contained more ^{210}Pb than dogs living in the cities and dogs eating dry food accumulate more ^{210}Po in their hair in comparison to fresh or mixed food eating dogs.

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MULTIVARIATE ANALYSIS OF CLIMATE VARIABLES, TELECONNECTION INDICES AND ACTIVITIES OF LEAD-210 AND BERYLLIUM-7 IN SURFACE AIR IN BELGRADE, SERBIA

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Activities of lead-210 and beryllium-7 have been monitored at the Vinča Institute of Nuclear Sciences in Belgrade, Serbia. The monthly mean activities in composite aerosol samples were determined on HPGe detectors by standard gamma spectrometry. The meteorological data, consisting of the temperature, atmospheric pressure, relative humidity, sunshine hours and cloud cover data were obtained from the European Climate Assessment & Dataset and the Republic Hydrometeorological Service of Serbia. Five teleconnection indices of large scale atmospheric circulation: North Atlantic Oscillation, East Atlantic Pattern, East Atlantic/West Russia Pattern, Scandinavia Pattern, and Polar/Eurasia Pattern were obtained from the data archive of the United States National Oceanic and Atmospheric Administration's Climate Prediction Center. The first lead-210 and beryllium-7 activities measured at the Vinča Institute date back to 1985 and 1991, respectively, and their relation with the climate variables and teleconnection indices is investigated using multivariate methods of analysis.

The most appropriate multivariate method of analysis of these sets of measurements is selected from a wide spectrum of multivariate methods developed for data analysis in high-energy physics and implemented in the Toolkit for Multivariate Analysis software package. The evaluation ranking results based on the best signal efficiency and purity, show that the Boosted Decision Trees (BDT) multivariate method is the most suitable for the variable analysis. Further multivariate analysis results give insight into the dependence of lead-210 and beryllium-7 concentrations upon the climate variables and atmospheric circulation (via the teleconnection indices) during the time of measurements. The BDT method singles out the Scandinavia Pattern index as the variable with the highest importance for both radionuclides. Amongst the climate variables, temperature shows the strongest influence on the radionuclide concentrations, while relative humidity is the lowest ranking variable. Moreover, the multivariate regression methods give a good approximation of lead-210 and beryllium-7 concentrations for all the sets of climate variables and teleconnection indices.

AQUATIC ECOSYSTEMS IN THE CHERNOBYL EXCLUSION ZONE: CURRENT LEVELS AND TRENDS OF RADIOACTIVE CONTAMINATION

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The current radiation level and its composition in aquatic ecosystems within the Chernobyl exclusion zone (ChEZ) are conditioned, above all things, by the amount of radioactive matters released as aerosols on a water surface and adjacent territories during the period of the active phase of the accident from destroyed of the ChNPP in 1986, and also by intensity and duration of the second processes of radionuclides washout from the catchment areas and hydrodynamic processes of their transport outside of water bodies. During last 10-15 years in soils of the ChEZ a tendency of increase of yield of the mobile bioavailable forms of radionuclides, which released into hydrological systems with surface and ground waters or localized in the closed water systems, where quickly involving in the biotic cycle is marked. On the example of lakes of the Krasnensky flood plain of the Pripyat River, which is one of the most contaminated by radionuclides territory of the ChEZ, was determined that the basic amount of radionuclides in lake ecosystem is deposited in the bottom sediments: ^{90}Sr - 89-95%, ^{137}Cs - 99%, transuranium elements (TUE) ^{238}Pu, $^{239+240}$Pu and ^{241}Am - almost 100% of the total radionuclide amount in ecosystem. The increased migration activity of ^{90}Sr determines its more high quantity in water (4-10%) on comparison with ^{137}Cs (0.5-0.6%) and TUE (0.03-0.04%) and, opposite, less - in sestone (0.15-0.16%) on comparison with ^{137}Cs (0.25-0.30%). The value of ^{90}Sr in biotic component amounts 0.25-0.61%, ^{137}Cs – 0.14-0.47% and TUE – 0.07-0.16% of the total quantity in ecosystem. The gradual decline of radionuclide specific activity is a dominant tendency in the dynamics of ^{137}Cs and ^{90}Sr in water and aquatic biota of the majority of reservoirs and water flow in the ChEZ. The exception is water bodies, located on the dammed territories of the Krasnensky flood plain, where at the proceeding decrease of ^{137}Cs concentration, from the end of 1990th there is a gradual increase of ^{90}Sr specific activity in different hydrobionts. It is assumed such dynamics is related to building of high-water dam complex and degradations of the existent reclamation systems on the area of left-bank flood plain of the Pripyat River, which entailed the change of the hydrological mode and strengthening of the processes of overwetting and swamping of the dammed territories. As a result, on a background of general tendencies of increase of mobile forms of ^{90}Sr in soils of catchment territories of the ChEZ, there is the gradual increase of radionuclide bioavailable forms in water of the lakes, located within the dammed territory and, accordingly, intensity of their concentration by aquatic species. The result of radionuclide species specificity concentration and its long-term dynamics in higher aquatic plants (30 species), freshwater mollusks (10 species) and fishes (18 species) from water bodies with different hydrological mode and level of radioactive contamination will be presented.

ASSESSMENT OF CONTEMPORARY RADIATION EXPOSURE OF MURINE RODENTS AT THE TERRITORIES OF THE EAST-URAL RADIOACTIVE TRACE

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Late effects of chronic radiation exposure of wild animals, that inhabit contaminated territories for many generations, should be considered as important source of knowledge on evolutionary adaptation processes. Valuable data on effects of exposure are observed in studies of small mammals at East-Ural Radioactive Trace (since 1957), where Sr-90 is primary contaminant. At the same time there is no reliable methodology of dose estimation that is necessary to study dose effect relationship. The investigation of contemporary radiation exposure of EURT mammals was performed using the bones of murine rodents trapped in 2005 on the sites with the surface contamination by Sr-90 24–40 MBq/m^2. Analysis included 38 skulls: *Sylvaemus uralensis* (14), *Microtus agrestis* (20), *Clethrionomys rutilus* (4). Internal dose estimations were based on the data on the Sr-90 activity concentration in bones measured via non-destructive method. The distribution of Sr-90 by organs and tissues was estimated using developed biokinetic model for mouse-like rodent that was adjusted and verified considering published experimental data on strontium retention in the bodies of laboratory and wild mice. A suggested set of transfer rates satisfactorily describes both the laboratory experiments and the data on strontium accumulation available for wild animals. Dose estimation procedure included application of the published values of absorbed fractions of beta-radiation energy for different combinations of source and target organs (Stabin e*t. al.*, 2006). We estimated 12 conversion coefficients linking skeleton Sr-90 activity concentration and doses to 11 organs and whole body for adult animal. Whole body dose rate normalised to whole body Sr-90 activity amounts 0.015 (mGy·day^{-1})/(Bq·g^{-1}). The estimation gives the following values of 45 days accumulated doses for *M. agrestis*, *S. uralensis* and *C. rutilus* respectively: maximum absorbed doses to skeleton due to the Sr-90 are 267, 121 and 160 mGy; mean whole body internal doses – 37, 14 and 23 mGy; mean internal dose rates on the last day before trapping – 1.2; 0.44 and 0.75 mGy/day. Mean external dose rate reaches 0.43 mGy/day. Thus, dose rate of irradiation of some species exceeds the Derived Consideration Reference Level (0.1-1 mGy/day) established by ICRP.

