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BOOK OF ABSTRACTS

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RAD2017

URANIUM MINING LEGACY AND RADIATION PROTECTION

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The exploitation of radium and uranium in Europe during the 20th century left a legacy of mining sites and milling facilities with radioactive contaminated materials that today fall in the framework of the European Basic Safety Standards (BSS) as existing situations of radiation exposure. In Europe the former radium and uranium producers are currently dealing with environmental remediation of such sites in order to meet the requirements of the European BSS. This is the case for example of Germany, France, Spain, Hungary, and Portugal amongst several former uranium producing countries.

The uranium production in Portugal took place mainly in the vein deposits of the granite region of center north of the country where sixty deposits of secondary uranium minerals were exploited. Uranium milling took place mainly at Urgeiriça, Bica, Guarda and Senhora dos Remédios and Castelejo mines. After closure of the last mine in 2001, public concerns about the fate of uranium residues motivated an assessment of the environmental contamination and public health risk of such residues in the former mine areas.

The environmental and radiological risk assessment investigation identified the amounts of waste, radionuclide concentrations and the situations were environmental dispersal of radionuclides were occurring and could expose local populations through water and food consumption, as well as the risk of radon exposure and radioactive dust inhalation. Following this radiation risk assessment the government approved an environmental remediation project for abandoned mine areas and, from 2005 to the present, about thirty of those former uranium sites were cleaned and remediated. Environmental radioactivity measurements in soils, water, agriculture products and livestock produced in the region were made and are made every year in order to maintain surveillance over the environmental contamination and radiation risks to man and biota.

The case study of the former uranium mine of Cunha Baixa is described in detail to provide insights into the concentrations of uranium radionuclides in mining and milling waste, mine drainage and in water from irrigation wells in the area of this mine. Furthermore, the agriculture products from the local farms, mostly products from irrigated horticulture and farm animals were analyzed as well and the radiation doses for consumers have been estimated. It was found that the ingestion of horticulture products grown with irrigation water from contaminated wells was originating a potential radiation exposure of members of the population of the village nearby, exceeding 1 mSv/year from mine radionuclides.

Remediation measures applied in Cunha Baixa mine included the coverage of the tailings, the continued treatment of mine water drainage, and removal of surface soil in contaminated areas. As the drinking water in the past was partially met with water wells, the supply of tap water through public waterways was accomplished decades ago. Irrigation of local farms was however an issue, because the contamination of the local aquifer with acid and radioactivity is high, and water is not adequate for irrigation. A surface water supply for irrigation was recently built and wells were sealed. These remediation measures reduced local contamination and exposure of the population to radioactivity and already improved the environmental and radiological conditions. Lessons from the past practices in uranium mining and milling and radiation protection measures adopted are similar amongst the former uranium mining countries. Lessons to retain and procedures currently recommended to avoid generating new uranium legacies are summarized.

HADRONTHERAPY: FROM THE CONVENTIONAL TO THE LASER-DRIVEN APPROACH

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Charged particle acceleration using ultra-intense and ultra- short laser pulses has gathered a strong interest in the scientific community and it is now one of the most attractive topics in the relativistic laser-plasma interaction research. Indeed, it could represent the future of particle acceleration and open new scenarios in multidisciplinary fields, in particular, medical applications.

One of the biggest challenges consists of using, in a future perspective, high intensity laser-target interaction to generate high-energy ions for therapeutic purposes, eventually replacing the old paradigm of acceleration, characterized by huge and complex machines.

The peculiarities of laser-driven beams led to develop new strategies and advanced techniques for transport, diagnostics and dosimetry of the accelerated particles, due to the wide energy spread, the angular divergence and the extremely intense pulses. In this framework, INFN-LNS (Italian Institute of Nuclear Physics, Catania (I)) in collaboration with ELI-Beamline Institute (Dolny Brezany, CZ) will realize, within 2017 the ELIMED (ELI-Beamlines MEDical and multidisciplinary applications) beamline.

ELIMED will be the first Users' addressed transport beamline dedicated to the medical and multidisciplinary studies with laser-accelerated ion beams and completely open to the scientific community wishing to perform experiments with these new beams.

The beamline will permit in-air irradiations of controlled laser-driven ion beams to perform typical multidisciplinary experiments, from biological irradiations to detector tests and general samples irradiation.

In this paper, a progress status of the beamline with its main transport, diagnostic and dosimetric elements, will be presented.

PET/MR IMAGING: TECHNICAL CONSIDERATIONS AND POTENTIAL CLINICAL APPLICATIONS

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Several investigators have proposed or developed techniques to improve the correlation between molecular and structural information from positron emission tomography (PET) and magnetic resonance (MR) imaging. PET/MR imaging has the potential to optimize the treatment of patients with various types of cancer before, during, and after therapeutic intervention. Furthermore, PET/MR imaging may be useful for optimizing drug development by noninvasively providing in vivo quantitative data about the pharmacokinetics (absorption, biodistribution, metabolism, and elimination) and pharmacodynamics of novel therapeutic agents of interest. Finally, PET/MR would reduce radiation exposure, which is highly desirable for all patients, especially for pediatric patients and those who undergo multiple examinations).

This presentation is intended to provide an overview of key technical features and challenges associated with combining PET and MR scanning which we will refer to as PET/MR even if it entails coordinated scanning on PET and MR simultaneously. On the other hand our goal is to emphasize the conceptual in order to serve a clinical audience, and therefore the presentation will focus on clinically relevant strategies and systems. We begin by reviewing the history of PET/CT as it provides historical context and a useful reference with which the motivation and development of PET/MR may be considered. We then describe the challenges of combining PET and MR scanning so that readers may understand some of the strategies used in building these systems. Subsequently we turn to specific examples of time of flight technology and how manufacturers have applied these strategies to build the systems that do hybrid PET/CT/ MR scanning for clinicians and consider the pros and cons of each approach.

APPLICABILITY OF K0-METHOD FOR ENVIRONMENTAL SAMPLES

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Neutron activation analysis (NAA) is a nuclear analytical method that utilises the specific properties of nuclear reactions, thereby enabling simultaneous determination of numerous elements in environmental samples. There are several possible techniques, differing in input radiation: i) Neutron Activation Analysis (NAA), ii) Charged-Particle Activation Analysis (CPAA) and iii) Photon Activation Analysis (PAA).

Due to its sensitivity, versatility and high reliability, NAA is the most prominent of all the activation techniques (AAS, AES-ICP, ICP-MS, XRF, PIXE, etc.). It enables multielemental analysis of macroscopic samples (up to 10-12 g of the element in a gram of sample) and the determination of a relatively large number of elements (approximately 70% of the elements in the periodic table have suitable characteristics for NAA).

Several different variations of absolute methods and activation analyses have been developed, which approximately four decades ago led to the introduction of the k0-standardisation method of NAA. This is a “quasi” absolute method that usually uses compound nuclear constants k0 and Q0 which are experimentally determined for each nuclide. These constants are in general use and are relatively independent of irradiation and counting devices. The k0-library today contains nuclear data for 144 radionuclides, which enables the determination of 68 elements in an unknown sample.

The Department of Environmental Sciences at the Jožef Stefan Institute (JSI) has been using the k0-method of NAA for routine analyses for approximately 25 years. The KayWin® commercial software is used for the determination of elemental concentrations from the analysed gamma spectra. The k0-method has been optimized for the determination of major, minor and trace elements in environmental samples using the 250 kW TRIGA Mark II reactor and measurement of induced gamma activities on absolutely calibrated HPGe detectors. The method has been successfully used in numerous intercomparison studies and characterisation of reference materials of different origin (biological, environmental, industrial, geological materials, etc.) prepared by IRMM, BAM, IAEA, NIST, etc. Last not least, the k0-NAA was applied in various CCQM-KC intercomparison studies demonstrating calibration and measurement capability (CMC) on national level in the field of Metrology in Chemistry for the amount of substance: Chemical and trace elements in the organic and inorganic materials. Some applications of the k0-method of NAA will be presented and discussed.

SCREENING METHOD FOR RADIOLOGICAL CHARACTERISATION OF REUSED BY-PRODUCT IN BUILDING MATERIALS

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NORM materials can pose a significant risk or a great opportunity. For example, in the building industry there is good potential in the reuse of NORM containing industrial by-products. The traditional deposition has its own risks as well, but the valorisation of the NORM, the design of new synthetic NORM based building materials is raising concerns among authorities, the public and scientists. The engineers and scientists are required to demonstrate that these materials do not pose significant risks to humans or the environment. In order to avoid the elevated risk an overall investigation procedure is required focused on the mobility of toxic components (leaching properties) and radiation exposure (gamma dose rate and radon/thoron exhalation).

Based on our earlier studies the "classic" gamma dose surplus "I index" is not enough to characterize the by-products. More comprehensive protocol is required.

The last decade in our institute the dominant parameters where studied to characterising the by-products e.g. radon exhalation, leachability.

Based on our protocol different by-products (red mud, manganese mud, coal ash, drilling mud, phosphogypsum, etc) were characterized from building material reusability aspects.

According to the results the classic gamma dose surplus determination and "aeric" radon exhalation is not contain enough information due to the strong influence of the inner structure (microporosity) to the radon potential. Therefore to get more reliable information to the radon potential estimation more comprehensive study is necessary.

Other hand a leaching tests are a very important tool for the assessment of long-term environmental behaviour and environmental impact. In the EU in spite of encouraging tendencies for the standardisation of methods such as the LEAF protocols, or the harmonisation of protocols for waste evaluation, there are still no commonly accepted methods for the evaluation of the leaching characteristics of NORM materials.

To characterize the leaching behaviour three leaching procedures were applied and compared, Hungarian standard, the international CEN/TS and the Tessier 5-step method.

According to the results the standard method complementing with the Tessier speciation method gives better insight to which fraction the radioisotopes are bound to.

MECHANISMS OF RADIATION HORMESIS

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The ionizing radiation damages DNA and cellular macromolecules directly or via production of reactive oxygen species. A number of mechanisms protect cell from impact of ionizing radiation. The purpose of this work was to investigate the role of cellular stress-resistance mechanisms including DNA repair, DNA damage response, detoxification of free radicals, and heat shock response in Drosophila melanogaster resistance to irradiation and longevity.

We analyzed the effect of ionizing radiation on the level of expression of stress response genes, and the lifespan of wild-type Drosophila melanogaster laboratory line. To elucidate the role of stress response genes in longevity we used mutant lines, that were defected in stress response genes, lines with overexpression of these genes, or flies in which stress signaling pathways were pharmacologically inhibited.

Results: We found that radiation hormesis, radioadaptive response, and hyperradiosensitivity can be observed not only in cell cultures but also at the organism level of Drosophila melanogaster by integral indicators such as lifespan. We also showed that the reaction of an organism to irradiation is determined by cellular mechanisms of stress resistance (DNA repair, DNA damage response, detoxification of free radicals, and heat shock response).

Thus, we investigated the roles of some components of cell stress signaling pathways in the lifespan alteration after the irradiation. We found that despite low-dose irradiation affects the level of genes expression predominantly stochastically, the mutations in stress response genes, pharmacological inhibition of their products or genes overexpression play crucial role in radioresistance and lifespan.

Acknowledgement. The study was supported by grant of the Presidium of Russian Academy of Sciences N15-4-4-23.

Special
Talk

B

NUCLEU2020 - A NETWORK OF HORIZON 2020 NATIONAL CONTACT POINTS (NCP)

Sofia Guedes Vaz

Foundation for Science and Technology, Portugal

NUCL-EU 2020 is a H2020 CSA (Coordination and Support Action) project aiming to create an European wide active network of EURATOM NCPs. The ultimate objective of NUCL-EU 2020 is to ensure support to Horizon 2020 potential applicants, raising awareness about potential topics and increase the average quality of proposals submitted under the EURATOM Framework Programme for Research and Innovation and the overall success rate at EU level. For this to happen there is a need for letting stakeholders – prospective EURATOM applicants – know of the existence and potential support of NCPs and in particular of a network of NCPs. For promoting more effective and successful participation in Horizon 2020, NUCL-EU 2020 offers training, partner search tools and brokerage events. NUCL-EU 2020 wants to contribute to a step forward on the R&D landscape at EU level.

Biochemistry 01

RECEPTOR ACTIVATOR OF NUCLEAR TRANSCRIPTION FACTOR NF-KAPPAB (RANK), ITS LIGAND (RANKL) AND NATURAL INHIBITOR OSTEOPROTEGERIN (OPG) IN BLOOD SERUM OF PRIMARY BONE TUMOR PATIENTS: ASSOCIATION WITH CLINICOPATHOLOGICAL FEATURES AND INFLAMMATORY CYTOKINES LEVELS

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Background: RANK/RANKL/OPG ligand-receptor system is a key player in bone tissue homeostasis directly regulating osteoclast differentiation and osteolysis. Many pathologic processes imposed by impairments in bone remodeling including tumor growth and metastasizing are associated with misbalancing of this system; it is also tightly involved in inflammation. Less is known about its role in primary bone neoplasms.

Objective: RANK/RANKL/OPG and key inflammatory cytokines determination in blood serum of patients with malignant, borderline and benign bone neoplasms, and analysis of associations between these markers and principal clinicopathological characteristics of bone tumors.

Design: 199 primary bone tumor patients were enclosed: 121 with bone sarcomas (53 osteosarcoma, 46 chondrosarcoma, 12 chordoma, 8 Ewing sarcoma), 32 with borderline giant cell bone tumor (GCBT), 46 with benign bone tumors; 131 persons comprised control group. OPG, sRANKL, sRANK, IL-6, 8, 16 serum levels were measured by standard ELISA kits.

Results: Measurable sRANK levels were detected in blood serum of less than 50% of malignant bone tumor patients and control persons, but in 54% of GCBT (median - 107 pg/ml) and in 59% of benign bone tumor patients. Serum sRANKL levels in GCBT patients' were significantly higher than in control and in malignant bone tumor patients. OPG level was insignificantly increased in patients with all tumor types as compared to control. The highest IL-6 levels were revealed in GCBT patients, while serum IL-8 and IL-16 did not differ between groups. The degree and direction of changes in RANK/RANKL/OPG system depended also on histological type of malignant bone tumors, the changes being more pronounced in chordoma and chondrosarcoma than in osteosarcoma patients. Serum sRANKL/OPG ratio was the highest in chondrosarcoma than in any other patients group or control.

Conclusions: Disturbances in osteolysis activators and inhibitors balance in blood serum of primary bone tumor patients were revealed. Their extent depended on neoplasm character (malignant, borderline, or benign) and histological structure of malignant sarcomas. Most prominent changes were found in GCBT characterized by active bone destruction and an accepted target of anti-RANKL antibody denosumab treatment. Hence, the proteins studied can be regarded as promising serologic markers and therapeutic targets in this rare disease.

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MOLECULAR MARKERS FOR PRECISE DIAGNOSIS AND THERAPY OF TYPE 2 DIABETES

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Type 2 diabetes (T2D) is a complex metabolic disease associated with disturbances in metabolism of carbohydrates, lipids and proteins, and largely under the influence of very complex interactions with genetic and environment factors. High prevalence and increasing number of patients with T2D in the world, represent constant challenge for better elucidation of pathogenic mechanisms which contribute to disease development.