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HIHG TIME RESOLUTION MEASUREMENTS OF THE 214PB CONCENTRATION IN RAINFALLS

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Simultaneous observation of the natural gamma background and meteorological parameters were performed in the city of Sao Jose dos Campos, SP, Brazil in 2013-2014. The instrumental set is capable to perform permanent measurements of the ambient parameters with a time resolution up to 1 minute. This accuracy allows a detailed comparison of rainfall and gammas time profiles to determine the concentration of radon progeny 214Pb in liquid precipitations. The radiation fallout (the amount of the deposited 214Pb) was determined through simulation of gamma intensity produced in the decay chain 214Pb ->214Bi -> 214Po -> 210Pb. The input time profile of the 214Pb fallout varied until the best fit of simulated gammas profile with the experimental one was obtained. The 214Pb concentration in the rainfall water is calculated as a ratio of thus reconstructed fallout rate to that of the observed rainfall measured. It was found that the 214Pb concentration significantly differs from one rainfall to another and also within a same one and varies within two orders of magnitude. An apparent anti-correlation between rainfall rate and 214Pb concentration in the rain water is observed. A maximal concentration observed in lasting drizzling rains and at the beginning of more intensive rainfalls. The hypothesis explaining this effect by existing of the two different radiation scavenging mechanisms namely the washout (below-cloud scavenging) and the rainout (in-cloud one) is discussed.

RADIOECOLOGICAL RESEARCH ON THREE SPECIES OF THE GENERA *LIZA* FROM THE SOUTH ADRIATIC SEA

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Among six Euro-Mediterranean mullet species occurring in the South Adriatic Sea, three are from the genera *Liza* (*Liza saliens* Risso, 1810; *Liza aurata* Risso, 1810; *Liza ramada* Risso, 1826), and they are considered in the present study for heavy metals content and radioactive isotopes activity. Since metals (can be toxic to aquatic species) are important pollutants, released into ecosystems by various processes, and since radioactivity (radiation) can cause different effects on non-human species (in dependence on dose rates), a consideration of both of them is important in environmental risk assessment. Therefore, together with considering heavy metals content (As, B, Cd, Hg, Cr, Cu, Mn, Ni, Pb, Zn, Ba, Mo) in whole individuals and muscles of three species of the genera *Liza* – sampled in the Boka Kotorska Bay, Montenegro (Tivat, Solila), and following biocentric approach in radioecological research (non-human biota considered as target, not as contaminant to humans only), eleven individuals of each species were considered for radioactivity due to ^{137}Cs, ^{40}K, ^{226}Ra (^{214}Pb, ^{214}Bi), ^{232}Th (^{228}Ac, ^{212}Pb) and ^{7}Be – two whole individuals, seven muscles, two gastrointestinal systems (for each of species). Two ORTEC HPGe spectrometers are used to determine activity concentrations. Cesium-137 activity concentration (the first measurements in the South Adriatic Sea environment – Coast of Montenegro, after the Fukushima accident) in the *Liza* species ranged from < 0.35 (in one *L. saliens* whole individual) to 1.5 Bq kg^{-1} (in one *L. saliens* gastrointestinal system), ^{40}K – from 53 (*L. ramada* muscle) to 211.8 Bq kg^{-1} (*L. aurata* gastrointestinal system), ^{214}Pb – from < 0.69 (*L. saliens* whole individual) to 29.7 Bq kg^{-1} (*L. aurata* muscle), ^{214}Bi – from < 0.64 (*L. saliens* whole individual) to 32.3 Bq kg^{-1} (*L. aurata* muscle), ^{232}Th (^{228}Ac) – from < 0.14 (*L. saliens* whole individual) to 13.1 Bq kg^{-1} (*L. saliens* gastrointestinal system), ^{212}Pb – from < 0.86 (*L. saliens* muscle) to 21.8 Bq kg^{-1} (*L. aurata* muscle), ^{7}Be – from < 3.78 (*L. ramada* whole individual) to 34.9 Bq kg^{-1} (*L. ramada* gastrointestinal system). These data are used to evaluate bioaccumulation of the radioisotopes in the *Liza* species (i.e., concentration factors – from seawater, sediment and mud with detritus – sampled at the same locality and then analyzed for radioactivity due to the same isotopes), as well as the total dose rate (internal and external exposure) – to evaluate whether effects could be expected, on individual, population or ecosystem level.

NATURAL RADIOACTIVITY IN VIRGIN SOILS AND SOILS FROM SOME AREAS WITH CLOSED URANIUM MINING FACILITIES IN BULGARIA

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It is necessary to study the natural radioactivity levels in soil to assess the dose for the population in order to know the health risks and to have a baseline for future changes in the environmental radioactivity due to human activities. The natural radionuclide (^{238}U, ^{226}Ra, and ^{232}Th) contents in soil were determined for three different regions in the country using high-resolution gamma-ray spectrometric analysis. A comparison of the dynamics of their behavior throughout the years is done. Bulgaria is a country with intensive uranium mining activities in the past years. That is why radiological monitoring of closed uranium mining facilities in different regions of the country are obligatory and of great interest. This work presents results from such investigations made in regions where remediation has been done. The results have been evaluated according to the Bulgarian radionuclide environment contamination legislation. The necessity of permanent environmental monitoring is assessed.

Key words: Natural radioactivity, gamma-spectrometry, soil, uranium, radium

WAVELET SPECTRAL ANALYSIS OF TELECONNECTION INDICES AND ACTIVITIES OF BERYLLIUM-7 AND LEAD-210 IN GROUND LEVEL AIR IN BELGRADE, SERBIA

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Activities of beryllium-7 and lead-210 were monitored in ground level air in Belgrade, Serbia. The measuring sites were located at the Institute of Nuclear Sciences Vinča. The activities were determined on HPGe detectors by standard gamma spectrometry. Five teleconnection indices of large scale atmospheric circulation: North Atlantic Oscillation, East Atlantic Pattern, East Atlantic/West Russia Pattern, Scandinavia Pattern, and Polar/Eurasia Pattern were obtained from the data archive of the United States National Oceanic and Atmospheric Administration's Climate Prediction Center. The colledted time series consist of monthly values and span more than two decades: beryllium-7 since 1991, lead-210 since 1985, and the teleconnection indices since 1950, thus offering data arrays of sufficient lengths for wavelet spectral analysis. A relation between the radionuclides' activities and the indices is first investigated using Pearson's correlation coefficients. The computed coefficients do not indicate a linear relationship between the variables, not even when a time lag of 1 to 12 months is included in the calculations. However, the wavelet spectral analysis shows a number of common characteristic frequencies in the data arrays. The annual cycle of all the variables is clearly evident. A common time period of two to three years is also found, as well as higher frequency variability corresponding to five to six months.

VERTICAL MIGRATION OF ^{137}Cs IN UNDISTURBED ARENOSOLS OF BANAT, SERBIA

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After the accident at the Chernobyl nuclear power plant in the Former Soviet Union on 26 April 1986 the radioactive cloud arrived to Serbia, resulting in the deposition of large quantities of artificial radionuclides ^{137}Cs. The studies of Chernobyl fallout indicated that soil is the main reservoir of ^{137}Cs and that its activity concentration decreases with soil depth. The migration and distribution of ^{137}Cs in the soil profile varies depending on soil properties (such as soil texture, organic matter content etc.), land use, management practices and climatic conditions. This paper deals with the vertical migration of ^{137}Cs in undisturbed arenosols of Banat and influence of organic matter content and soil particle size distribution on its migration. The ^{137}Cs activity concentration of Chernobyl-derived in undisturbed arenosols of Banat determined by gamma-ray spectrometry ranged from 0.20 to 139 Bq kg^{-1}, with the mean value of 12.8 Bq kg^{-1}. Negative correlations were found between sand content and the ^{137}Cs activity concentration, while a positive correlation was found between organic matter and silt content and ^{137}Cs activity concentration.

RADIUM-226 ACTIVITY CONCENTRATIONS IN WELL AND SPRING WATERS IN SERBIA: SPATIAL DISTRIBUTION AND RELATION TO GEOLOGICAL FORMATIONS

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This study presents the survey results of the ^{226}Ra activity concentrations in well and spring waters from 170 sampling sites in Serbia which are not under monitoring programme in Serbia. The purpose of use of the majority of the analysed waters by small rural communities is not under surveillance. The mean activity concentrations of ^{226}Ra were found to be 0.36 Bq L^{-1} and 0.57 Bq L^{-1} in well and spring waters, respectively. In more than 90% of the analysed waters the ^{226}Ra activity concentrations were below 1 Bq L^{-1}. The high ^{226}Ra activity concentrations were associated mainly with granitic and metamorphic rocks with occurrences of uranium mineralisations. The activity concentrations of this radionuclide were found to be highest in crystalline rocks- and carbon dioxide rich-aquifers (up to 17 Bq L^{-1}). The geographical mapping results provide a baseline to identify regions that may require additional assessment of radiation exposure by local communities. The study indicate the need of further investigation which should include chemical composition of water, geochemical conditions of the environment, discharge rates, transport and other phenomena which could influence radium migration and accumulation in groundwater.

USING ^{137}CS ANALYSIS TO STUDY THE EFFECT OF SLOPE ASPECT ON THE HILLSLOPE EROSION

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The well understanding of the effect of slope aspects on the distribution of soil erosion is an important prerequisite for the soil and water conservation in the Wind-water Erosion Crisscross Region. The purpose of this study was to analyze and evaluate quantitatively the soil erosion rates on hillsides with different slope aspects and slope positions by the resident cesium-137 deficit technique. The soil samples were collected at 15-m intervals on hillslopes along four transects on the south and north aspects in 2011. Results showed that the slope aspect had great impact on the soil erosion intensity, and the erosion intensity on the shady slope was about 1.7 times of that on the sunny slope. For the north hillside the highest net soil loss intensity occurred on the middle slope, whereas it occurred on the top for the sunny slope. This characteristic has great relation with the wind erosion.

Key words: ^{137}Cs, soil erosion, slope aspect, slope position

DOSE ASSESMENT FROM BUILDING MATERIALS USED IN HOUSING SECTOR IN SERBIA

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The results of mass activity measuring in many domestic building materials used in housing sector are presented. Natural radionuclides 40-K, 226-Ra, 232-Th, 235-U and 238-U as well as artificial radinuclide 137-Cs were detected using gamma spectrometry. Based on measured mass activity values, the absorbed dose rate from examined building materials was calculated following EC standards. According UNSCEAR procedure, the annual effective dose was also calculated.

PRELIMINARY EXAMINATION OF THE GROSS ALPHA AND GROSS BETA ACTIVITY IN VITAMINS

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In this paper, preliminary examination of the gross alpha and gross beta activity in vitamins is presented. The gross alpha and gross beta activities in five vitamin samples collected in the local pharmacies (produced in Serbia, except vitamin B complex, which is produced in Austria) were determined. Investigation was performed in only these five vitamins because they can be found in pure form. Sampling and measurement were carried out by Radiation and Environmental Protection Department of the Vinča Institute of Nuclear Sciences. The instrumentation which was used for count the gross alpha and gross beta activities is α/β low level proportional counter Thermo Eberline FHT 770T. Preparation of the vitamin samples for the gross alpha and gross beta activity measurement was performed used MARLAP method.

Vitamins which were covered by these preliminary measurements are: C (ascorbic acid) in bag and tablet, D (cholecalciferol), E (tocopherol) and B complex. The obtained results for the gross alpha activity were less than minimum detectable activity (MDA), while the gross beta activity ranged from less than MDA to 347 Bq kg^{-1}.

Because of health hazard to the population which used vitamins every day, it is necessary to periodically monitor the content of radionuclides in vitamins samples.

RADIOACTIVITY OF PRIVATE DRINKING WATER WELLS

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At least 10% inhabitants in the Czech Republic are supplied by water from private sources (private wells, boreholes). With the increasing cost of water, the number of people who will use their own sources of drinking water will be likely to increase. According to the Decree of the State Office for Nuclear Safety about the Radiation Protection 307/2002 as amended by Decree 499/2005, the guideline value for the supplied drinking water ("drinking water for public supply") for radon concentration is 50 $Bq \cdot l^{-1}$. This guideline does not apply to private sources of drinking water.

The paper presents results of a research project supported by the Ministry of Interior of the Czech Republic VG20102014035: "Determination of the gross concentration of radionuclides emitting alpha and beta particles and determination of concentration of individual radionuclides in water drinking sources". The main scope of this project is monitored the main variables characterizing the level of radioactivity in private drinking water sources: gross alpha and beta, the uranium, radium and radon concentration.