In this study, we try to summarize new molecular markers (biomarkers) which emerged from recent studies in applied genomics, metabolomics and other modern "omics" technologies as powerful tools in diagnosis of T2D. Metabolomics, in this context, has a special potential since it uses newly developed analytical methods in analyses of wide range of metabolites in biological samples.

Number of prospective studies has shown that changes in the concentration of some individual amino acids, acylcarnitines, hexoses and phospholipids augment or attenuate risk factors for developing T2D. Polymorphisms in TCF7L2 gene were also significantly associated with increasing risk for T2D development while studies of lipidomics, genomics and transcriptomics identified molecular markers for glucose intolerance. Some specific gene variations were identified which affected *de novo* lipogenesis (synthesis and metabolism of fatty acids as well cellular signaling and metabolic pathways) and were significantly associated with concentrations of palmitic, stearic, palmitoleic and oleic acids, the major saturated and unsaturated fatty acids.

Development of new trends in analysis and detection of different metabolites, especially fatty acids and amino acids, along with genetic polymorphisms points out new directions in precise diagnosis and therapy of Type 2 diabetes.

THE ROLE OF XANTHINE OXIDASE SYSTEM IN RAT'S LYMPHOCYTE APOPTOSIS UNDER X-RAY EXPOSURE

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The complex role of xanthine oxidase (XO) system is linked to the implication in radiation–induced apoptotic cell death in rat's lymphocytes. According to modern views the principle regulatory role of xanthine oxidase during radiation-induced apoptosis is associated with increase production of reactive oxygen species which cause the activation of intrinsic apoptotic pathways and changes in expression of redox-responsive genes etc. Therefore, it was important to assess the xanthine oxidase activity in response to radiation injury and modulation effect of inosine (commercial name "Riboxine"). According to obtained results the increase (in 2.3 times) of xanthine oxidase activity in thymus lymphocytes was observed in 3 h after ionizing exposure in 1.0 Gy dose. More significant elevation (in 3.0 times) of xanthine oxidase activity was detected after ionizing exposure in 7.78 Gy dose. The increase of xanthine oxidase activity and XO-generated reactive oxygen species resulted in high level of Bax - the first identified proapoptotic member of the Bcl-2 protein family (main executors of mitochondrial apoptotic pathway). Bax activates the caspase-9/-3 signalling cascade as a part of intrinsic apoptotic pathway. Herein we reported about dose-dependent increment of Bax level in the thymus lymphocytes in 3 h after X-ray exposure. Our investigations also demonstrated the pivotal role of the redox-sensitive transcription factors NF-κB and AP-1 and the existence of cross talk between these factors and xanthine oxidase system during radiation–induced apoptosis. The injection of inosine prior X-ray exposure led to modulation of radiation-induced apoptotic pathways.

RELATIONSHIP BETWEEN BEHAVIORS AND CATECHOLAMINE CONTENT IN PREFRONTAL CORTEX AND HIPPOCAMPUS OF CHRONICALLY STRESSED RATS

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Chronic stress induces over-activation and dysfunction of stress-activated systems, resulting in further brain damage and depressive-like behavior. Depression is a potentially life-threatening disorder that affects people and therefore it is one of the most important public health problems.

This study examined the effects of chronic restraint stress (CRS: 2 hours × 14 days) on anxiety-like and depression-like behaviors in rats, as well as on the possible changes in concentrations of dopamine (DA) and noradrenaline (NA) in prefrontal cortex and hippocampus.

We observed a decrease in the number of entries into open arms and time spent in open arms during the elevated plus-maze test (anxiety-like behavior), as well as increased immobility during the forced swimming test (depression-like behavior). In addition, we found that CRS increases concentration of NA and decreases concentration of DA in prefrontal cortex and hippocampus. Also, we recorded a significant correlation between animal behavior and levels of neurotransmitters in the prefrontal cortex and hippocampus in stress conditions provoked by CRS.

The results presented here suggest that there is a relationship between animal behavior and levels of neurotransmitters in the prefrontal cortex and hippocampus in stress conditions provoked by CRS, which may be important in the research of numerous psychiatric diseases caused by chronic stress.

UV/Γ IRRADIATION: ACTIVATION AND ANTIOXIDANT ACTIVITY AFTER LOW-LEVEL IRRADIATION OF BULGARIAN ESSENTIAL OILS

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During the last years was proven that exposure to UV/γ radiation leads to significant changes in biological systems and normal metabolism of the body, caused an increase in the free radicals level and continuous oxidative changes.

The Bulgarian essential oils, Rosa Damascena Mill., Lavandula Angustifolia Mill., and Mentha Piperita Lab. and their components, exhibit antibacterial and antifungal activities, protect against cancer, dementia, depression, muscle relaxant, body-stress, sleep disorders, headaches and have demonstrated good antioxidant activity and reduced oxidative changes. Natural oils as typical antioxidants have compounds able to prevent oxidation processes; reduce oxidation by reacting with free radicals and by acting as oxygen-scavengers and transferring hydrogen atoms to the free radical structures. Many scientific reports demonstrated the usefulness of essential extracts as reducing and radioprotective agents that effectively modulate radiation-induced oxidative stress.

Here, we report freshly extracted oils which reduce or completely neutralized ionizing radiation and by an additional stage could be used to develop efficient cosmetics radioprotectants, also applicable in medicine. In this connection the effects were investigated under low-level UV and γ-irradiation on antioxidant, radio-modulatory and free-radical scavenging properties of Bulgarian oils by using in vitro spectrofotometrical and EPR methods.

For the antioxidant and radio-modulatory activity, essential oils of rose, lavender and mentha oils (50 µg/µL) (97%) from IREMK, Kazanlak, Bulgaria were used. Oils samples were irradiated by using UV-light (290-320 nm; UV–vis Transilluminator- 4000 Stratagene)/ rate of 2 hrs; 60Co source at doses of 2.5, 5, 10, 20, and 30 Gy (Gamma cell 5000, India; 1.4 Gy/h). Immediately irradiated oils were stored at laboratory conditions (humidity 40 %). EPR experiments were carried out in triplicate at 23°C on an X-band EMXmicro, spectrometer Bruker-Germany (simulation was performed with WIN-EPR and SimFonia).

The spectrophotometric studies (EDPA, DPPH, ABTS+, OH., LP, NO, O.2-) of the UV/ γ-irradiated samples with a dose of 5 Gy of the rose oil, were significantly increased compared to those of the non/irradiated samples of lavender and mentha oils. It was found, when the γ-radiation doses increased, the antioxidant activities, radio-modulatory and free-radical scavenging properties decreased.

The intensities of the EPR signals registered in the UV and γ-irradiated samples at 5Gy were considerably higher than those of the non-irradiated samples. 30 and 60 days after post-irradiation, the same EPR spectra with almost the same intensities were registered in the low-level UV and γ-irradiated oils, indicating that the radical structures formed after irradiation in the studied Bulgarian oils were quite stable, and oils could find application as a good antioxidants/radioprotective agents in cosmetic.

DNA-DAMAGE INDUCED STRESS RESPONSE IN BLEOMYCIN-TREATED OR BYSTANDER CELLS IS MODULATED BY PINK1 IN NEURONAL AND NON-NEURONAL CELLS

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DNA-damage represents a very harmful event for a cell, and so on to the organism as it may lead either to cellular death or mutations that may induce cancer. It is now known that cells react to DNA lesions not only by intracellular mechanisms, aimed to repair the damages or to induce apoptosis, but also by intercellular communication generating bystander effects. The phenomena include induction of similar lesions in neighbor cells, but to a much lesser extent. While the manifestations of bystander communication were highly studied, their physiological role was not yet clarified, recently being more likely regarded as a form of adaptive phenomena. Few studies address bystander communication in neuronal diseases, the vast majority of them being focused on radiation induced bystander effects and his role in cancer induction and secondary tumors.

We investigated here mechanisms of bystander communication in a neuronal model (SH-SY5Y cell line) and in non-neuronal cells (MEFs – Mouse Embrionary Fibroblasts), with emphasis on the role of a Parkinson-related kinase, PINK1 in this type of signaling.

We proved that PINK1 is required for bystander signaling both in MEFs but also in SH-SY5Y cells. While bleomycin treatment induced similar lesions in both cellular types (increased DNA damage, lower viability, induction of apoptosis), the analysis of molecular markers of compartmental stress showed striking differences in signaling pathways. Secondary, we analyzed the lesions induced in bystander cells. We proved that the bystander effect, showed as increased genotoxicity, was not accompanied by viability loss or induction of apoptosis in neither of the cell lines. Regarding intracellular pathways of stress, we highlighted opposite mechanisms in neuronal and non-neuronal cells: while in bystander fibroblasts cells the majority of the stress markers evaluated showed decrease levels following incubation with conditioned medium, in SH-SY5Y cells the levels increased in the same conditions. All the bystander manifestations were inhibited when we used PINK1 deficient cells (KD/KO) either in the directly treated cells (medium donor), or as bystander cells.

Therefore, DNA-damage stress induces activation of different biochemical pathways in neuronal vs non-neuronal cells in both directly injured and bystander cells. PINK1 is required for bystander induction irrespective of the cellular type.

INDUCTION OF BIOCHEMICAL ACTIVITY OF LACTOCOCCUS LACTIS SSP. LACTIS UNDER THE INFLUENCE OF ULTRAVIOLET RADIATION

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Introduction: Among the various types of radiation UV-rays are the most common and capable to induce biochemical processes in cells. It is known that the sensitivity to UV- is not the same for different bacterial species and strains. The radiation is enhanced by the formation of active free radicals, which are the cause of the non-genetic effects of radiation for the organism. In the initial stage of the development of culture, the enzymes of the intracellular fund are activated by "SOS" proteins, which protect the cell from unfavorable factors. Lactic acid bacteria synthesizing bacteriocins of a peptide nature have antimutagenic properties. The aim of the research is to induce of biochemical processes of lactococci under the influence of UV-rays.

Materials and Methods: A wild strain of *Lactococcus lactis* ssp.*lactis* 229 with nisin-synthesizing activity of 2500 IU/ml was used. Actively growing young cells are most susceptible to the action of mutagens. Irradiation of cells of lactococci in dose of 7600 erg/mm^2 for 1-10 min was followed by their growth in MRS medium and selection after UV-rays treatment. Some lactoccoci had double UV treatment. The novel strains were restored after lyophilization and storage. Changes in their antibiotic and enzymatic activity were studied after passages.

Results: The increase in UV exposure to 5 min increased the number of inactive clones to 29.3% and 36% had nisin synthetic activity below the baseline level. The 12% plus variants with an activity level above 3100-3350 IU/ml were identified after treatment the bacterial suspension for 10 minutes. It was an effective dose. As a result variant No.6 with an antibiotic activity of 3350 IU / mL was selected, which is 27.7% higher than the initial one. The study of the physiological and biochemical properties of variant No 6, selected after UV-rays treatment, showed that they somewhat changed the rate of their growth and the synthesis of nisin. This strain became less sensitive to penicillins, but not cephalosporins and acquired resistance to aminoglycosides inhibiting RNA synthesis.

A study of the dynamics of growth and development of variant No. 12 showed that double UV treatment extended the exponential phase of growth to 15 hours and the level of accumulation of nisin with its maximum to 3850 IU/ml. This strain with regard to fermentation of carbohydrates showed similarity to the initial strain for the consumption of pentoses and more resistant to antibiotics inhibiting protein synthesis.

It has been established that strain No.6 after lyophilization and storage has been moved to the wild type both on the level of antibiotic activity and enzymatic activity. Variants No. 12 obtained by stepwise, double UV-rays, retained the stability of the changed properties.

Conclusion: UV-rays are leading to the induction of biochemical activity in a population of bacteriocin-producing lactococci.

QSAR MODELING OF ANTIMICROBIAL ACTIVITY OF SOME SUBSTITUTED HYDRAZONES

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Quantitative structure/property-activity relationships (QSAR/QSPR) represent attempts to correlate activities/properties with structural descriptors of compounds. Correlation and prediction of physical, chemical and biological activity/property from molecular structure is a very significant and an unsolved problem not only in various chemistry fields (theoretical; computational; environmental) but in life science as well.

One important class of organic compounds is hydrazones which find huge application in many scientific areas. They possess a wide spectrum of biological activity and the changes in this activity depend on the substituents present in its molecule. The use of the hydrazones in medicine is due to their anticonvulsant, antidepressant, analgesic, antiinflammatory, antiplatelet, antimicrobial, antitumoral, antischistosomiasis and antiviral activity. On the other hand, hydrazones possessing an *azometine proton* (-NHN=CH-) constitute an important class of compounds for new drug development. The wide palette of the useful medical properties has attracted considerable scientific interest for their synthesis. Combining appropriate starting materials such as carbonyl compounds and hydrazine, the sensitivity as analytical reagents could be improved and they could be used as analytical reagents for transition metal analysis and as catalyst for epoxidation of olefins. Due to their physiological activity, they are used as herbicides, insecticides, and plant growth stimulants. Some aromatic hydrazones are DNA gyrase inhibitors.

QSAR study of substituted hydrazones was performed to estimate the quantitative effects of the selected topological and physicochemical descriptors on their antimicrobial activity. All hydrazones were tested for their *in vitro* growth inhibitory activity against *Bacillus subtilis, Candida utilis* and *Aspergillus niger* using filter paper disc method. Stock solutions of compounds were prepared in DMSO, as inert medium in three concentrations. The diameter of zone inhibition (mm) was measured. Inhibitory activity data determined as mg/mL were transformed to the negative logarithms of molar MICs ($\log 1/c_{MIC}$). The 2D structures of all compounds were drawn and topological descriptors were calculated using softer packaging Marvin sketch. None of hydrazones inhibit the growth of the *Aspergillus spp,* and the data for the antifungal activity of the compounds relative to *Candida utilis* was insufficient to develop a reliable statistical QSAR models. Efforts were focused on developing the QSAR models of compounds with antibacterial activity against *Bacillus subtilis.* In order to test the quality of the regression models, the following statistical parameters were used: R^2; Sd; F-test; R^2_{adj}; Q; S_{PRESS}; PSE and Q^2.

Key words: QSAR, hydrazones, antimicrobial activity, topological and physicochemical descriptors

Bioinformatics 02

ELECTRONIC SURVEY AS EFFECTIVE DATA COLLECTION TOOL FOR RESEARCH, PARTICULARLY TO STUDY PREDICTORS OF ALCOHOL ADDICTION AMONG YOUTH IN UKRAINE

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Background: Alcohol is the most widely used substance across many countries: in Ukraine, Russia, Belarus, European countries and the USA. There is international acceptance of addressing addiction to alcohol as a public health priority, given medical, social, moral, ethical, economical and mental costs to society.

Studies suggest that youth actually feel more comfortable answering personal questions truthfully when completing questionnaires electronically (Turner et al. 1998), which can lead to higher levels of self-reported substance use and other risky behaviors. Both Lygidakis and colleagues (2010) and Wang and colleagues (2005) indicate that adolescents completing electronic surveys reported higher levels of alcohol and other drug use compared with those completing paper-and-pencil versions. Thus, our proposal will use a survey design in which students will self-administer an online survey in an anonymous fashion.

Purpose: The overall objective to this study is to examine the rates and correlates of alcohol and drug use among young people in Ukraine. The study will be conducted by electronic survey method. 1,200 of youth in Kharkov, Ukraine will receive cards with the invitation to participate in an electronic survey.