The samples of water were taken directly from tap in the bathroom. The "freshness" of water was ensured by pumping of sufficient amount of water before the sampling. Concentration of radon in the drinking water is determined by scintillation cells after transferring of gas radon from liquid sample. Determination of gross alpha activity was specify in accordance ČSN 75 7611. Concentration of radium and uranium were determined in accordance PNU 83 0501 and ČSN 83 0533 respectively.

Overall number of localities monitored within the project exceeds 400. Due to geological difficulty of the Czech Republic are compared individual results from one geological units and set of results from different geological units between themselves. The relationships between individual measured variables were found out in the overall set of results.

The results map the development of measured values at individual locations in the Czech Republic. Furthermore, the results may serve as the basis of background levels, which can be used in the event of intentional contamination of drinking water or in the event of an accident involving release of radioactive substances into the environment.

IMPACT OF SHARP TEMPERATURE VARIATIONS ON THE MIGRATION ABILITY OF ^{137}Cs IN FOUR SOIL TYPES FROM BULGARIA

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Extreme variations of the environmental conditions, like sharp temperature increase or decrease, soil drought or intensive falls may influence the environmental behavior of radionuclides in nature. Their impact is highest in the first weeks after radioactive contamination due to the weak fixation of the radionuclides to the soil matrix.

This study presents the effects of the sharp temperature increase or decrease on the water-soluble and exchangeable forms of ^{137}Cs one month after its entrance in the soil. The binding of the radionuclide with humic and fulvic acid and its water-solubility were studied after two months conditioning under different temperature regimes. The impact of the sharp variations of the environmental temperature on the migration ability of ^{137}Cs was investigated in soils, taken from four different regions in Bulgaria.

The soil samples were contaminated with aqueous solution of ^{137}Cs and stored in a climate chamber and a freezer for a period of two months. The water-soluble, exchangeable forms of the radionuclide, as well as the forms, bound to humic and fulvic acids were determined by single extractions with distilled water, 1 M NH_4NO_3 and 0,1 $MNa_4P_2O_7$, followed by gamma-spectrometric determination. HPGe detector Canberra 7221 coupled to a 16000-channel analyzer DSA-1000 was used and the gamma spectra were processed by Genie-2000 Basic Spectroscopy Software.

The results showed that the conditioning for one month at increased temperature decreases the water-soluble and exchangeable ^{137}Cs, while the freezing has the opposite effect. The sharp warming and freezing two months after the contamination reduces the binding of the radionuclide to humic and fulvic acids. The impact of the extreme temperature changes on the water-solubility of ^{137}Cs is different and depends on the soil characteristics.

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IODINE BEHAVIOUR IN CEMENTED RADIOACTIVE WASTE STORAGE BARRIERS

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There are actual problems in operating radioactive waste repositories for a long-term as long-lived radionuclides such as ^{99}Tc ($T_{1/2}$ = 2.13x10^5 m.), ^{129}I (1.57 x 10^7 m.), actinoids: ^{237}Np (2.14 x 10^6 m.), ^{242}Pu (3.75 x10^5 m.), ^{239}Pu (2.4 x 10^4 m.), ^{235}U (7.04 x 10^8 m.), ^{238}U (4.47 x 10^9 m.) determine that these repositories should operate no less than hundreds thousands of years. Radioactive nuclides migration from the repository through the containers and engineered barriers is induced because of their disintegration by ground water, microorganisms, cement's degradation, corrosion.

Final disposal of long-lived radioactive waste in the repositories implies the long-term risk related to their potential spreading in the surrounding solid and liquid phases. One of these radionuclides is iodine-129. ^{129}I distribution in waste streams occurs due to the chemistry of iodine. It is of large radiological concern, because of the relative high mobility of different species of iodine in natural water environments. The knowledge of the extent of iodine interaction with engineered barriers is of vital importance in modeling iodine release from irradiated nuclear reactor fuel elements stored in underground vaults.

The objective of this study was to investigate iodine interactions with cementitious materials under hyperalkaline conditions (pH<12) with/without reductant $Na_2S_2O_5$. For this purpose, a series of K_D experiments using ^{127}I, as tracers, were performed. The concentrations of iodine in solution were measured by ICP-MS. The distribution coeficient for ^{127}I in cement-water system was calculated.

Under the investigation conditions the gradual removal of I^- from the solution was observed. The results showed that under alkaline (pH<12) conditions, in the system with reductant $Na_2S_2O_5$, after exposure period of 7 days, about 70% of I^- was incorporated into cement and removed from solution. The remainder of I^- concentration in the experimental system without reductant was approximately 25%.

The K_D values of ^{127}I ranged from ~ 80 in the experiment with $Na_2S_2O_5$ to ~170 in the experiment without $Na_2S_2O_5$, thus, demonstrating the influence of chemical speciation of iodine on its interactions with cementitious materials under hyperalkaline conditions.

DETERMINATION OF ^{238}U AND ^{232}Th IN SAMPLES FROM ENVIRONMENT, SOIL AND PLANTS

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In this paper we measure the uptake value from soils to plants, transfer coefficient (TF), temporal variations of U and Th in different plant species using two methods. The detected area (Buhovo, Bulgaria) is contaminated with natural isotopes from the uranium mines.

The analysis was made of the content of uranium and thorium in soil and growing vegetation on it by combining two methods, the soil was analyzed by gamma spectrometer avoiding complete dissolution and analysis with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was made only of the plant samples.

We believe that ICP-MS is the most appropriate method for the determination of natural radionuclides in environmental samples, but the purpose of using a combination of both methods was to reduce the cost and the duration of analysis and we recommend it.

RADIOACTIVITY MONITORING OF THE CITY OF NIŠ

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The paper presents the results and discussion of the comprehensive radioactivity monitoring of the city of Niš in south-east region of Serbia. Monitoring was financial supported by Administration of Economy, Sustainable Development and Environmental Protection, City of Niš. During the spring and autumn season of 2013 gamma spectrometry measurements of agricultural soil and seasonal fruits and vegetables from 25 different locations were performed and analyzed. The transfer factors from soil to plants and also radionuclides distribution and correlations were calculated and discussed. The radioactivity monitoring of soil from school and kindergartens yards, indoor radon measurements in dwellings and schools, the results of gross alpha-beta measurements of tap and surface water for the municipality of Niš are also presented in this paper. Ten illegal dumps were investigated with dose measurements and radionuclides analysis in soil samples. The effective annual dose from ingestion was estimated from the results of gamma spectrometry measurements of ^{137}Cs in food from Niš supermarkets. This investigation leads to some conclusions and recommendations for further research.