<u>Research goals</u>**:**

A. Conduct the first comprehensive electronic survey among youth recruited from a community setting in Ukraine to determine need for interventions by age and gender.

B. Identify correlates of alcohol and drug use among youth in Ukraine recruited from a community setting, including externalizing behavior, mental health, impact of the war, and social factors.

Exploratory analyses will examine:
1. Rates of alcohol and drug use.
2. Correlates of alcohol and drug use including:
a. Motives of alcohol and drug use will help us to inform early prevention.
b. Sensation seeking (impulsivity and self-control ability) and externalizing will be greater in the risky drinking group and drug using groups.
c. War impacts (e.g., psychological and social consequences of conflict/war) will be greater in the risky drinking and drug using groups.
d. Depression and anxiety will be greater in the risky drinking group and drug using groups.

3. Service Use Questionnaire data will help to understand methods of improvement of medical and psychological care for youth based on risky drinking and drug use.

Significance: Understanding rates and correlates of alcohol consumption and drug use among youth is a critical public health issue. The lack of understanding of the prevalence and correlates of substance use among youth in the Ukraine hinders intervention efforts for this problem. The proposed community survey study of youth is an appropriate strategy to inform a future intervention research.

Key words: Electronic survey, alcohol addiction, predictors, youth, Ukraine

Biomaterials

03

THE OPTICAL LIMITING EFFECT IN THE ORGANICS DOPED WITH NANOPARTICLES

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An active interest has been taking in photophysics of organic p-conjugated systems doped with nanoobjects (such as fullerenes, nanotubes, nanoparticles, *J*-aggregates, nanofibers, shungites, graphene oxides, etc.) due to their exclusive linear and nonlinear optics, dynamics and structural features [1-5]. These can be exploited as effective optical limiters, modulators and laser beam switchers. Different mechanisms, promoting the action, can be activated, among which there are reverse saturable absorption, laser-induced change in the refractive index, carrier free absorption, complex formations, etc. Nanoobject insertion stimulates the media self-organization as well as an increase in the polarizability and order parameters that results in the formation of quasi-photonic organic systems.

The present paper is devoted to the consideration of the charge transfer complex formation mechanism and the high frequency Kerr one as the generally activated in the conjugated doped organics to reveal th optical limiting process. Both experimental and calculation results point to a wide area of feasible optoelectronics application of these systems treated at 532, 805, 1047, 1064, 1315, 1500, 2940 nm. Moreover, these structures are fairly promising for applications in medicine, biology and display technique.

Key words: Organics, doping, nanoparticles, charge transfer complex formation, laser-induced change in the refractive index

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OBTAINING AN AQUEOUS COLLOIDAL SOLUTION OF SELENIUM BY MECHANICAL DISPERSION

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Selenium is one of the most important chemical elements in the structure of human body cells. The presence of Se in the required amount reduces the risk of cancer and enhances the body's immunity against various diseases. Currently, Se nanoparticles are used in medicine and biology as antioxidant supplements for the treatment of cancer and to improve productivity in animal husbandry.

Various methods of producing Se nanoparticles are known. There are laser ablation, ultrasonic dispersion and chemical methods. In this paper a simple method of preparation of Se nanoparticles by mechanical dispersion of granules of «gray» Se in twice-distilled water was shown. The dispersion process was carried out on vibrating machine Metapolan-2 (Bulgaria) with vibration frequency 100 Hz at temperature 300K. It was found that the Se particles of three various sizes (23, 108 and 500 nm) are formed in an aqueous solution. Characteristic Se nanoparticle sizes are in good agreement with the theory of aggregation. The Se particle concentration was 100 mg/l. It was found that the concentration of Se in the colloidal solution depends significantly on duration of the mechanical dispersion and container material. In a plastic container red (amorphous) Se is besieged on the wall, and "gray" Se is besieged at the bottom of the vessel. Herewith concentration of Se in the solution is reduced to 3-4 mg/l. The use of a glass container allows us to obtain Se concentration about 10 mg/l, while the amorphous Se besieging on the container walls was not observed. Measuring of Se solution pH indicates slightly acidic effect (pH=6.25; twice-distilled water – pH=6.68). The acidic environment can be associated with the dissolution of SeO_2 in H_2O and selenious acid. The presence of SeO_2 on the surface of «gray» Se granules is caused by thermal heating of material on air in the process of granules production.

Thus, the obtained results allow us to conclude that Se nanoparticles in colloidal solution can be obtained by mechanical dispersion of "gray" Se granules in water. Concentration of Se in the solution can reach values of about 10 mg/l. However, an aqueous solution of Se has acidic properties that must be taken in to the consideration when using ones in the latest medical and biological research.

CHLOROPHYLL STABILITY TO CONTINUAL UVA, UVB AND UVC IRRADIATION INSIDE THE LIPOSOMES

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The unique role of chlorophyll (Chl) is based on its specific and very diverse chemical reactivity which provide its use in many industrial technologies (*e.g.* in food, pharmaceutical and cosmetic industry), but also in medicine, as drug in photodynamic therapy (PDT) for the treatment of certain types of cancer. Chlorophyll is considered as relatively unstable compound, especially in the presence of light and oxygen; on the other hand, if used in biomedical applications incorporated in liposomes, Chl is found as safe, widely available and cost effective due to its good antioxidant and antimicrobial properties, and biocompatibility. The main goal of this work was to examine stability of chlorophyll (inside of liposomes) to the oxidative stress induced by continual UVA, UV-B and UVC irradiation, followed by absorption spectroscopy method. The experiments were performed on two types of Chl-SUV liposomes, SUV-PC-Chl and SUV-DMPC-Chl (small unilamelar, phosphatidylcholine & 1,2-dimyristoyl-sn-glycero-3-phosphocholine liposomes, respectively, with incorporated Chl). The results showed instability of chlorophyll to UV irradiation in the order to energy input strength: UVA < UVB < UVC. UV-induced degradation of chlorophyll inside liposomes followed a first order kinetics with similar rate constants obtained for both, SUV-PC-Chl and SUV-DMPC-Chl samples. One exception was obtained for UVC-effects: the corresponding rate constant for SUV-DMPC-Chl was several times higher to the one obtained for SUV-PC-Chl, probable due to different lipid used for the liposomes preparation.

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UHPLC-MS/MS ANALYSIS OF HEMATOPORPHYRIN DERIVATIVES MIXTURE

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Porphyrins are widely used photosensitizers in photodynamic therapy (PDT) of tumors, which also used as precursors in oligomerization produced new PDT-sensitizers. Hematoporphyrin derivatives belong to the family of porphyrin compounds found in the products used in PDT such as Photofrin® and Photodit®. Ultra-high performance chromatography (UHPLC) coupled with mass spectrometry (MS) was used for separation and identification of hematoporphyrin mixture. The separations were performed on a RP-C18 column (50×2.1 mm, 1.9 μm) with the mobile phase consisted of water and methanol in a linear gradient program at flow rate of 0.200 ml min^{-1}. Mass spectrometric analysis was performed using a ion trap mass spectrometer with electrospray ionization (ESI) in positive ion mode: source voltage 4.5 kV, capillary voltage 48 V, tube lens voltage 115 V, capillary temperature 300°C, nitrogen sheath and auxiliary gas flow 32 and 8 arbitrary units. MS-spectra were acquired by full range acquisition of *m/z* 100–1000. For fragmentation study (MS/MS), a data dependent scan was performed by deploying the collision–induced dissociation with normalized collision energy set at 20 eV. Four compounds in the mixture were found in the order of their elution: hematoporphyrin IX (8,13-bis(1-hydroxyethyl)-3,7,12,17-tetramethyl-21H,23H-porphine-2,18-dipropionic acid), two related hydroxyethyl-vinyl-derivatives and protoporphyrin IX (3,7,12,17-tetramethyl-8,13-divinyl-21H,23H-porphine-2,18-dipropionic acid), confirmed by MS-spectra of the molecular ions at *m/z* values corresponding to the molecular weights of the compounds (MW+1: *m/z* 599, 581, 563, 591, respectively).

Acknowledgements: This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia under the Project No. TR 34012.

FABRICATION AND TESTING OF NOVEL MULTIFUNCTIONAL NANOSYSTEMS FOR CHEMO- AND RADIO- SENSITIZATION OF TUMOR CELLS

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Modern multimodal cancer treatment often comprises surgical excision of the tumor, radio- and chemo- therapy. Radiotherapy, a key component applied in about 60% of all cancer patients, has been intensively used in the treatment of various types of cancer by means of directed ionizing radiation, however it is possible that its efficiency is reduced in the treatment of several resistant types of cancer. A potential approach to further improve cancer treatment options is the use of nanotechnology.

Here, we propose the design, synthesize and characterize of different new constructs of core-shell nanoparticles, based on magnetite, for chemo- and radio- sensitizing purposes of cancer cells. The nanoparticles' characterizing was done in terms of crystallinity, chemical composition and structure. Regarding the biological effects, the *in vitro* cytotoxic potential was proved for different tumor models using both quantitative and qualitative estimations, correlated with the determinations of nanoparticles cellular entrapment efficiency.

Biomedical Engineering

04

EXPERIMENTAL SETUP USING LOW ENERGY X-RAYS FOR RADIOBIOLOGICAL STUDIES

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Low energy x-rays are often used in imaging medical procedures such as fluoroscopy, angiography, urography and dentistry. In all these instances, x-ray beam irradiation of live cells can cause specific damages. To explore processes occurring in live cells after irradiation, an experimental setup for radiobiological studies was created and built at Jan Kochanowski University in Kielce, Poland. The radiation system uses an X-ray Diffraction (XRD) C-tech tube - type lamp with a molybdenum target (Mo) and Long Fine Focus. Dosimetry was done using EBT2 and XR-RV3 Gafchromic films and a plane ionization chamber TM77334 PTW-Freiburg. Distribution of radiation intensity and absorbed dose were determined showing homogeneity of the x-ray beam in a range +/- 2.5%. Dose equivalent rate was calculated to show that the experimental setup was safe to work. The first experiments were done to show the survival curve for CHO-K1 cells. To verify the measured doses the experimental setup was simulated with the FLUKA code 2011 version 2c.4.

Biomedicine

05

THE IMPACT OF SMOKING ON THE HEALTH OF PERIODONTAL TISSUE

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Purpose: The aim is to emphasize the notions: determinant indicator and predictor of risk factors for periodontal pathologies, and to show the interconnection logic, analyzing the effects of one of the risk factors, in this case smoking, mainly to the amount of gingival fluid.

Materials and methods: For achieving this, measurements were carried out, in mm of the wet amount of adsorbent placed in sulcus, before and 30 minutes after smoking; held in sulcus, for 3 minutes. This procedure was repeated several times. In the end, we organized the summary table, the interconnection of concepts about periodontal risk.

Results: What represents the human body, consisting of the host which is subjected to the action of oral bacterial flora, interactions that extend in time, where the diet operates with mechanical elements.

It is noted that the change in wetting the adsorbent was only 1 or 0.5 millimeters, 3 minutes. Small change, but in total for the whole mouth, is great. Once this 0.5 mm, produced in 6 different points around the tooth, and 32 teeth simultaneously.

Conclusions: Smoking increases the amount of crevicular fluid, but also promotes bone and destructiveness, whose clinical signs to the naked eye, being visible.

Key words: Smoking, determinants, forecasters, indicators, crevicular fluid

HEMANGIOMAS OF THE OMF REGION: TREATMENT WITH PROPRANOLOL EXPRESSED IN THE COMPARATIVE RESULTS

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Purpose: The incidence of infantile hemangioma is from 1.1, up to 2.6%. This incidence increases with 10.1% in each year of change of age. The ways of treatment vary with their advantages and disadvantages. Given the difficulty, to predict whether a lesion will be roughly progress or not, we have tried for the comparison in quantitative manner of treatment methodologies.

Materials and methods: In the study are included 32 children with hemangioma, in variable localization, to treat with various methods of treatment, in order partial or total regression. Are analyzed the results between localization and method of therapy, regression, complications associated with the provided demographic data (male, female and age).

Results: The link between partial and total regression for hemangioma under division in regions of the face, head and neck, in the amount p value, is 0.0001. Relationship between partial regression and age speaks for positive results, as the age reduces.

Conclusions: Treatment of hemangioma is always in development options, in terms of interference with as most of the few surgical. Regression is most positive in the age of many more to be minor.

Key words: Hemangioma, regression, complications, OMF localization

PREGNANCY OUTCOMES FOR WOMEN WITH HOMOZYGOUS HEMOGLOBINOPATHY DIAGNOSIS

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Purpose: Purpose of the study is to highlight pregnancy and delivery in major hemoglobinopathies.

Design setting and participants: Twenty four clinical cases of pregnant women are investigated; 22 suffered from homozygous sickle cell anemia and 2 from major thalassemia. Patient age, parity served as baseline characteristics and delivery way, infant average weight at birth were studied as primary and secondary outcomes. The 24 women, subjects of the study, gave birth within the time frame of 1992-2013.

Results: These past two years, for the first time in "Mbreteresha Geraldine", the Obstetric-Gynecology University Hospital of Tirana, there were two pregnant women with Thalassemia major. Both patients delivered their babies through cesarean section due to fetal suffering. They have had blood transfusion every three weeks during the pregnancy.

The other 22 patients being studied had a frequency of blood transfusion of 4.5 times during pregnancy. Out of 22, 10 women had vaginal delivery, while for the other 22 cesarean section was performed. A total of 15 pregnant women were primiparous (62.5%), 6 (25%) were secondiparous and only 1 terciparous case (4.2%). The other 2 patients with thalassemia major diagnosis were nuliparous (8.3%). The average babies' weight at birth of the women with hemoglobinopathy diagnosis (24) x= 2425.32$\pm$59.74 was compared with average babies' weight at birth of healthy mothers (46 women) x=3309.78$\pm$78.69. Results were statistically significant ($p<0.01$)

Conclusion: Pregnant women with homozygous hemoglobinopathy diagnosis followed with multidisciplinary and contemporary therapy are able to give birth, but multiple complications for mother and the baby must be taken into consideration.

ASSESSMENT OF HEMATOLOGICAL PARAMETERS, ACID-BASE STATUS AND ARTERIAL BLOOD GAS TEST BEFORE AND AFTER MANAGEMENT OF ACUTE BRONCHIOLITIS IN CHILDREN

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Objective: The purpose of our retrospective study was to investigate the necessity of some laboratory testing in patients with acute bronchiolitis before and after treatment.

Methods: We have taken blood samples of all children puncturing the cubital vein, and analyzed it using the Colter appliances-automatic counter blood count, for analyzes of some erythrocytes, leukocytes, platelets, differential blood count, Hct, Hb. CRP concentration in serum of patients determined by laser nephelometry with CardioPhase® high sensitivity C-reactive protein (hsCRP). For assessment of acid-base status and arterial blood gas analysis were used ABL5 and ABL700 Radiometer Copenhagen. We monitored the following parameters: pH, pCO_2, HCO_3^-, total CO_2, base excess, pO_2, SpO_2.

Results: There was a significant improvement of hypoxemia after management of acute bronchiolitis in the form of a significant increase in average values of pO_2 and SpO_2 after treatment of acute bronchiolitis. The mean value of the number of leukocytes and value of CRP in children were significantly decreased before and after management of acute bronchiolitis. There was no significant difference in duration of hospitalization in term and preterm newborns.

Conclusion: No diagnostic tests are used routinely. However, there is an improvement of hypoxemia after management of acute bronchiolitis in children.

Key words: Bronchiolitis, Hematological Tests, Acid-Base Balance, Blood Gas Analysis

SUPEROXIDE DISMUTASE AND LIPID PEROXIDATION IN CHILDREN AFFECTED BY CELIAC DISEASE

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Coeliac disease (CD) is an autoimmune disorder provoked by wheat gluten and related proteins from other grains. The only treatment for the patients is a lifelong gluten free diet (GFD). Oxidative stress has been implicated in the pathogenesis of CD.

The aim of this study was to examine the modulation of the biochemical response to oxidative stress in children affected by CD. Study involved peripheral blood samples and small intestinal biopsies from 69 children diagnosed with CD. According to the histological findings, patients were divided into following groups: Marsh 0: normal mucosa with no signs of inflammation (n=31); Marsh 1: mucosa was characterized by intraepithelial lymphocytosis (n=5); Marsh 2: intraepithelial lymphocytosis was accompanied by crypt hyperplasia (n=4); Marsh 3a: mucosa showed partial villous atrophy (n=20); Marsh 3b: subtotal villous atrophy was present (n=9). For the statistical purposes groups Marsh 1 and Marsh 2 were treated as one (Marsh 1+2, n=9).

The activities and protein levels of Copper, zinc superoxide dismutase (CuZnSOD) and manganese SOD (MnSOD), as well as the concentrations of lipid hydroperoxides (LOOH) were determined in intestinal biopsies, while in the peripheral blood, MnSOD activity was not measured, due to the methodological obstacles.

CuZnSOD activity in the blood varied significantly between the analyzed groups. Marsh 3a and Marsh 3b had increased CuZnSOD activity comparing to the Marsh 0 ($P < 0.05$). LOOH concentration also varied significantly. LOOH level was higher in the blood of Marsh 3a ($P < 0.001$) and Marsh 3b ($P < 0.05$), than in Marsh 0.

In the biopsy samples, MnSOD activity and LOOH concentration showed significant differences between the groups, while no significant difference was found for CuZnSOD activity. In comparison to Marsh 0, MnSOD activity was significantly elevated in Marsh 3a ($P < 0.01$). Significant increase in LOOH concentration was found in Marsh 3a ($P < 0.001$) and Marsh 3b ($P < 0.01$), comparing to Marsh 0. In addition, Marsh 3a group had higher LOOH concentration than Marsh 1+2.

Relative MnSOD and CuZnSOD protein level in peripheral blood and intestinal mucosa did not vary significantly between the analyzed groups.

Positive correlations were found between the severity of mucosal lesion and CuZnSOD activity ($P < 0.001$), as well as LOOH concentration ($P < 0.001$) in peripheral blood. Similar correlations were found also in intestinal mucosa: MnSOD: $P < 0.05$; CuZnSOD: $P < 0.05$; LOOH: $P < 0.001$.

Our results show that oxidant/antioxidant balance is disturbed in CD patients with mucosal lesions. An increase in SOD activity as a consequence of oxidant pressure is not enough to maintain the normal level of free radicals, which leads to enhanced lipid peroxidation. These processes persist even in some patients on a long-term GFD.

SKIN PROTECTION AGAINST SOLAR UV RADIATION BY NATURAL PLANT PRODUCTS: EXTRACTS FROM ELDER FRUIT (SAMBUCUS NIGRA L.)

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Solar radiation has harmful effects on exposed skin, producing accelerated aging processes (wrinkles, dryness, telangiectasia, dyspigmentation). Also, there is an increased ROS generation in skin exposed to the UV-A and UV-B radiation. This resulting in oxidative stress, photodamage of skin macromolecules and photocarcinogenesis processes. In order to prevent this, botanical extracts with antioxidant properties can be used in anti-photoaging preparations, as a substitute for traditional sunscreen products. The increasing interest for natural products in recent years is due to their higher tolerability and also for environmental and toxicological reasons. Plant extracts, rich in natural polyphenols, exert a less sensitization effects on skin and are very effective against oxidative damaging caused by UV radiation.

The aim of this study was to evaluate the antioxidative activity of different elder (*Sambucus nigra* L.) fruit extracts. Active components of *S. nigra*, such as polyphenols, have an important biological activity. Fruit extracts were obtained by maceration method using four different solvents (methanol - ME, propylenglycol 45% v/v - PE, ethanol 70% v/v - EE and distilled water - WE). To study antioxidant activity, we used two *in vitro* assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging and ferric reducing antioxidant power (FRAP) assay.

The concentration at which 50% of the DPPH radicals were scavenged (IC50) were 3.54, 3.94 and 12.07 mg/ml for the samples EE, ME and PE, respectively. Sample WE showed stronger scavenging activity (IC50 value was 2.62 mg/ml). The FRAP values were 242.29 and 686.43 µmol Fe^{2+}/g of dry extract for samples PE and ME, respectively. The higher values were obtained using the samples EE and WE, 793.54 and 934.81 µmol Fe^{2+}/g of dry extract, respectively. FRAP assay showed a significant ($p < 0.05$) negative correlation ($r = -0.975$) with radical scavenging capacity (IC50 values).

The extract WE (distilled water was used as a solvent) showed the highest antioxidant activity when compared with other extracts. In fact, all investigated extracts have antioxidative potential, more or less, and can be used in skin formulations as a protective agents against UV radiation.

Key words: Natural antioxidants, UV radiation, skin, *Sambucus nigra*, fruit extracts

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THE DETERMINATION OF THE ACTION SPECTRUM OF LIGHT-INDUCED CELL VIABILITY DAMAGE IN EYE CELLS

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Dysfunctions eye cells as a result of radiation non-ionizing electromagnetic spectrum optical range occur under the influence of direct and reflected sunlight, and as a result the impact of lighting devices. Damage caused by artificial light, has recently come to the fore and is becoming increasingly important.

It is known that prolonged exposure to light on the retina formed ROS affect to cell viability of the retina, which leads to their destruction and loss of vision. Recent work showed that photodamage can lead to cell degeneration of retinal cells, especially receptors and its pigment epithelium cells. We investigated the effect of light in the blue (λmax = 470 nm), the purple part of the spectrum (λmax = 395 nm), red (λmax = 625 nm) and visible light of high intensity on the viability of SIRC cell lines (rabbit cornea) and ARPE19 (pigment epithelium human retina). For the study was used MTT viability test, JC1 staining and test live/dead.

Irradiation in different parts of the spectrum is the inhibition of cell viability, while red light irradiation did not affected cell function. High-intensity light exposure causes the most severe consequences.

Thus, we have shown that photodamage can lead to cell degeneration.

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THE EFFECTIVENESS OF THE COMPLEX TREATMENT OF PATIENTS SUFFERING FROM CHRONIC GINGIVITIS

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The method of the complex treatment for patients suffering from the chronic gingivitis including the trypsin applications in the 1%-solution of the sodium bicarbonate, Kudesan medicine as well as the ultrasonic scaling using curette with toe. The increase of effectiveness for the present treatment method has been determined dynamically in 55 patients suffering from the chronic gingivitis. The complex therapy in accordance with the described method allows to reach the full destruction of the microbial biofilm after 7-8 days as well as to improve significantly both the hygiene status of the oral cavity and the periodontal tissues and the general condition of patients in 2-3 weeks.

IMMUNOLOGICAL AND MICROBIOLOGICAL ASPECTS OF HYGIENE EFFECTIVENESS FOR THE ORAL CAVITY IN PATIENTS SUFFERING FROM INFLAMMATORY PARODONTIUM DISEASES

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The research objective consisted in studying of local factors of protection of an oral cavity on the basis of balance definition between proinflammatory (INf - γ, TNF - α, IL-8) and anti-inflammatory (IL-4) cytokines with the degree account colonization of Candida at patients with chronic generalized parodontitis. By results of work it has been established, that at patients with chronic parodontitis easy and moderate severity level high degree colonization periodontal pockets Candida tropicalis correlates with substantial increase proinflammatory cytokines(TNF - α, IL-8), concentration fall INF - γ and increase in level anti-inflammatory cytokinesIL-4.

APPEALABILITY STRUCTURE IN PATIENTS WITH TEMPOROMANDIBULAR DISORDERS

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Objective. Analyze appealability structure and the nature of formation of clinical groups of patients with temporomandibular disorders (TMD).

Materials and methods. We examined 28 men and 148 women with TMD. We analyzed 604 tomography images. Statistical processing included cross tables and chi-square analysis.

Study results. 28% of patients were primary followed up in general clinical network with facial pain. Dental clinics established primary clinical diagnosis: arthrosis and arthritis (71%), dislocation or subluxation of the temporomandibular joint head (16.5%), temporomandibular joint dysfunction (12.5%). X-ray norm was observed in 9% cases. By the nature of TMJ visualizations we established clinical features of TMD women depending on the reproductive period.

In puberty period limiting joint mobility (44.4%, $p = 0.045$ compared to the head dislocation and arthritis, $p = 0.024$) was predominant; in early reproductive period - head subluxation (48.5%, $p < 0.010$ for all kinds of detectable pathology but deforming arthrosis). In the late reproductive period and perimenopause half of the examined patients had deforming arthrosis (52.8% in the late reproductive period, $p < 0.01$, for all kinds of detectable pathology, except for limited joint mobility; 50% in perimenopause ($p < 0.05$ with radiologic norm, dislocation of the head and arthritis), in postmenopausal women - arthritis, sclerotic arthrosis (30.8% and 27.8%).

Conclusions. The nature of the formation of clinical groups of patients with TMD is determined by the place of the primary treatment, specialization of the institution and the level of techniques of primary diagnosis of TMD. This affects the patients' quality of routing and is a cause of chronic (58%) TMD.

ELASTOGRAPHY AND SHEAR WAVE ELASTOMETRY-BASED VALUES OF YOUNG'S MODULUS OF ENDOMETRIUM IN HEALTHY WOMEN OF REPRODUCTIVE AGE

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The analysis of the data of uterus examination of 45 healthy women of reproductive age was carried out; 22 of the patients were practically healthy nulliparous women, 23 of the patients were healthy parous women (1 or 2 children).The age of the patients ranged from 24 to 48 years old (mean age 33.9 ± 2.9 years). Comprehensive ultrasound examination of the uterus and appendages with the use of ultrasound elastography and shear wave elastometry modes (SWE - Shear Wave Elastography) was carried out on the unit Aixplorer (Supersonic Imagine, France) using a convex abdominal transducer with frequency range 1.0-6.0 MHz and intracavitary vaginal broadband probe 3-12 MHz.

SWE results in the control group showed that the quantitative values of Young's modulus of unmodified endometrium and myometrium in healthy women of reproductive age were not potentially dependant on various phases of menstrual cycle ($\rho > 0.05$).Young's modulus values of the mucous in the cervix (endocervix) and uterus corpus (endometrium) differed significantly and in healthy women had greater values in the cervix (Emean 33.1 kPa; Emax 38.8 kPa; SD 1.9) rather than in the corpus of uterus (Emean 16.5 kPa; Emax 17.6 kPa; SD 1.0; $\rho < 0.05$).

Depending on the parity, healthy parous women had higher values of endometrium stiffness - Emean 17.5 kPa; Emax 35.5 kPa; SD 3.1 than nulliparous women -16.1 kPa; 19.9 kPa; 0.7 ($\rho < 0.05$). Quantitative values of Young's modulus of the myometrium in healthy patients were also higher in the cervix rather than in the corpus of uterus (Emean 42.3 kPa; Emax 52.4 kPa; SD 3.2 and Emean 22.3 kPa; Emax 29.3 kPa; SD 1.7; $\rho < 0.05$ respectively).

In the examination of women of reproductive age, that was carried out on the basis of the data obtained from the use of elastography and shear wave elastometry technology, standard values for Young's modulus for an unmodified endometrium, endocervicx, myometrium of the uterus corpus and cervix in healthy women of reproductive age were defined.

Key words: Ultrasound diagnostics, ultrasound elastography, shear wave elastography, elastometry, endometrium

POSSIBILITIES OF ULTRASONOGRAPHY AT THE STAGES OF THE SURGICAL COMBINED TREATMENT OF WIDESPREAD LIVER ALVEOCOCCOSIS

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Relevance. Liver alveococcosis (LA) is a potentially dangerous natural focal parasitic disease, which is characterized by severe chronic progression and frequent recurrences. Although histopathologically a benign disease, LA shows the characteristics of a malignant tumor with destructive tissue growth, invasion of adjacent organs, and distant dissemination. Surgery is the only radical treatment of LA, but LA is diagnosed at later stages often, when the progression of the disease precludes the implementation of radical surgery.

Aim. To estimate the possibilities of ultrasonography at stages of the surgical combined treatment of widespread LA.

Materials and methods. We have an experience of surgical treatment of 87 patients with widespread LA (joint or separate defeat of both liver lobes with various degree of an involvement of each lobes) in A.V. Vishnevsky Institute of Surgery. Ultrasonography carried out to all patients (pre/intra/postoperative), CT/MRI (reference methods).

The patients in assessment of treatment were divided into two stages. Treatment was executed only by means of surgery till 2012 (I group: n = 65 (74.7%). Since 2012 we have begun to use cryoablation on the remainder of the parasitic tissue using Russian apparatus. This surgery with cryoablation was performed in 22 (25.3%) patients (II group). Cryoablation procedure lasted from 2 to 5 minutes of freezing at T from -175 to -186°C.

All patients subsequently underwent appropriate worming chemotherapy.

Results. Criteria of treatment tactics definition: defeat volume, localization, involvement of the liver main vessels. Preoperative sensitivity, accuracy, specificity of ultrasonography (at coincidence of all criteria): 93.0%, 57.0%, 82.0%.

I group: the recurrence of LA has been revealed at 16 (24.6%) patients, the second recurrence – at 2 (3.1%).

II group: liver resection was performed in all 22 patients, with additional nephrectomy in 2, additional resection of portal vein in 1. Cryoablation of adjacent affected tissues infected was performed in all cases. Cryoablation was also performed on the remaining part of the parasite on the right dome of the diaphragm (2), in the gate of the liver (7), the remaining parenchyma of the left lobe after right lobe resection (6), in the para-aortic tissue (4), in the course of the right urether (1).

Stages of US-control and diagnostic characteristics of tissue changes after krioeffect: 1.navigation; 2. “iceball” formation; 3.thawing; 4.after applicator removal.

All patients are alive. Comprehensive survey, including ultrasonography, CT, MRI, showed no signs of continuing parasitic growth.

Conclusion. Ultrasonography in specialized clinic, having experience of LA treatment, is an effective method of diagnostics. Dynamic observations of the patients with LA after the carried-out combined treatment in the remote period need to be made in a complex: regular ultrasonography is supplemented with CT or MRI through rather long periods.

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NON-SURGICAL LIFT AND CONTROL OF INFLAMMATION WITH PHOTOBIOMODULATION

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Side effects of aesthetic procedures come from injury of the epidermis (liftings, ablative and semi ablative lasers, ablative fractional radio frequency, peelings, dermabrasion....)

Most common side effects – areoedemas, implicating social down time, slower healing, scarring and necrosis.