NATURAL RADIONUCLIDES IN SOIL SAMPLES IN THE SURROUNDING OF THE CITY OF SKOPJE, MACEDONIA

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Soil acts as a potential source of radionuclides through which they can enter the food chain and end up in people. Radioactive materials that naturally occur in soil are one of the components of the external exposure to gamma rays to which people are regularly exposed. So the soil acts as a potential source of the radionuclides, through which they can enter the food chain and up in people. The natural radioactivity of the environment and the related external exposure due to gamma radiation primarily depends on the geological and geographical conditions and they exist at different levels in the soils from every region of the world. Taking into consideration the importance of the distribution and the transfer of radionuclides in the soil, an attempt was made in this work, to determine the concentration of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in the same.

In order to determine the activities of the natural and the artificial radionuclides in the soil, samples of uncultivated soil were taken, from locations in the surrounding of Skopje. The sampling from the soil was performed in the months of May and June in 2013. The area was divided into 14 locations. The sampling was performed from 0-15cm with an increment of 5cm. The locations selected for sampling were flat land where the vegetation was removed. The homogenized samples of the soil were packed in plastic containers which had the same geometry as the one for the reference materials and upon ensuring time balance between the successors of ^{238}U and ^{232}Th series (60 days), these sealed samples were prepared for an analysis. The radiometric analysis of these samples was performed by using a system based on a personal computer, with gamma spectrometry with high resolution that consists of germanium with high purity (HPGe), coaxial detector (relative efficiency: 30%, active volume: 180 cubic centimeters with a beryllium window in the end and FWHM: 2.0 keV at 1332 KeV for ^{60}Co. The calculation was performed for 65000 seconds for the reference materials and the soil samples. The spectrums were analyzed by a commercially available software GENIE-2000 obtained from Canberra Packard, which provides identification of radionuclides and assessment of their activity.

It was determined that the activity levels follow the recorded normal distribution.

The values are between 19,20Bq/kg to 40,00Bq/kg for ^{226}Ra, from 25,49Bq/kg to 25,49Bq/kg and from 399,02Bq/kg to 666,10Bq/kg, respectively. The concentrations of these radionuclides are compared with the available data from the other countries. Data shows that the average value of activity of ^{232}Th is higher than the one of ^{226}Ra which may be due to the longer half-life of ^{232}Th in relation to ^{226}Ra. The concentration of activity of ^{40}K in the soil has a value that is higher than the one of ^{232}Th and ^{226}Ra for all soils. Also the measured values of concentration of activity of the radionuclides ^{40}K, ^{226}Ra and ^{232}Th in all soils that are being examined, are within the global range specified by the international organizations.

Key words: Radioactivity, soils, analysis, gamma spectrometry, results

RADIATION DOSE OF NATURAL RADIONUCLIDES AND PECULIARITIES OF SPATIAL WASTE DISPOSAL (RADIONUCLIDES, METALS) OF THE MINING INDUSTRY OF THE KYRGYZSTAN REPUBLIC

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Kyrgyzstan is tucked into Central Asia's geographical vortex amid a massive knot of colliding mountain ranges. Monster mountains and their associated scraggy valleys, glaciers, gorges and ice-blue lakes dominate over 90% of the country. There are 254.4 million cube meters of mining wastes located in 92 facilities of the Kyrgyzstan republic, which contain radionuclides as well as other substances, harmful and toxic for people. 36 tailing dumps and 25 dumping sites with the total amount of 15.7 million cube meters are under the supervision of the Emergency Ministry of the Kyrgyzstan Republic. These are 31 tailing dumps with the radioactive waste amount of 7.2 million cube meters, and 5 tailings with the amount of toxic wastes of 5.2 million cube meters, and 25 mining dumping sites of substandard ores with the amount of 3.3 million cube meters.

The aim of the study is to analyze the main data on the wastes of the mining production of Kyrgyzstan taking into account their spatial disposal, natural radiation dose and to make calculations for a new engineering and geonomical schematic map of the area distribution of the hazards due to the radioactive and toxic dangerous tailings and rock dumping sites.

When discharged into the rivers the mining production wastes of the tailing dumps constitute a threat of radioactive pollution for the populated areas of the Nookensk Region: Kyzylkya, Kypsakdala, Kok-Tash, Kochkor-At and farther through the boundary for the Uzbekistan area. The exposure doses of the gamma-radiation of the tailings surface are within the range of 17-40-60 μR/h. The level of gamma-radiation amounts up to 400 – 500 μR/h in the baring sites of the protective screens on the surface of the tailing dumps.

Ionization radiation sources (IRS) are concentrated in the landfill such as radionuclides: cobalt-60, americium-241, radium-226, cesium-137, cadmium-109, thillium-170, promethium-147, plutonium-238, europium-152,154, as well as high activity therapeutic devices (cobalt-60, cesium-137 up to 4000 curie) and densimeters, level sensors, polonium-beryllium sources of fast neutrons, radium-226, used in different industries, geology and medicine.

The deposit development and exploitation resulted in a vast amount of radioactive wastes located in the Kyrgyzstan Republic, which creates a radiation dose several times exceeding the existing Sanitary Regulations. Taking into account the fact that the area of the country is seismo-dangerous and a considerable part of the lands is subject to natural hazards (mud flows, floods, etc.), the radiation environment is considered to be unfavorable. Moreover, the danger exists not only for the areas of the country itself but for the neighboring states as well due to the transboundary wind and water waste transport, there being various water bodies in the country.

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MATHEMATICAL MODELING OF TOTAL DOSE TO A HYPOTHETICAL RESIDENT IN THE ENVIRONMENT OF NUCLEAR FACILITY BY CONTAMINATION THROUGH THE ATMOSPHERE

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This paper presents an algorithm for the calculation of internal and external doses, which is an integral part of the mathematical model of atmospheric dispersion. The results obtained by the model for atmospheric dispersion of radionuclides, which has been developed to control the environment of nuclear reactors at Vinča RA, were compared with values from an IAEA publication for a given scenario of radionuclide emission to the atmospheric boundary layer.

Results obtained by comparing the value of this scenario of IAEA and modeled values for a given scenario of radionuclides emissions in the boundary layer of the atmosphere, show that the algorithm for calculating dose, together with a mathematical model for atmospheric dispersion, due to small differences in the results, compared to the IAEA recommended model, can be used as a basis for this type of analysis.

With determining the field of radiation dose using the module for a dose, it is possible to get the assessment of environmental impacts of emissions of radionuclides into the atmosphere in routine or accidental circumstances, using assumptions emission for the selected source (nuclear facility), further based on measured meteorological data and on the basis of other contemporary data on the location and resources.

In order to illustrate the application of this mathematical model (atmospheric dispersion + module for the calculation of dose), using data on the hypothetical emission of radionuclides, according to Brook Haven Lab. literature data related to emission of radionuclides from the ventilation parameters, applied to the reactor RA, then 3D topography in Vinča and meteorological data, field of total annual dose, based on the total dose received by hypothetical resident in the vicinity of the reactor RA at Vinča, during operation of the reactor is presented.

DISEQUILIBRIUM ACTIVITY BETWEEN URANIUM (^{234}U, ^{235}U, ^{238}U) ISOTOPES IN THE ENVIRONMENT AROUND PHOSPHOGYPSUM WASTE HEAP IN NORTHERN POLAND

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The aim of this study was to examine the values of the $^{234}U/^{238}U$ and $^{235}U/^{238}U$ activity ratios in soils, water and plant samples collected in the area of phosphogypsum waste heap in Wiślinka. The values of the activity ratios in analyzed soil, water and plant samples were estimated in the wide range. The results for uranium suggest that ^{234}U, ^{235}U and ^{238}U radioisotopes that are present in the vicinity of phosphogypsum waste heap are of natural origin (the $^{234}U/^{238}U$ activity ratio is between 0.90±0.05 and 0.92±0.03 in water samples, the $^{234}U/^{238}U$ activity ratio is between 0.97±0.05 and 1.01±0.02 in plant samples, the $^{234}U/^{238}U$ activity ratio is between 0.98±0.04 and 1.05±0.03 in soil samples). The values of the activity ratio between ^{234}U and ^{238}U are in a relative state of activity equilibrium. The values of the $^{235}U/^{238}U$ activity ratio are between 0.021±0.003 and 0.060±0.004 in the analyzed samples. The obtained values of the activity ratio between ^{234}U, ^{235}U and ^{238}U are probably connected with the agricultural use of fertilizers and erosion and leakages from phosphogypsum waste heap into surrounding environment.

The obtained values of the $^{234}U/^{238}U$ activity ratio in all analyzed plants, waters and soils near phosphogypsum stockpile in Wiślinka (northern Poland) are close to one, which indicates that source of uranium in analyzed samples is phosphogypsum. The values of the $^{234}U/^{238}U$ activity ratio in water with immediate area of waste heap are considerably lower than in the waters of the Martwa Wisła river. The values of the $^{234}U/^{238}U$ activity ratio are approximately about one in the phosphogypsum and in the water of retention reservoir and pumping station, while in the water from the Martwa Wisła River they are slightly higher than one. Also the influence of phosphogypsum on radioactive contamination of environmental zone around the heap waste in Wiślinka (northern Poland) was observed for mosses from Sobieszewo Island, where the values of the $^{234}U/^{238}U$ activity ratio in analyzed mosses from Sobieszewo Island range from 0.97±0.03 to 1.00±0.07.

THE POTENTIAL SOURCES OF URANIUM ISOTOPES (^{234}U, ^{235}U, ^{238}U) CONTAMINATION IN THE BALTIC SEA FROM POLAND

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The main sources of uranium in northern Poland, which significantly affect the value of the activity ratio between ^{234}U and ^{238}U in both terrestrial as well as marine environment are phosphogypsum stockpiles, located on the territory of Poland in Police and Wiślinka near Gdańsk. Wiślinka is a village in the administrative district of Pruszcz Gdański, within Gdańsk County, Pomeranian Voivodeship, in northern Poland. It lies approximately 14 kilometres north-east of Pruszcz Gdański and 12 km east of the regional capital Gdańsk. Police is a town in the West Pomeranian Voivodeship, northwestern Poland. Police town is situated on the Oder River and its estuary, south of the Szczecin Lagoon and the Bay of Pomerania. In central Poland large amounts of uranium are the result of the use of phosphate fertilizers many by farms. The largest producers of phosphate fertilizers in Poland are currently Chemical Works Police SA and Gdansk Phosphate Fertilizer Plants. Uranium sources in southern Poland are burning of coal and coal mining. Coal is a strategic resource in Poland, it meets 60% of the energy needs of the country. Polish resources of this rock are among the largest in the world. Most of them are located in the Lublin province and Upper Silesia. Lublin resources are greater, lie on a smaller depth and are of high quality, although they are less well documented. The deposits extend from Łuków and Radzyń Podlaski to Hrubieszów and combine with the Lvov-Volyn Coal Basin, Ukraine. For many years Poland took top place among five countries with the largest coal mining. Another important source of uranium discovered in Upper Silesia is the so-called radioekological anomaly, resulting from mine water and quarrying industry. This phenomenon can be observed on the example of the Bystrzyca River. Small amounts of uranium are the results erosion and weathering of rocks, minor amounts from combustion of coal and oil and dry and wet precipitation (e.g. rain, snow).

NATURAL AND ARTIFICIAL RADIONUCLIDE CONTENT OF SURFACE SEDIMENTS IN CANDARLI GULF, TURKEY

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Studies on concentrations of natural and artificial radionuclides in sediment samples of Candarlı Gulf, Turkey were carried out. Measurements were made by gamma spectrometry employing an HPGe detector. The results are used to assess the potential radiological hazards associated with these materials by computing the specific activity of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs, the radium equivalent activity, the external terrestrial gamma dose rate and the annual effective dose rate. The results have been compared with other radioactivity measurements in different country's sediments.

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SIMPLE RADIO ARRAYS FOR EXTRAGALACTIC NEUTRINOS

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We are investigating the possibility to construct a radio Askaryan observatory for cosmic neutrinos emitted by energetic neutrino sources.

As ultra high energy neutrinos can be a proof of the theoretical upper limit on the energy of cosmic rays from distant sources (the Greisen-Zatsepin-Kuzmin limit, play an important - but not completely understood – role in the Big Bang scenario, quantic gravitation etc. and also represent a key to unveil the mystery of the cosmic accelerator (pulsars, gamma ray bursts, active galactic nuclei, supernova) their detection is scientifically important.

Neutrinos cannot be directly detected, but they can be indirectly observed through their interactions with ordinary matter. We consider a detection strategy based on measurements of coherent Askaryan radiation produced in neutrino-induced electromagnetic showers from interactions with the atmosphere.

The first step is to determine the optimal geometry such that the cost of experiment remains small but detection is still possible. The radio antenna array characteristics are also determined together with its spatial resolution and sensitivity and energy threshold.

ULF WAVES AND PARTICLE FLUX IN THE EARTH'S MAGNETOSPHERE

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Among different space weather factors, sudden enhancements of energetic particle flux are the most dangerous for satellites. Different models of resonant and non-resonant electron acceleration do not agree with the registered times of particle enhancements. Experimental correlations exist between high solar wind velocities, geomagnetic storms and high amplitudes of ULF waves in the frequency range 10^{-3}-10^{-2}Hz with enhanced electron flux levels. However, specific space weather conditions responsible for geoefficiency of each of these factors are not established yet. The present study is related to comparative analysis of experimental data for particle flux, plasma and ULF geomagnetic disturbances in the magnetosphere and the ionosphere and parameters of space and ground measured geomagnetic pulsations. Interrelations between ULF parameters, space weather conditions and particle flux are studied at different time and spatial scales using the data of THEMIS, GOES and LANL magnetospheric satellites, ionospheric data from CHAMP and DEMETER satellites and Sodankyla ionosonde, and pulsation data from ground magnetometer networks.