Gestion of oedemas can be achieved using LED (light emitting diode); the combination of red and infrared light (630nm/850nm) having an anti inflammatory effect on tissues. LED 850nm provokes the degranulation of pro inflammatory substances, the tissue having the impression to be wounded. 630nm, red light, activates fibroblasts and thus wound healing.

C-limonene is a molecule known to have tissue repair properties. Applying a topical solution containing d-limonene in post treatment reduces the down time and accelerates skin repair.

A NEW ANTI-INFLAMMATORY MOLECULE MASTERING TISSUE REPAIR AND ANTI-ANGIOGENESIS

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Introduction. Epithelial barriers are major determinants of innate immunity, preserving the integrity of environmental interfaces. These barriers include mucosal areas as well as the most exposed skin envelope. In the epidermis, dermis, epithelia and mucosae lamina propria, numerous fine-tuned mechanisms allow to exclude pathogens and irritants while containing inflammation. In case of chronic inflammation or wound, restoring the epithelial function can be performed by pharmacological compounds or natural substances. To this avail, monoterpenes have proven to be useful to control inflammation and thymol was recently shown to accelerate wound healing whereas d-Limonene, the prototype of monoterpenes, through its metabolite perillyl alcohol (POH), has been reported to have tissue repair properties.

Material and Methods. Two murine models of respectively 12-O-Tetradecanoylphorbol-13-Acetate (TPA)-induced dermatitis and mechanical skin lesion were used to assess the efficacy of d-Limonene or POH applied topically. Macroscopic and microscopic evaluation of skin lesions was performed as well as immunolabelling assessment of P-selectin expression, together with measurements of serum concentrations of IL-1beta, IL-6 and TNF-alpha in the first model. Healing and angiogenesis around the scar were examined in the second model. The effect of both d-Limonene and POH was further tested on an in vitro matrigel model of endothelial microtubules formation.

Results. Both d-Limonene and POH reduced the severity and extension of TPA-induced skin lesions with significantly lowered macroscopic and microscopic scores ($p<0.04$ in both cases). Moreover, the expression of P-selectin induced by TPA was abrogated by POH and significantly lower serum concentrations of IL-6 and TNF-alpha were observed in d-Limonene- and POH-treated mice ($p<0.04$ and 0.03). In the second model, tissue regeneration was improved, especially by POH, and was clearly associated with reduced neovascularization. This surprising anti-angiogenic effect was confirmed in the matrigel model of endothelial microtubules formation.

Discussion and Conclusion. These studies show that d-Limonene and POH demonstrate significant anti-inflammatory effects in murine dermal inflammation and wound-healing. The decreased systemic cytokine production as well as a consistent inhibition of endothelial P-selectin expression and neo-vascularization induced by this monoterpene and its metabolite contribute to healing effects on the epidermal barrier. This capacity could be relevant for treating psoriasis and post-acneic scars, as well as for targeted treatment of major burns. Finally, many innovative practices of aesthetic medicine would benefit from the anti-inflammatory / anti-angiogenic inhibition byd-Limonene in order to restore injured tissue.

ENDOVASCULAR TECHNIQUE: EMBOLIZATION OF INTRACRANIAL ANEURYSMS

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Introduction. Rupture of an intracranial aneurysm is a very common cause of intracerebral and subarachnoid hemorrhage. A development of MDCT and MR angiography imaging techniques led to the diagnosis of asymptomatic and non-ruptured aneurysm. Endovascular embolization of intracranial aneurysms is a minimally invasive treatment whose goals are prevention of the aneurysmal rupture or exclusion of ruptured aneurysm from the arterial circulation.

Objective. Display of endovascular techniques in the treatment of intracranial aneurysms.

Materials and Methods. Intracranial aneurysms were diagnosed by MDCT, Aquilon, Toshiba; MRI, Avanto, Siemens 1.5T; and Angio Diagnost Allura, Philips. Depending on the localization of the aneurysm, its size and width of the aneurysmal neck, decision on the method of endovascular treatment of intracranial aneurysm was made. Aneurysms with narrow neck and volume without "mass effect" on the surrounding intracranial structures were embolized with platinum coils. Aneurysms with wide necks were embolized with a stent protection, through the aneurism neck, and then with stent assisted coiling. Implantation of "divert flow" stent, without the coil, was used for large aneurysms. Following coils were applied for embolization: Target, Saphire, Deltapaque, Micrussphere, Penumbra, Axium and subsequent stents: Leo +, Enterprisse, Papaline, Neuroform³.

Results. During the time period from March 2007 to December 2016, 565 endovascular embolizations of intracranial aneurysms were performed. There were 432 ruptured intracranial aneurysms and 133 non-ruptured. Coiling without stent or occlusive balloon protection was executed on 382 patients (68%). Coiling with stent application was carried out in 132 patients (23%), coiling with the use of occlusive balloon was performed on 16 patients (3%) and in 35 patients (6%) "divert flow" stents were implanted. The average duration of hospitalization was 18 days in patients with ruptured aneurysms and 3 days in patients with aneurisms that did not rupture.

Conclusion. Endovascular embolization of ruptured and non-ruptured intracranial aneurysms is a minimally invasive therapeutic procedure, which effectively excludes the aneurysm from circulation, significantly shortens the length of hospital treatment and reduces the risk of neurological deficits.

Key words: Intracranial aneurysm, coil, "flow divert stent"

ENDOVASCULAR TREATMENT OF ACUTE CEREBRAL INFARCTION - METHODS AND TECHNIQUES

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Introduction. There are several problem solving approaches in the field of revascularization, such as systemic application of recombinant tissue plasminogen activator, intra-arterial administration of thrombolytic agents, mechanical thrombectomy, mechanical separation of thrombus and aspiration, stenting and balloon dilatation. Aim of this study is to show possible methods of cerebral revascularization in acute cerebral infarction.

Materials and Methods. Based on the clinical picture of acute stroke, patients underwent the MDCT-Aquilion, Toshiba. CT angiography was performed in the same act. Endovascular treatment was carried out during the time period of 4 hours after the onset of symptoms. Selective artery catheterization of occluded blood vessel was used to attempt the recanalization by mechanical separation and aspiration of the thrombus, mechanical thrombectomy and possible balloon angioplasty. Treatment technique consists of vacuum aspiration of thrombus with Penumbra aspirator. For the mechanical extraction we used Trevo, Stryker and Solitere and Covidien extractors.

Results. Cerebral revascularization was performed in 55 patients, whereby 10 patients were treated with intra-arterial thrombolytic therapy, 33 patients underwent mechanical separation and vacuum thrombus aspiration, and 12 patients were subjected to the mechanical extraction of thrombus and stenting. The procedure was successful in 40 patients, or 72%. Three patients, in which the time frame was exceeded, had complications and formed malignant brain edema after the revascularization.

Conclusion. Execution of therapeutic procedure in an appropriate time after the occurrence of acute infarction and well trained multidisciplinary team in formed stroke center are necessary for the success of endovascular cerebral revascularization.

Key words: Acute cerebral infarction, endovascular revascularization, thrombolysis

THE SYSTEM OF OPTICAL CORRECTION OF OXIDATIVE STRESS PROCESSES IN THE BRAIN

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Purpose. To develop a manpac, portable system for correction of disorders provoked by oxidative stress processes in the brain and investigate photobiological effects in living tissues treated by optical radiation.

Introduction. High intensity visible and near infrared light (NIR) can be used to provide medical treatments on living tissues suffered from oxidative stress. Active oxygen forms provoke remarkable alterations in the cellular membranes, activities of enzymes that control the processes of lipid peroxidation and modification of proteins, influence on blood flow in capillaries and tiny vessels. The oxidative stress can be provoked in human being organism by various ways. They include the processes of ischemia of both the heart and the brain tissues, the degenerative processes in the brain, the ischemia of lower extremities, irradiation of living tissues by high-intensity non-ionizing and ionizing radiation. This list could be continued. In all these cases we observe the similar biochemical and physiological consequences that provoke production of uncontrolled levels of the active oxygen forms in the affected tissues. The similarity of the pathological processes in all these pathological processes partially explains technical unity of photoherapeutic technique that can be used to compensate the stress processes, decrease or even totally compensate them.

Materials and methods. Twenty LED were arranged according to the 20 standard Electro-Encephallogram (EEG) leads. The spectral peak wavelength was 808 nm, halfwidth 35 nm, fluence rate, 35 mJ/cm^2. The NIR sources produced pulsed radiation (frequency 100 Hz), the frequency and sequence regimen are controlled by using WiFi. Distribution of light in transcranial procedures was investigated in two cadavers. The effects of direct high-power light irradiation on the brain were investigated on 5 rabbits by using the standard lipid peroxidation methods.

Results. NIR intensity decreases in the cranial bones up to 2% with respect to the incoming light fluence rate on the scalp tissues. The experiments on the animals demonstrate presence of the therapeutic effect of NIR on the brain tissues suffered from excessive doses light radiation.

Conclusion. Transcranial treatments of the brain cortex can help to decrease consequences of oxidative stress and control levels of lipid peroxidation in the living tissues.

ANALYSIS OF BIOCLIMATIC CHARACTERISTICS OF NIŠKA BANJA

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Bioclimatic multivariate influences on health, as well as selection of spas have a particular importance from medical aspects. Niška Banja (248 m elevation) is situated on the south edge of Niš valley in the zone of Rhodope Massif and Limestone Mountains of East Serbia. With average year temperature of 11.7 °C, belong to moderate continental climate. Bioclimatic observation for a spa of Niška Banja is based on physiological heat index and weather condition with Kriger's anthropo-climatic classification. Sharl's method was used for calculation of water vapour, as well. Enjoyable wheatear type during five months (April, May, September, October and November) is usually dominant. All classes are represented (chilly, comfortable, hot). The class hot occurs in May and September. This period is characterized by anticyclone influence and desirable bio-climatic features. Cold weather types exceed four months, with classes cold (December, January, February) and moderate-cold (March). The physiological feeling of heat with class extremely-cold does not exist (T_{ek}<5.0 °C). Winter is a specific period with dominant influence of middle European anticyclone which brings dry and gloomy weather. The hottest weather type with class light-vapor occurs in (June, July and August). The classes hot and the hottest do not occur. That was produced by anticyclone and local relief characteristics of the terrain. On a climatic table, hot vapour marked with the closed shape of curve borders the curve of comfort climate in one segment. From a bio-climatic view of equivalent temperatures and climatic table, spa of Niška Banja is highly advisable for health usage with excellent physical, geographical and anthropogeographical characteristics.

EVALUATION OF THE VOLUME OF BASAL GANGLIA IN THE PATIENTS WITH MAJOR DEPRESSION BY STEREOLOGICAL METHODS

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Introduction: This study aims to measure the volumes of the nuc.caudatus, the putamen and the globus pallidus from the brain magnetic resonance images (MRI) of patients with major depressive disorder (MDD) with three different measurement methods.

Materials and Methods: Patients who applied to the Psychiatry Outpatients Clinic of Balikesir University Faculty of Medicine and have been diagnosed with major depressive disorder were divided in two groups; patients in group 1 were having their first episode of major depression (n=10) and in group 2 were currently experiencing a major depressive episode with a score of 15 or greater on the 17-item Hamilton Depression Rating Scale (HDRS) (n=10). The control group has been chosen from healthy individuals (n=10). Three-dimensional structural MRI scans were acquired from a 1, 5 Tesla using a T1-weighted magnetization. The total brain, right and left hemisphere, right and left nuc.caudatus, right and left putamen and right and left globus pallidus volumes were measured by three different methods, namely; manually by using Cavalieri principle of stereological volume measurements, by planimetry methods and automatically by doing brain parcellation with MriStudio (DTIStudio, ROIEditor & Diffeomap) which is an Atlas based image analyzing program.

Results: Compared to the healthy group, there was a decrease in the total brain volume, the right and left brain hemisphere, the right and left nuc.caudatus, the right and left putamen and the right and left globus pallidus volumes in patients with major depressive disorder, but the difference was not statistically significant (p>0,05). In the analysis of the correlation, when the Hamilton depression rating score increased it was observed that the volume of basal ganglia decreased in the first episode patient group (r= - 0, 74) (p<0, 05). And when the ratio of the volume of basal ganglia to the volume of brain hemispheres was evaluated, it was found that right and left nuc.caudatus volume ratio was statistically decreased in the second group (p<0,05). Excellent agreement was found among the three methods of measuring volumetric techniques according to Bland–Altman plots.

Conclusion: Our results might explain the neurobiological mechanism of MDD by clarified initial structural changes in the brain of MDD patients and may contribute to future studies which aim to investigate the etiology of MDD.

Key words: Major depressive disorder, stereology, Cavalieri method, basal ganglions

PHOTODYNAMIC THERAPY AND PSYCHOLOGICAL SUPPORT OF PATIENTS WITH DIABETIC FOOT SYNDROME (CLINICAL CASE)

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Background: 40-60% of all non-traumatic lower limb amputations account on diabetic foot syndrome (SDS) that leads to disability and reduced quality of life for patients.

Purpose: Elaboration of a complex treatment method of diabetic foot syndrome to reduce the rate of amputations concerning a diabetic gangrene.

Method: The clinic GI "V.T. Zaycev Institute of General and Urgent Surgery of NAMS of Ukraine" develops a comprehensive treatment approach in the treatment of diabetic foot syndrome, where photodynamic therapy (PDT) and psychotherapy are applied in the treatment plan in addition to infusion-detoxification, anti-bacterial, anti-inflammatory and insulin therapy.

Here is clinical case: Patient 27 years old was diagnosed with the type I diabetes, severe degree, subcompensated, SDS, extensive necrotic wound of the left foot, osteomyelitis of the Vth metatarsal bone; P 1, E 18.9 cm3, D 3, I 3, S 2 (according PEDIS classification) – unfavorable prognosis in the case of standard treatment methods using. On the background of pharmaceutical therapy necrosis zone was treated by the photosensitizer Dimegin (20 min exposure), then the wound was exposed by blue light (wavelength 440 nm) using Korobov A. – Korobov V. "Barva-Flex" matrices during 20 minutes. After 4 sessions of PDT necrectomy was performed. Then local treatment included irradiation of wound with red light (660 nm, 20 minutes exposure and then Levosin ointment applying, daily). On the 7th day of treatment the volume of the wound has decreased by 72.15%, granulations and edge epithelization was expressed. Then skin xenotransplantation was made. Continued local treatment consisted in red light irradiating daily (20 minutes duration, the multiplicity - 10). In the psychological status symptoms of anxiety and depressive condition were present and the psychotherapy was assigned (motivational interviewing, music therapy - Beethoven "Symphony 6", Part 2, "Waltzes" Strauss).

Result: The patient was discharged in a satisfactory condition with wound epithelialization. Psychological condition of the patient has been normalized. The patient is employed and adaptable to the social environment.

Conclusion: Comprehensiveness of aid modalities (using photodynamic therapy and psychological support in addition to standard medical and surgical treatment) is important in the successful treatment of diabetic foot syndrome. This approach gives the highest performance even in difficult clinical cases.