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JOINT USE OF HEAVY IONS AND LASER FACILITIES FOR SINGLE EVENT EFFECTS TESTING

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Single event effect (SEE) is an effect induced by a single particle or ion that can cause different phenomena in IC. Traditional methods of SEE sensitivity characterization are based on the testing with ion accelerators. The alternatives methods are based on the employment of the focused laser irradiation. This work reports results of SEE investigation under focused laser and ion beams. Basic single event effects (SEU, SEL and SET) in different types of devices were compared.

Experimental technique with heavy ions and laser testing is described. Joint use of heavy ions and laser methods is based on the known linear ratio between laser energy and LET and assumption that the ratio between SEE cross-sections obtained under laser and ion irradiation is linear as well. So the objective is to estimate the correlation coefficients K_j and K_σ for the following relations:

$$L_{ie} = K_j \cdot J \tag{1}$$

$$\sigma_{ie} = K_\sigma \cdot \sigma_l(J) \tag{2}$$

where L_{ie} is equivalent LET, J is pulse laser energy (focused irradiation), σ_{ie} is equivalent ion SEE cross-section, $\sigma_l(J)$ is the SEE cross-section obtained using laser technique at a given value of J. Assuming the correlation mentioned above we expect the σ_l versus J (or L_{ie}) dependence to be described by Weibull function:

$$\sigma_l(J) = \sigma_{sl} \cdot \left\{1 - \exp\left[-\left(\frac{(J - J_0)}{W}\right)^s\right]\right\} \tag{3}$$

where J_0 is SEE laser threshold energy, σ_{sl} is laser SEE saturation cross-section, W, and s is approximation shape parameter.

To perform the correlation coefficient's estimation we should perform both laser and ion SEE tests. Through the laser SEE test we obtain a function $\sigma_l(J)$ using the fact that laser technique provides almost continuous series of pulsed laser energy in contradiction to ion tests. To match both laser and ion data we should get at least two cross-sections σ_{i1} and σ_{i2} at different ion LETs (LET_1 and LET_2) so that one of cross-section values corresponds to saturation region and the other lies at the near-threshold region of the Weibull curve.

Estimation of the correlation coefficient K_j can be performed using the equation (4), whereas the correlation coefficient K_σ is to be estimated from the relation:

$$\frac{\sigma_{i1}}{\sigma_{i2}} - \frac{\sigma_l(LET_1/K_j)}{\sigma_l(LET_2/K_j)} = 0 \cdot \tag{4}$$

$$K_\sigma = \frac{\sigma_{i1}}{\sigma_l(L_{i1}/K_j)} \tag{5}$$

Finally the estimated cross-section curve (3) can be determined. The result of joint use of heavy ions and laser methods is discussed.

Single Event Upset (SEU) took place under focused laser irradiation and heavy ion irradiation in two types of SRAM and FPGA. Single Event Latchup (SEL) was observed in RISC 64-Bit Processor and Single Event Transient (SET) was observed in standard logic IC.

INTRA-DEVICE LEAKAGE MODELING IN 180 AND 90 NM BULK CMOS DEVICES

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TID degradation caused by charge trapping in gate oxides has reduced significantly for modern CMOS technologies due to downscaling of the gate oxide thickness. As a result, the major contribution to TID response is due to radiation-induced charge buildup in shallow trench isolation (STI) [1].

The goal of this work was to create a technology computer aided design (TCAD) model for STI charge trapping in order to estimate the radiation-induced leakage current in NMOS transistors.

The paper presents TCAD calculated results of TID response for 180 and 90 nm NMOS transistors. Transistors' models under investigation were based on technology models for commercial high performance CMOS transistors provided by JSC Micron (Russia). The model takes into account the field dependence of hole and electron capture cross-sections and effect of positive trapped charge neutralization by electrons from silicon near Si/SiO_2 interface. The parameterization of traps and their spatial distribution was defined with consideration of deposited oxide properties and deposition technology dependence reported in [2].

The comparison of results obtained for different technology nodes allowed to conclude significant TID hardness increase for bulk CMOS technology with device scaling.

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FLASH MEMORY CELLS DATA LOSS CAUSED BY TOTAL IONIZING DOSE AND HEAVY IONS

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Flash memory due to its non-volatility and density is very attractive for use in harsh environment applications for data and code storage. But ionizing radiation can damage floating gate cells of memory and cause the critical data loss. The paper provides experimental results that show information loss caused by total dose and heavy ions and describes what tests must be performed to characterize flash memory storage capability for harsh environment application.

A few years ago it was believed that the flash memory cells are much less sensitive to radiation than control circuitry and charge pump [1], but scaling of advanced flash memory has led to the cells become more sensitive to ionizing radiation. We conducted total dose tests of 4Gb NAND flash memory in read only mode, and also read/erase/write mode. The first observed failure was data loss in some memory cells in read only mode. The failure in read/erase/write mode took place at much higher total ionizing dose (TID) levels. For a better understanding of the data loss mechanism we investigated the specially designed test chips based on floating gate cells only. The result of this test shows that total dose caused loss of charge stored in floating gate, and threshold voltage of floating gate transistor changes. This result explains observed much higher failure levels in read/erase/write mode wherein each write restore charge on floating gate. Flash memory is widely used in harsh environment applications for critical boot data storage and our experimental results must be taken into account for correct flash memory behavior characterization.

We performed heavy ion tests (Ne, Ar, Kr and Xe) of NOR flash memory manufactured by 110 nm Spansion MirrorBit© technology. Devices were irradiated in biased and unbiased modes, and some devices were irradiated by heavy ions after TID exposure to TID level up to 75 percent of failure one. For all ions single event upsets (SEU) in memory cells were observed. We've calculated SEU cross section and received its dependence vs linear energy transfer (LET) of heavy ions. We observed no difference in SEU cross section for biased and unbiased modes, and no difference between devices preiradiated by TID and irradiated by heavy ions only. These results also must be taken into account before performing heavy ion characterization of flash memory for harsh environment applications.

So on we propose some guidelines for test mode selection for radiation characterization of flash memory.

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SINGLE-EVENT EFFECTS TESTING OF 65 NM CMOS SRAM

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The current scaling trend for SRAM devices leads to a significant decrease of the critical charge needed to produce a memory bit upset [1]. In the same way, the reduction of the distance between two adjacent cells (measured in fractions of a micrometer) increases the production of events with multiple errors (MCUs). We study the design of different SRAM blocks based on a commercial 65 nm CMOS technology and discuss the experimental results for proton and heavy ion irradiation campaigns.

The test chip was designed by the Scientific Research Institute of System Analysis (SRISA), Russian Academy of Sciences. The "6T" is standard high density block with 6-transistor (6T) cell. The "6T_GR" is based on 6T cell with N+ and P+ guard rings. The "DICE_GR" block has solid guard rings and the "DICE" block has intermittent rings.

The heavy-ion irradiations were conducted on the ion accelerator "U-400" (JINR, Dubna, Russian Federation). Different incident angles of the beam with the chip were used during the experiment. 1 GeV proton SEE tests were performed at the St.Petersburg Nuclear Physics Institute (Gatchina, Russian Federation). No SEL was found at room temperature in all SRAM blocks. The contribution of SEU and MCU was estimated in total event cross section for "6T" and "6T_GR" during heavy ion tests with different incident angles of the beam. There were different kinds of SEU and MCU for single heavy ion: from 1-bit to 8-bit upsets [3].

The results obtained show that the number of affected bits depends not only on LET value, but also on incident angle of the beam. Also the dependence of cross-sections of 6T-cells from data pattern was obtained.

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COMPARISON AND VALIDATION OF GEANT4 MODELS OF THE INTERACTION OF HEAVY IONS WITH SEVERAL MATERIALS

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The Galactic Cosmic Radiation (GCR) represents a serious risk to astronauts during space travels. Different studies have been conducted to identify materials, used to shield the crew from CGR, adopted in the construction of the spacecraft and the inflatable modules. The shielding is the only countermeasure that can be taken into account for to galactic cosmic radiation exposure during space travel. Various studies have shown that hydrogenated light materials, such as water and polyethylene, provide the best shielding against space radiation. The behavior of two materials, Kevlar (which is rich in carbon atoms) and Nextel that have very similar characteristics (high tensile strength), is very interesting and useful in case of presence of micrometeorites or debris inside the International Space Station (ISS), but they give a different answer in terms of equivalent dose. A problem caused from cosmic radiation shieldings is due to the secondary nuclear fragments produced in the interaction with the target materials. It is known that heavy ions, although they are the minor component of the galactic cosmic radiation (≈ 1 %), provide the main contribution to the equivalent dose. In this work we will present the comparison and validation of Geant4 models of the interaction of heavy ions with several materials. The validation of this model could be used in the future to predict the behavior of other materials when subjected to an irradiation with heavy ions. We will show the first results obtained by comparing the experimental data with simulated data.

LINEAR AND SWITCHING DC-DC CONVERTERS' TID HARDNESS INVESTIGATION

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Total dose experimental data for linear and switching DC-DC converters is presented. The electrical mode influence on TID hardness is analyzed. The worst irradiation cases are revealed.

Linear and switching DC-DC converters are the essential parts of the spacecraft power systems. Therefore the influence of the electrical conditions on total dose behavior of DC-DC converters is the important point for both developers and testers.

This work accumulates total dose test information for integral linear converters (bipolar and CMOS), integral switching converters (CMOS and BiCMOS) and hybrid switching converters in order to discover the worst conditions for irradiation.

The Load Current: The most important DC-DC parameters are the output voltage and the load currents. Total dose experiment results for different DC-DC's load currents are present in this paper. The difference between total dose hardness of hybrid DC-DC converters is 1.2...1.5 times less for irradiations with minimum and maximum load. TID dependences of output voltage are presented in fig. 1. The increase of load current in CMOS and BiCMOS integral converters accelerates the temperature annealing and therefore decreases TID sensitivity.

The Shutdown Mode: Most of the modern DC-DC converters provide sleeping (shutdown) mode. Usually there are two or three power converters in high-reliable systems: one is active, and others are in shutdown mode (reserved). Experimental radiation data of hybrid and integral converters reveals, that irradiation in shutdown mode is the worst case for most circuits. Difference in TID hardness level can reach up to 3 times. Moreover, TID degradation behavior can be different. Different TID dependences of output voltage for active (full load) and shutdown mode irradiations are presented in fig. 2.

The Unbiased Irradiation: There is one more type of reservation used in spacecraft systems – passive (unbiased) reservation with no power supplying of reserved converters. Our experimental results show, that irradiation in such "power off mode" is the worst case for some bipolar converters. Confirming TID dependences of supply current in sleeping mode for active (minimal load) and passive (power off) mode irradiations are presented in fig. 3.

More experimental results will be present in the final paper.

Conclusion: The goal of this work is identify the worst irradiation conditions for modern DC-DC converters.

There is no "one for all" worst condition for DC-DC converters. All suggested conditions should be taken into account during TID hardness investigation.

SPACE RADIATION SHIELDING: A COMPARATIVE APPROACH TO STUDY THE INTERACTION OF SPACE RADIATION CHARGED PARTICLES AS WELL AS SECONDARY GENERATED PARTICLES WITH POLYMERIC COMPOUNDS

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The present simulation study applies Monte Carlo methods using MCNPX and SRIM codes to investigate the interaction between space radiation charged particles such as protons and alpha particles, and different polymeric compounds, polyethylene, polypropylene, polystyrene, polyvinyl chloride (PVC) and polyvinyl acetate (PVA), comparatively. In this regard, linear stopping power equations have been applied to calculate the range of particles as well as optimized thickness of polymeric shielding. Finally, the flux of secondary neutrons produced by nuclear interactions with materials has been calculated. Comparing the results support the idea that polyvinyl based compounds have more stopping power. Moreover, polyvinyl compounds, specifically polyvinyl chloride (PVC), have more nuclear conversion efficiency of fast neutrons to thermal ones.

THE EFFECT OF SC FLIGHT RADIATION ENVIRONMENT ON REQUIREMENTS TO RADIATION HARDNESS OF COMPONENTS OF ONBOARD ELECTRONIC DEVICES

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This report has a methodological character. It is of interest and has a practical value for the space industry - for developers of spacecraft and space technology. On the basis of classification of SC typical orbits and interplanetary missions the requirements to the radiation hardness (for dose and single-event effects) of electronic onboard equipment components were developed.

Near-the-Earth orbits and interplanetary trajectories differ significantly by space radiation effect onto onboard devices. As a result, to make a reasonable choice of electronic components providing onboard equipment serviceability within SC active lifetime it is necessary, firstly, to analyze SC flight radiation environment and radiation effects caused by it. To solve this problem the classification of SC typical orbits and trajectories was made and parameters of flight radiation conditions were calculated.

The results are presented in tables containing values of sufficient dose hardness of components (in krad) and parameters which are characteristic of electronic components' hardness to single-event effects (threshold value of LET, Lo, and saturation cross-section, σ_o) for different types of missions.