Key words: Diabetic foot syndrome, amputation, photodynamic therapy, photosensitizer Dimegin, Korobov matrix, "Barva-Flex" matrices, psychotherapy, motivational interviewing, music therapy

PHOTOTHERAPY AND PSYCHOTHERAPY IN TREATMENT OF PATIENTS WITH OBLITERATIVE LESIONS OF LOWER EXTREMITY VESSELS

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Introduction: Critical limb ischemia caused by extensive obliterative lesions in arteries is the most common cause of the "high" amputations. It is unlikely to achieve healing of ulcerative necrotic lesions and to avoid amputation without the restoration of the main blood flow in the foot.

Purpose: Complex treatment development of obliterating vascular lesions of the lower extremities with the use of phototherapy methods and psychotherapy.

Method: The clinic GI "V.T. Zaycev Institute of General and Urgent Surgery of NAMS of Ukraine" develops a comprehensive treatment approach in the treatment of diabetic foot syndrome, where photodynamic therapy (PDT) and psychotherapy are applied in the treatment plan in addition to standard medical and surgical treatment.

Here is clinical case: Patient 67 years old was diagnosed with the Leriche syndrome, chronic ischemia III B, extensive pyonecrotic wound of left anticnemion, the tibia osteomyelitis. After aorto-femoral synthetic graft bypass, femoropopliteal autovenous bypass and necrectomy the volume of the wound was 36.8 cm3.

In the postoperative period in addition to standard therapy local treatment with with exposure by green (525 nm) photonic matrix A. Korobov - V. Korobov "Barva-Flex / 24 Green, duration 20 minutes, the multiplicity – 5 (for local and systemic immune response stimulation) and red light (625 nm) of the photon matrix A. Korobov - V. Korobov "Barva-Flex / 24 Red were performed daily for 10 days, duration 20 minutes (for enhancement of blood microcirculation, stimulation of tissue regeneration, granulation growth and collagen formation). Methods of psychotherapy were used during these sessions (motivational interviewing, music therapy - Beethoven "Symphony 6", Part 2, "Waltzes" Strauss).

Result: Wound volume reduction was observed on the 5th day by 39.2%, on the 8th day - by 50.6%. Marginal epithelialization appeared on the 6th day. The plastic was made on the 12th day after the skin necrectomy. The wound has healed. The feelings of fear and anxiety have been reduced; hypochondria symptoms are gone; mood has been improved; activity has been increased.

Conclusion: The complexity of the treatment allows to avoid amputation, helps to reduce the duration of treatment at least on 20%, and returns patient to an active life in the social environment.

Key words: Obliterative lesions of lower extremities vessels, amputation, photodynamic therapy, photosensitizer Dimegin, Korobov matrix, "Barva-Flex" matrices, psychotherapy, motivational interviewing, music therapy

SIGNIFICANCE OF FLUOROSCOPICALLY-GUIDED TRANS-BRONCHIAL BIOPSY FOR DIAGNOSIS OF SOLITARY LUNG NODULES

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Flexible bronchoscopy (FB) was introduced in 1968, and today it is an essential procedure in respiratory medicine. The overall diagnostic utility and the rate of complications using fluoroscopically guided transbronchial biopsy are estimated in Special Hospital for nonspecific pulmonary diseases "Sokobanja" in Sokobanja, Serbia. The study included 92 patients with solitary pulmonary nodule (SPN), which have been previously confirmed by classical radiology during selected period from 01.01.2014 to the 30.09.2016.year. In this study were 65 men and 27 women, average age 65.2 years old, while the youngest was 41 and the oldest was 83 years. Representative histological diagnosis was made in 67 patients from obtained tissues after biopsy. Results showed that from total investigated patients, the 43 lesions were malignant (38 lung cancer metastasis and 5 extra pulmonary malignancy) and 24 non-malignant (12 Tuberculosis (TBC) granulomata caseificata and 5 non-caseificata, 4 pneumonia, 2 aspergillosis and 1 hamartoma). The total diagnostic value of this procedure for all investigated patients was 72.8%. Complications that can occur during the procedure, are related to moderate bleeding in the studied population occurred in 7 patients (7.6%). Pneumothorax and mortality has not been noticed in this study. Fluoroscopically guided transbronchial biopsy offers good diagnostic utility and low level of complications in the diagnosis of solitary pulmonary nodules. To conclude, bronchoscopy is a safe procedure in terms of complications such as mortality, pneumothorax, and bleeding that necessitate intervention.

CAN A MULTI-SLICE CT SCAN HELP TO RESOLVE A DILEMMA: PULMONARY TUBERCULOSIS OR SARCOIDOSIS

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Introduction: Sarcoidosis is a systemic disease of unknown cause characterized by the formation of immune granulomas in various organs, mainly the lungs to the lymph system. However, tuberculosis is an infectious chronic granulomatous disease that usually gives the modified morphological picture of the lungs. If untreated tuberculosis respective leads to death in the first year from diagnosis in higher percentage. Since, radiographic manifestations of sarcoidosis and pulmonary tuberculosis are usually identical, so it is necessary to the implementation of differential diagnostic procedures in order to establish the right diagnosis and the therapy.

Case report: Here we present the clinical course of the disease and monitoring of patients with the help of CT scan, age of 56 years who was hospitalized several times in the hospital, "Ozren" in the period from 1995 to 2016. Due to the presence of tubercle bacilli in a biopsy in 1995 and 1997 year, the patient was treated with drugs against tuberculosis, firstly under the Protocol for the first category, and later under the Protocol for relapse. During this period, the radiological images showed signs of infiltration of tissues with signs of decomposition and shadows in the upper parts of the lungs. Based on the radiological pictures of the right lung in the tops and the middle lung field, tissue preparation from 1995 year analyses is repeated and results pointed to the *likely sarcoidosis granulomatous* disease with proven *lymphocytic alveolitis*. Then he started treatment with immunosuppressive therapy and continue with chemoprophylaxis including isoniazid. On multi slice CT recordings made during 2006, 2008 and 2010, 2011 was observed sclerosis in both lungs in the upper parts, with no signs of activity tuberculosis, sarcoidosis or tumors. On CT recording from 2016 clearly visible cystic fibrosis bronchiectasis with pronounced tissue fibrosis that reduces the volume of the right upper lobe of the lung and trachea by moving to the right.

Conclusion: When tuberculosis relapsed with the development of fibrosis, it is necessary to prove or to eliminate suspected sarcoidosis using other diagnostic procedures, due to the same or similar radiological images for a completely different therapeutic treatment.

ELECTROMAGNETIC FIELD THERAPY AND IMMUNE MECHANISMS WHICH ARE INVOLVED IN ANTI-INFLAMMATORY RESPONSE

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Introduction: In the recent years, due to of the advantages presented by the electromagnetic field therapy, where the results were very good in comparison with other treatments for infection and healing tissue, the interest in its application has rapidly increased. The latest immunological data highlight that the immune system serves as the most important part of the general defense barrier against microbes and viruses, but EMFs can penetrate the entire body. EMF can interfere with the immune functions through stimulation or suppressive reactions, and can interfere the free radicals (FR) generation, induced in the most part by inflammatory cells, and so there is possibility to interfere with inflammation.

Objective: The aim of this study was to evaluate the mechanism by which EMF therapy can interfere with modified immune and oxidative reactions by experimental approach in the lab animals.

Material and methods: In vivo and vitro experiment was carried out on 60 Wistar rats that were divided in the 4 groups as following: 1. Control-group sacrificed at 10 days ; 2.LF-EMF-exposed group sacrificed at 10 days ; 3. Group that received intra-dermic staphylococcus culture (SC)and was sacrificed at 10 days ; 4. Group that received intradermic SC and was treated with LF- EMF, and after 10 days was sacrificed. The rats were exposed to the 50 Hz, 1 mT. Splenic lymphocytes and alveolar macrophages for the cellular cultures were harvested. The following parameters were assessed: a) 3HTdR incorporation test; b) Macrophage inhibition factor (MIF) assay; c) IL-1 assay; d) TNF-assay; e) Chemiluminiscence assay; f) Phagocytosis assay.

Results: The 3HTdR incorporation test, tests targeting the cytokine‘s activity and phagocytosis test point out a partial reversibility of the values in the EMF-exposed groups that was treated with staphylococcus cultures.

Conclusions: Our experiment reveals that the EMF interferes with the immune and oxidative systems. Inflammation involves the activation of the immune system in response to infection; without an acute inflammatory response the body would not be able to repair itself, but if the immune system is always activated, acute inflammation becomes chronic and plays a key role in the development of the serious diseases. EMF-therapy can be beneficial in reducing of the inflammation by interfering of the inflammatory molecules and of surface receptors.

EVALUATION OF CYCLOCRYOTHERAPY DURING 7 YEARS

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Cyclodestruction procedures aim to decrease IOP by decreasing the production of aqueous humour by destroying secretory ciliary epithelium and reducing blood flow to the ciliary body. Ciliary ablation is indicated to lower IOP in eyes that have glaucoma resistant to conventional medical and surgical therapies and it is contraindicated in eyes with good vision acuity because of the risk of losing it. The aim of this research was to show the effect of cyclocryotherapy on intraocular pressure in patients with glaucoma absolute. The cryoprobe is placed with the tip approximately 2 mm posterior to the limbus. Cyclocryotherapy should be limited to a maximum of 6 clock hours (180 degrees of the eye's circumference) at any one session, using approximately 1 freeze-spot per clock hour (40 to 60 seconds each at -60 ° C), with the anterior edge of a large 2.5 mm diameter cryoprobe placed 1-1.5 mm posterior to the limbus and care to avoid the 3 area of the limbus should also be avoided and care should be taken during a freeze to avoid contact 1 cm, which can happen as the entire eye cools down with sequential freeze applications. All glaucoma medications (except miotics and acetazolamide) are continued postoperatively. Our retrospective study included 22 patients history in the period from January 2010 to December 2016 years who underwent cyclecryotherapy. 13 patients (59.09%) were males and 9 (40.91%) female patients. The average age of the patients was 60.87±15:37, the youngest patient was 22 years old and the oldest was 81 years, after discharge from the hospital. Visual acuity before surgery: NPL 13 (59.09%), PL 5 (22.73%), HM 2 (9.09%), CF 1 (4.55%), 0.05 1 (4.55%) patients. The same ratio was and after surgery, only one patient with PL worsened to NPL, and one of NLP improved to PL. Average pressure measured with Goldman applanation tonometer, before surgery was 51.00±12.64 mmHg, the lowest was 30 mmHg, while the highest was 72 mmHg. Average pressure after surgery was 25.99±10:38 mmHg, the lowest was 8 mmHg and the highest 54 mmHg. In our study, there was only one complication, which ended with enucleation of the eye. Cyclocryotherapy is the last option for patients with increased intraocular pressure and severe pain in the eye

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CYTOTOXIC AND APOPTOTIC EFFECTS OF ARTEMISIA ALBA TURRA AND ARTEMISIA VULGARIS L. ETHYL ACETATE EXTRACTS ON SW-480 COLON CANCER CELLS

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In this study we evaluated the cytotoxic and apoptotic effects of ethyl acetate extracts from the *Artemisia alba* Turra (AA) and *Artemisia vulgaris* L. (AV) in six different concentrations (1, 10, 50, 100, 250, 500 µg/mL). Cell viability was determined by MTT assay, when the IC_{50} was used as a parameter of cytotoxicity and apoptotic effects by flow cytometry. Both extracts AA and AV significantly inhibited the proliferation of SW-480 colon cancer cells in a dose and time dependent manner, but AA was more effective (IC_{50} were 169.40 µg/mL after 24 and 40.40 µg/mL after 72 hours for AA and >500 µg/mL after 24 and 248.40 µg/mL after 72 hours for AV). Flow cytometry analyses showed that AA extract significantly induced early apoptosis (33.51 ± 1.58 for AA vs 0.70 ± 0.08 for AV, p = 0.001) whereas AV significantly induced the necrosis (82.38 ± 5.02 for AV vs 53.91 ± 2.32 for AA, p = 0.001) of colon cancer cells. Our results suggest that *Artemisia alba* and *Artemisia vulgaris* have potent cytotoxic and apoptotic effects but *Artemisia alba* is more effective. Therefore, *Artemisia alba* is potentially used as an integral component of therapeutics against human colon cancer.

Key words: Artemisia alba, Artemisia vulgaris, colon cancer cells, cytotoxic effect, apoptotic effect

PHENOLIC PROFILE AND IN VITRO GENOTOXIC ACTIVITY OF METHANOLIC EXTRACT OF TEUCRIUM POLIUM

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Teucrium species are known for their medicinal and biological properties such as hypoglycemic, hypolipidemic, hepatoprotective, antipyretic, anti-inflammatory, antiulcerogenic, antitumor and antimicrobial activities. In this study we characterized the methanolic extract obtained from *Teucrium polium* by analyzing the content of antioxidant compounds such as polyphenols and flavonoids using high-performance liquid chromatography (HPLC). Genotoxic potential of extract was evaluated in four different concentrations (125, 250, 500 and 1000 µg/mL) in whole blood lymphocytes by the use of *in vitro* cytokinesis block micronucleus (MN) assay. In the plant extract five phenolic acids (gallic, vanilic, coffeic, chlorogenic and p-coumaric acid) and six flavonoids (catechin, rutin, myricetin, luteolin, quercetin and apigenin) were identified and quantified. Furthermore, the results showed that the highest tested concentration of extract (1000 µg/mL) induced statistically significant increase in DNA damage assessed with the MN assay. With the regard to the cell cycle kinetics, all tested concentrations of extract caused no significant differences of NDI (nuclear division index) compared to the control cells. In addition to that, all tested concentrations of extract significantly decreased MMC-induced DNA damage, but NDI decreased only in the highest tested concentrations (500 and 1000 µg/mL). Our results demonstrated that only higher tested concentration of extract was genotoxic and not cytotoxic. The results of co-treatments of extract with MMC revealed antioxidant effect clearly and suggest that *T. polium* is a natural source of antioxidants that with certainty can be recommended to patients who are in the process of receiving chemotherapy.

Key words: Teucrium polium, antioxidants, micronucleus assay, nuclear division index, DNA damage

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OPTICAL SPECIFICITY OF THIN SHELL FOR NANO-DELIVERY MODEL

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The subject of the research in this paper includes theoretical investigation of nanomaterials modeling in the field of pharmaceutical technology for biomedical application. This includes very precise encapsulated drug delivery, on exactly defined place in the human tissue or organ and disintegration of capsule – drug carrier, so that the medicament can start producing its effect. The goal of multidisciplinary researches with biocompatible molecular nanomaterials is to find the parameters and the possibilities to construct boundary surfaces that will, in interaction with biological environment, create such properties of nanolayers that are convenient for use for layers of drug carrier capsules, biochips and biomarkers. These layers should demonstrate controlled disintegration of structure, better dielectric properties, discrete luminescence and appropriate bioporosity as all these are the requirements of contemporary nanomedicine. The main advantage of the theoretical approach is essential knowledge of the mechanisms that allow us to comprehend the experimental conditions that we have to fulfill to be able to get the desired results. The results achieved up to now by our research group in application of the Green's function method on flat ultrathin films are promising for applications in the frame of optical core-shell models. This paper presents review of our current achievement in the field of theoretical physics of exciton ultrathin films and possible ways to materialize the same in the field of nanopharmacy.

ERYTHROCYTES AND DNA STUDY VIA OPTICAL- AND BIO-TECHNOLOGY

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It is well known that the physical phenomena resulting from forces exerted on a liquid-crystal mesophase on account of the electric, magnetic, thermal fields and deformation are due to the weak intermolecular interaction of the structural elements of liquid-crystal media. To take an advantage of such factors as the presence of weak dispersion forces between the molecules of liquid crystals and the high orienting ability, the liquid-crystal anisotropic medium can be considered for visualizing, fixing, and orienting human red blood cells and DNA [1,2]. The feedback mechanism of liquid crystal self-organization [3] due to interaction with erythrocytes has been before discussed as well as the spectral features of the LC with DNA have been previously shown [4].

In the present paper the special accent will be given on the refractive parameters change of the composites with the bio-objects and on the self-ordering effect in them.

Key words: Liquid crystal, bio-particles, self-arrangements, refractive index

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RADIOACTIVITY IN THE LIGHT OF THE FUNDAMENTAL LAW OF PHYSICS

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One of fundamental laws of physics is the law of efficiency of conversion of one kind of energy into another which is formulated in second half of the 20-th century for whole region of electromagnetic radiation. On the basis of this law for weak influences (isothermal processes) whole region of wavelengths of electromagnetic radiation breaks up on two parts strictly corresponding to the W. Wien region and the Rayleigh-Jeans region, in which efficiency laws are essentially various. Gamma radiation is the most high-energy part of electromagnetic radiation. It is the top frequency boundary for the W. Wien region. Efficiency of conversion of energy for different frequencies of the W. Wien region in approach of reversible process has been considered. Influence of irreversibility on conversion of energy in system for a value of efficiency has been shown. Features of laws of efficiency of conversion for endergonic and exergonic processes are considered.

DIRECTED IMPACT OF THERAPEUTIC ULTRASOUND ON PHYSIOLOGICAL STATE OF ANIMAL PLATELET

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Morphological, biophysical and physiological studies on animal platelets after exposure to ultrasound (US) were conducted. The US carrier frequency was 0.88 MHz or 2.64 MHz, therapeutic levels of intensity I_{SATA} — average over space and time intensity — were from 0.05 W/cm² to 1.0 W/cm². The active modulation frequency ranged in 10–150 Hz and 700–1000 Hz. The irradiated blood volume from dogs, cats and horses ranged from 1 to 1.5 ml. No animals were harmed. The unused blood had been left over from the planned clinical and hematological studies in animal clinics and branches of the Academy were irradiated.

Destructive, cytolytic and several other effects of continuous and amplitude-modulated ultrasound were detected. The *in vitro* active frequencies' spectra and intensities that affect the state of platelets were revealed. We recorded changes in platelet permeability, shape, deformation, rupture of the cytoplasmic membranes and trespassing. The possibility of directional acoustic impact on the state of the blood platelets & on the structure of their membranes was checked. We have worked out a technique of the deep color of all animal's blood cells of any kind to study the morphology, to diagnostic any cell membranes changes in and to identify morphological features of blood platelets.

Continuous ultrasound. Platelet were stained after blood sonication with traveling continuous mode US wave from 20 to 45 sec with the intensity of 0.4 W/cm², followed by the preparation of blood smears and differential coloring dyes.

The amplitude-modulated ultrasound. The dyeing of platelets was performed after US exposure on blood samples. Depending on the US intensity different exposure was used. With 0.05 W/cm² intensity we treated for 30–40 sec, with intensity of 0.2 W/cm² — 20–35 sec, of 0.4 W/cm² — 15–30 sec, and with 0.7 W/cm² — for 10–20 sec (The carrier frequency was 0.88 MHz). At the same time, we imposed on these modes any number of the 10 – 30 Hz modulation frequency range or 800 Hz, the duty cycle 2. The same result can be achieved using the carrier frequency of 2.64 MHz & the intensity of 0.4 W/cm² (exposure time 15–30 sec).

The ranges of US intensity, active frequencies and time exposure found provides guaranteed quality of platelets coloring in all cases (regardless of the specific characteristics of the cells, blood storage conditions, animal status, and the presence of a pathological process) without impacting adversely on the other formed elements coloring. The method allows uniform deep differential staining of all blood cells, including platelets. Our findings can be used for non-invasive animals' blood test.

CALCULATION OF CHEMICAL REACTION RATES BASED ON RAMAN AND FTIR SPECTRAL DATA

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The rate of chemical reaction is the most important characteristic of a chemical process. Today several highly sensitive and specific methods can be used to measure reaction rates. Some of these methods are indispensable. Each method is efficient in the measurements of concentration of a certain reaction component, but no universal method is known at the moment. In physics, one of the most informative methods of studying the structure of molecules is a vibrational spectroscopy (Raman and FTIR spectroscopy). Both methods have some disadvantages, but in combination with each other, they give a complete picture of the nature of the sample.

In this work, we apply the methods of Raman and ATR FTIR spectroscopy in the study of the kinetics of chemical reactions.

It is shown that Raman spectroscopy can be used to calculate the chemical reaction rates. Chemical reaction of alkaline hydrolysis of ethyl acetate is studied. Reaction kinetics is interpreted as time dependence of the intensity (area) of a single Raman band. To determine reaction rates, we fit experimental kinetics with analytical solution of the corresponding system of kinetic equations. The temperature dependence of reaction rates is measured in an interval of 15-45°C. The results are consistent with available literature data. Activation energy of the reaction is calculated. Intensity dependences of several Raman bands are studied. Reaction rates calculated with the help of different kinetic dependences varies by about 6%.

Raman spectroscopy can also be used in the analysis of enzymatic reaction kinetics (hydrolysis of 2,4-dinitrophenyl acetate catalyzed by α-chymotrypsin). The values of the reaction constant of spontaneous hydrolysis and the Michaelis constant are obtained.

The difference between the ATR FTIR and Raman data on chemical reaction rates is discussed. The reason for such a difference is the specific interaction of reaction solution with the surface of ATR crystal. Spectral changes with time are obtained for several pure substances and chemically stable mixtures in the FTIR measurements using attenuated total reflection configuration.

Key words: Raman spectroscopy, FTIR, ATR FTIR, chemical reactions, reaction rate, chemical kinetics, enzymes, functional activity

PHYSIOLOGICAL PROCESSES WHEN AN ELECTRICAL CURRENT PASSES THROUGH THE TISSUES AND ORGANS

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We performed a study that some physiological processes are caused by electrical current when passing through the tissues and organs. The basic idea of diathermia, medical treatment and therapy with alternating high frequency electric current, is to use transformation of electric power into heat when current goes through the tissue and internal biological environment. The important fact in this process is to avoid massive displacement of ions, which could be potentially destructing side effect. Advantage and importance of using the alternate current (with frequency ~1 MHz) over the direct current is explained, as well as the fact that this effect was spotted almost simultaneously by Nikola Tesla and Jaques d'Arsonval, at the end of 19th century. This paper also explains later cooperation between two scientists and basic principles of diathermy – heating effect with high frequency alternate current.

MODIFICATION OF SPECTRAL PROPERTIES OF PHOTOSYNTHETIC LIGHT-HARVESTING COMPLEXES BY INTENSE OPTICAL IRRADIATION

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Single-particle (-molecule, -protein, or -membrane) spectroscopy, by getting rid of unwanted ensemble averaging, has become a valuable tool in biophysical research. Yet in these studies necessarily rather high excitation intensity is used that may significantly modify the spectral as well as structural properties of the studied particles. Here, the fluorescence spectra of excitons in the peripheral LH2 antenna pigment–proteincomplex were investigated under continuous-wave laser excitation. The samples purified from two different species of photosynthetic purple bacteria (non-sulphur *Rhodobactersphaeroides* and sulphur *Allochromatiumminutissimum*) were interrogated under the excitation intensity, which varied over more than four ordersof magnitude, between 0.1 W/cm^2 (the full sunlight intensity) and 2 kW/cm^2. Excitationin to the Q_x absorption band of the bacteriochlorophyll-*a* chromophores at 594 nm was employed. The spectra studied upon strong and prolonged illumination at ambient temperature revealed important permanent modifications. This damage, being much more extensive in complexes from sulphur bacteria, was shown to be due to photo-oxidation of various numbers of bacteriochlorophyll-*a* molecules in the B850 compartment of LH2. In our presentation, we also discuss whether the observed spectral variations might be a part of the adaptation strategy of the bacteria to variant environmental conditions.

BIOCOMPATIBILITY OF CdSe QUANTUM DOTS

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The composition and very small size of quantum dots (QDs) gives them unique and very stable fluorescent optical properties that are readily tunable by changing their physical composition or size. The ability to create dots that emit a rainbow of colors suggest that they could be used as biosensors. Most commonly used QDs is core/shell CdSe/ZnS. After synthesis, core/shell quantum dots must be covered with an organic layer or incorporated within the organic shell to make them water-soluble and biocompatible. Biocompatible quantum dots represent a powerful tool for the direct readout of information down to single molecule level.

SENSITIVITY OF REMOTELY-SENSED SPECTRAL REFLECTANCE TO BIOPHYSICAL VARIABLES OF PLANTS

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Precise estimation of the leaf biophysical and biochemical variables provides useful information of important physiological processes in vegetation that can be readily assessed via hyperspectral remote sensing (HRS). The key variables include leaf chlorophyll and water content, leaf dry matter content, leaf area index (LAI), and leaf structure. HRS technology of spectral reflectance provides simultaneous acquisition of information in narrow but continuous spectral bands which are sufficient to detect subtle absorption features in foliar spectra and to study correlations of these features to biophysical parameters. Variability of leaf optical properties is wavelength dependent. Leaf chlorophyll strongly affects the visible region of the reflectance spectra while LAI and leaf structure have a large impact on the near infrared region. To translate HRS data into information about vegetation biophysical and biochemical parameters, specialized algorithms and approaches are needed. Two common approaches are the empirical-statistical approach and physical modeling. The first approach includes spectral vegetation indices computation and regression model application. Considerable progress has been made in physically based models that simulate leaf spectral characteristics based on interactions of incident radiation with foliar medium.

The objective of this paper is to investigate the sensitivity of remotely-sensed reflectance data to variations in the biophysical parameters at leaf scale using a modeling approach. Hyperspectral reflectance data were collected by means of a portable fiber-optics spectrometer in the visible and near infrared spectral regions (350-1100 nm) of the electromagnetic spectrum with a spectral resolution of 1.5 nm. Some stress factors (viral infections) were applied to young horticultural plants (potato, tomato). Several vegetation indices (VIs) were developed to reveal the estimation accuracy of vegetation variables. Modified Chlorophyll Absorption in Reflectance Index (MCARI), Blue Green pigment Index (BGI), Plant Biochemical Index (PBI), and Chlorophyll Absorption Ratio Index (CARI) were chosen for estimating plant pigment contents.Enhanced VI (EVI), modified Normalized Difference (mND705), Normalized Difference VI (NDVI), and Greenness Index (GI) were applied for estimating plant biomass from hyperspectral data. Photochemical Reflectance Index (PRI) was used for estimation of stand photosynthesis from remotely sensed data. For the physical-based approach Fourier amplitude sensitivity test was applies. The model sensitivity is decomposed into the first-order index, which represents the individual effect of each model parameter in accounting for model output variation.

THE EFFECT OF PLANT DISEASES ON HYPERSPECTRAL LEAF REFLECTANCE AND BIOPHYSICAL PARAMETERS

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Spatial and temporal monitoring of biophysical parameters of plant ecosystems provides important information on their status and responses to changing environmental conditions. The chlorophyll content and fraction of absorbed photosynthetically active radiation are widely applied in environmental studies concerning growth monitoring, stress detection, and yield estimation. Hyperspectral remote sensing method based on measurements of leaf reflectance in hundreds of narrow spectral bands provides the possibility for accurately studying and objective assessment of the spectral responses of plants to adverse environmental conditions. As a unique cost effective resource, hyperspectral reflectance data have been proposed as a good solution for assessment of the vegetation biophysical parameters and their variables.

Remotely-sensed reflectance data collected by means of a portable fiber-optics spectrometer in the visible and near infrared spectral ranges (350-1100 nm) were used to extract information on the effect of biotic stresses (two viral infections) on young potato plants. The test data were subjected to different digital image processing techniques. This included statistical (Student’s t-criterion), first derivative and cluster analyses and several vegetation indices were estimated. Statistical analyses were carried out 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). The strong relationship, which was found between the results from the remote sensing technique of spectral reflectance and serological analyses (DAS-ELISA) for the presence and degree of the diseases, indicates the importance of hyperspectral reflectance data for conducting, easily and without damage, rapid assessments of plant biophysical variables and plants health. Emphasis was put on current capability and future potential of the leaf reflectance for assessment of the physiological state of plants and on defining the optimal spectral regions and vegetation indices for analyses of these biophysical variables.

PELAGE ALKALINE HYDROLYSATES' REDOX CHANGE VIA LIGHT FLASH

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The effect of pelage alkaline hydrolysates' redox change under the light flash (redox-photo effect) was examined.

Hydrolysates were prepared during 30-minute incubation of hair in *NaOH* solution (*4M*) in a boiling water bath. After incubation, the hydrolysate was diluted to a pH = 12.5; the final keratin concentration was 2 mg/ml.

Studies have shown that: 1) Pelage alkaline hydrolysates' redox-potentials from various animals differ significantly; 2) The majority of these solutions is characterized with redox change under the light flash; 3) Redox amplitude shifts range under light exposure in diapason of ± (5 ÷ 20) mV from initial value and greatly depend on the source of material; 4) The redox value displacement varies slightly with increased concentration of the keratin solution; 5) When the flash exposure does not exceed 300 sec the redox shift is completely reversible, the longer exposition can result in the irreversible redox shift; 6) The redox dynamics under the influence of the flash exposure of 100 ÷ 300 sec corresponds meander shape with time growth of both fronts not more than 3 seconds.

The redox-dependence revealed is probably associated with a different melanin content and different ratios of sulfide and disulfide groups. The method developed can be used in the pelage and fur expertise.

SPECTROPHOTOMETRY RESEARCH OF FLEECE ALKALINE HYDROLYSATES

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As a model object the goat fell from different parts of its body was chosen. Animals varied in breed, sex and age. Fell alkaline hydrolysates were prepared during 30-minute hair incubation in *NaOH* solution (*4M*) in a boiling water bath. Then samples were cooled and diluted 40 times.

The spectrophotometry method is based on the ability of biological solutions to absorb light with different intensities under various conditions and wavelengths. Thus, we can determine the absorption spectrum, characterizing each substance. We determined the light absorption by fleece alkaline hydrolysates in the range of 205–750 nm.

The results obtained showed that fleece alkaline hydrolysates from adult goats' hair (females and males) start to absorb light at 245–275 nm. In its spectrum two absorption bands are present: 410 — 510 nm and 550 — 650 nm. Alkaline fleece hydrolysates from the hair of newborn goats don't absorb at the wavelength of 275 — 285 nm and 300 — 350 nm. Fleece alkaline hydrolysates solutions from pregnant goat hair lacked to absorb at 300 — 370 nm wavelength.

We think that the technique developed will allow us to identify the species of various animal hair.

PERCEPTION, FEELINGS AND NEUROREGULATORY SIGNALS AS MUSIC-LIKE PATTERNS EMBODIED IN IONIC WAVES INDUCED BY PROTEINS

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We introduce a hypothesis that both: afferent and efferent neural pathways involve additional mechanism of signal transduction in form of a hydro-ionic waves in brain and body tissues, being induced by proteins and protein interactions and having properties similar to musical patterns, namely: rhythm, meaningful frequencies and presumably, consonance. Mechanisms of our feelings could also include the same biophysical substrate composed of the hydro-ionic waves. After introducing a sketch of the model, the results of two unpublished pilot experiments and the well-known Chladni dynamical patterns are brought in support of the hypothesis. First, we show some examples to prove that the structure of proteins embodies a matrix able to generate musical patterns. Second, we compare feelings with the musical patterns that generate Chladni effects in vibrating metal plates covered with sand. Third, we report a pilot experiment of electrical stimulation of brain tissue with musical patterns. We suggest that purposefully composed sound sequences are able to cause targeted biological effects in case they mimic the rhythm and frequencies of Music-Like Patterns of natural neuro-regulatory signals. Examples of the natural "Bio-music" obtained by direct computer-assisted transcription of some protein amino acid sequences into the sound sequences will be presented. Possible applications include activation of regeneration processes, regulation of hormonal misbalances, correction of biochemical, immunological and psycho-neurological reactions.

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EFFECTS OF MODULATED ULTRASOUND ON GROWTH AND EMISSION PROCESSES

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The purpose of our research was to identify the basic effects of amplitude-modulated ultrasonic waves in various organophotoheterotrophic prokaryotes cells. As the test objects, the representatives of unicellular organisms, photobacteria, were selected, i.m. – the culture of marine luminescent halotolerant bacteria *Aliivibrio fischeri 6*. Cells were exposed for 15 min to ultrasound (US) intensity I_{SATA} of 0.2 W/cm² and 0.4 W/cm² with modulation frequency range of 0.1 – 10 Hz and 100 – 1000 Hz using the US therapeutic apparatus UST–5. The carrier frequency was 880 kHz; modulating generators G3–112 and CP–110 provides the ability to create a modularize signal in a wide range of frequencies (0.001 Hz–1999 kHz).

It was found that the intensity of bioluminescence in growing control cells depends on the population density. The maximum intensity of luminescence is characterized by state of the population of growing cells *A. fischeri*, called *«quorum sensing»*. The emission was absent at low concentrations of cells (optical density = 0.2-0.3), and sharply increased and reached a maximum after 20 hours when the population reached its critical density (OD = 2). Cell synthesized autoinductor of luminescence (acyl-derivate of L-homoserine, N-3-oksogeksanoillakton) diffused freely across cell membranes. It was involved in cell communication via the «quorum sensing» system and it was the main factor affecting the expression of the *A. fischeri lux*-genes.

The experimental results showed that low-intensity ultrasound (0.05-0.1 W/cm², the exposure time of 1-3 minutes), did not effect on the growth and development of the bacterial culture, but lowered the intensity of the sonicated cells' luminescence. Probably it has not been reached the state of "quorum sensing". However, the emission intensity quickly restored after the ultrasonic termination. The intensity increases from 0.1 to 0.2 W/cm²caused the intensification of luminescence which gradually reached the reference value. Exposure to US intensity of 0.4 W/cm² stimulated the bioluminescence and the growth rate of *A. fischeri*. In the range between 0.4 and 0.6 W/cm² visible bacterial luminescence changes weren't observed. It is obvious that under these intensities suppression and stimulation of bioluminescence effects are equal. US intensities, greater than 0.6 W/cm², irreversible inhibition of bioluminescence was observed. The number of viable cells progressively reduced. The US intensity when bioluminescence suppression starts, coincides with the thresholds of cavitation in the slurry, which was confirmed by experiments on the generation of ultrasonic cavitation emission in free from bacterial cells media under intensities greater than 0.6 W/cm².

It was found that the directional effect of 0.2 W/cm² US intensity and of the modulation frequency less than 85 Hz changed minimally the degree of cell culture emission, whereas at the frequency of 120 Hz completely inhibited the bioluminescence. The US modulation frequency range from 85 to 100 Hz at the same US intensity of 0.2 W/cm² increased the degree of emission.

US intensity of 0.4 W/cm² and a modulative frequency of 14 Hz and 9 Hz did not affect significantly on the degree of bacterial cells' luminescence. But under lower modulation frequencies, 5–7 Hz, the emission intensity fell twice – fivefold. The stimulation of luminescence was observed only when the modulation frequency was equal to 10-12 Hz.

GAMMA IRRADIATION FOR USEFUL WHEAT GENETIC VARIABILITY

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Usefulness application of gamma rays irradiation in plant breeding has resulted in the release of more than 3500 cultivars worldwide, in over 170 crop species, including common wheat.

In addition, a wealth of genetic variability has been generated by using induced mutants as one of the parents in the breeding programs.

At NARDI Fundulea, a valuable genetic variability for several important wheat agronomic traits was generated through specific protocol utilization including two modern wheat genotypes, two irradiation cycles application with gamma rays and DH (doubled haploid) technology based on biotechnological Zea system.

The genotype Izvor is the most drought tolerant genotype released in Romania, with high yield ability in dry years ("or" recessive allele controlling osmotic adjustment, and the genes Lr34/Yr18/Pn38/Sr57/Ltn51, for foliar pathogens).

The advanced breeding line F00628G-34 with good resistance to foliar pathogens, higher yielding potential in areas without water stress, carries 1A/1R translocation.

Up to now, 314 mutant/recombinant DH lines were thoroughly screened at molecular level for the presence/absence of Lr34 and "or" genes, 1AL/1RS translocation and for GluA3 and secaline locus. In 23 mutant/recombinant DH lines we identified the presence of Glu-A3c locus on 1RS arm in lines with 1AL/1RS translocation.

Identification of mutated/recombinant DH lines possessing GluA3 locus on translocated chromosome 1AL/1RS, with or without the presence of secaline locus (ω secaline and γ secaline) opens possibilities of improving quality parameters of bread wheat by using these new genetic variability sources.

Key words: Mutant/recombinant, secaline, Glu-A3, quality

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CANDIDA RUGOSA LIPASE IMMOBILIZED ONTO TITANIA: IMPROVED THERMAL STABILITY AND REUSE POTENTIAL

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Enzyme catalyzed reactions have been extensively exploited for a wide range of applications in biotechnology. In spite of a broad implementation of enzymes in different fields, some constraints referred to their cost and process stability still exists. To overcome a limit related to short catalytic lifetime of enzymes in process conditions, a spectrum of immobilization methods have been extensively studied to increase stability and enhance reuse, offer easier separation, making production economically viable.

Lipase from *C. rugosa* is a globular glycoprotein with molecular mass of 57 kDa. With 31 acidic and 18 basic amino acids exposed on the surface, its IEP is located at pH 4.65. Titania (Degussa P25) was selected as support material for its well defined morphology: nanometer-sized solid particles of spherical shape. Being amphoteric, titania particles develop positive and negative charge below and above IEP (pH 6.7), respectively.

Tris-HCl buffer at pH 7.6 was used for immobilization. Although the overall charge of lipase is negative, localized electrostatic attractions together with hydrophobic interactions govern the adsorption of enzyme onto the support. Owing to the patchwork surface charge of lipase, positively charged Lys are accessible for the electrostatic interactions with the negatively charged support.

The adsorption of lipase onto titania was fast, after 1h 65% of lipase was adsorbed.

One of advantages of enzyme immobilization is improvement in thermal stability. Therefore, the stability of lipase immobilized onto titania was determined at 50 and 60 °C. In terms of half-life, at 50 °C, $t_{1/2}$ of free lipase was 55 min, while after immobilization, $t_{1/2}$ increased to 180 min. The thermostability of lipase was increased more than 3-fold after immobilization. After 1 h of incubation at 60 °C, the free lipase was inactive, while the remaining activity of immobilized enzyme was close to 60%. Even after 2h the activity remained 40%, or in terms of half-life, increased more than 7-fold.

A significant improvement in thermal stability of immobilized lipase seems to be result of restrict movements of protein after adsorption, preventing conformational changes and unfolding.

The reusability of immobilized enzyme is one of the most important advantages for application. Adsorption, as an immobilization method, is usually considered as a method with poor reuse potential, as the linkages established are usually weak and the enzyme could be easily desorbed. Reuse stability in water was tested. Remaining lipase activity was about 90% after nine reuses. As strength of interaction between enzyme and support can be judged from the ability of enzyme to resist removal – leaching, the result implies a strong interaction between lipase and titania as support. The result points to the significant potential for reuse of lipase in water environment after immobilization onto titania.

CANDIDA RUGOSA LIPASE IMMOBILIZED ONTO TITANIA AS NANOBIOCATALYST IN ORGANIC SOLVENT

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Kinetic measurements can be used to predict the optimum kinetic behaviour of a particular biocatalyst. Based on those predictions, optimisation of biocatalytic reactions, as well as process design to improve productivity and reduce the cost of various processes can be performed.

The kinetic parameters of lipase immobilized onto titania were determined in cyclohexane using solutions of amyl alcohol and octanoic acid in a range of concentrations: 0.05 to 0.6 M for alcohol and 0.05 to 1 M for acid. at 40 °C with mechanical stirring at 150 rpm on rotary shaker. One unit (1 U) is defined as that quantity of enzyme which under test conditions synthesizes 1 mmol of amyl-octanoate per min.

The rate of esterification was determine as the residual acid content by titration with sodium hydroxide, The quantity of ester formed was calculated as being equivalent to acid consumed. This was confirmed by determination of ester concentration using gas chromatography–mass spectrometry (GC-MS) performed with a GCMS (QP2010 Ultra, Shimadzu, Kyoto, Japan). Spectrum analysis was performed using NIST11 and Wiley8 database libraries, and relative ratios of components were calculated from the corresponding peak areas.

Most of the kinetic studies of lipase catalyzed esterification reaction in organic solvent assume ping-pong model with inhibition by alcohol. In order to find kinetic model of amyl caprylate synthesis, catalyzed with *C. rugosa* lipase immobilized onto titania, series of experiments were performed at determined conditions. The experimentally obtained data were fitted with model for bisubstrate ping-pong bi-bi model with alcohol inhibition using Matlab software. The rate equation describing this model is given by:

$$v=(V_{\max}, [Ac]\,[Al])/([Al][Ac] + K_{Al}[Ac] + K_{Ac}[Al] + (K_{Ac}/ K_{i,al})\,[Al]^2)$$

where v is the initial reaction rate, $V_{\max}$ is the maximum reaction rate, [Ac] and [Al] are the concentrations of octanoic acid and amyl alcohol, K_{Al} and K_{Ac} are Michaelis constants for amyl alcohol and octanoic acid, and $K_{i,al}$ is the amyl alcohol inhibition constant.

Kinetic constants ($V_{\max}$, K_{Al}, K_{Ac}, $K_{i,al}$) were calculated using a non-linear regression fit of the 48 experimental points. Parameters were optimized using MatLab software.

Values of kinetic constants from ping-pong bi-bi model with alcohol inhibition are: $V_{\max}$ = 26.36 μmol min^{-1}g^{-1}; K_{Al} = 0.200 moldm^{-3}; K_{Ac} = 0.522 moldm^{-3}; $K_{i,al}$ =0.644 moldm^{-3}

The increase of concentration of octanoic acid increases the rate of esterification achieving the maximum rate of 26.36 μmol min^{-1} at 1 mol/L of acid and 0.3 mol/L of alcohol. On the other hand, the increase of concentration of amyl alcohol confirmed hypothesis of substrate inhibition.

Cancer
Research

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LOCALISED HYPERTHERMIA WITH MAGNETIC NANOPARTICLES: TEMPERATURE MEASUREMENTS AND DEVELOPMENT OF LABORATORY DEVICES

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Cancer is one of the major causes of mortality worldwide. Several current methods used to treat cancers can be classified into conventional and modern methods. Hyperthermia has been recently introduced as an adjuvant therapy for cancer and holds great promise for combating this disease. Hyperthermia is defined as a treatment in which the target tissue is exposed to high temperatures that either destroy the tissues directly (thermal ablation with temperatures above 47 °C) or render the cancer cells more susceptible to other treatment modalities (thermal sensitization in the temperature ranges of 41–45 °C).

Nanotechnology has been introduced into the biomedical applications with the expectation of revolutionizing current diagnostic and treatment techniques. Nanoparticles can absorb energy from an external source and enhance the effects of hyperthermia. There have been an increasing number of investigations, in the past two decades, into various aspects of magnetic nanomaterials for hyperthermia-based therapy. In order to increase the heating efficiency simultaneous process are also available where synergic effects can occur.

In this study we used only magnetic hyperthermia.

Temperature measurements of magnetic nanoparticles were performed on either aero gel matrix or liquid and ferrofluid nanomaterials. For this purpose, the external magnetic field was applied through a series RLC circuit that can produce IF magnetic field up to 14 kA/m, at 250 kHz frequency. The temperature was measured with a multichannel fibre optic thermometer (Luxtron FOT Lab kit).

In order to measure the magnetic susceptibility and its dependency on temperature of different magnetic nanomatrials, we developed a broadband (10 kHz-1 MHz) magnetic susceptometer.

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ANTITUMOR EFFICACY OF COMBINED USE OF NOS-INHIBITOR AND ELECTRON-AFFINIC COMPOUND

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Introduction. Endogenous nitric oxide (NO) is actively involved in many physiological and pathological processes, such as regulation of neoangiogenesis, including the tumor growth. Currently it is shown that nitric oxide may regulate proliferation activity and apoptosis of tumor cells and have a direct influence on the results of chemotherapy. Suppressing the activity of nitric oxide synthases (NOS) using NOS-inhibitors cause a reversible hypoxia in tumor and peritumoral tissues. We have found that the compound ITU-II from the chemical class of isothiourea, synthesized by the laboratory of radiation pharmacology in A. Tsyb MRRC is able to selectively and reversibly inhibit the NO synthases. Our recent researches which we had made have shown the anti-tumor and anti-metastatic effectiveness our original substances.

There are an electron-affinic compounds aimed on hypoxic tumor cells – a priori resistant to radiotherapy and chemotherapy. They affect on cellular respiration, the sensitivity of tumor cells to chemotherapeutic drugs. In this context, the investigation of combined use of NOS-inhibitor with electron-affinic compounds which potentially capable selectively sensitize of tumors to the action of these drugs is very perspective.

Materials and methods. Research were made on male mice F1 [CBAxC57Bl6] at the age of 2-2.5 months, weighing 25-28 g with inoculated Lewis lung carcinoma (LLC). Two series of experiments were carried out, each included six experimental groups (15 animals in group). Experimental animals were injected with Metronidazole (electron-affinic compound) and NOS-inhibitor ITU-II from 7th till 20th days of tumor growth in a specific pattern. Every 4 days were measured the volume of the tumor and the weight dynamics of animals. On 21th day of tumor growth the animals were euthanized. Antitumor effect was evaluated by the index of tumor growth inhibition (TGI, %). Also the number of metastases was counted in the lungs which were fixed in acidic Bouin's fluid.

Results. Isolated injection of Metronidazole inhibited the tumor growth on 20% and 34% (10th and 14th day respectively), but at the terminal stage of tumor growth a complete lack of antitumor effect was observed. Isolated injection of ITU-II inhibited tumor growth on 15-20% throughout the experiment. The group that received the combination of two drugs had a pronounced TGI effect. Maximum of effectiveness was obtained at 14th day (30%) and kept until the end of the experiment (22%). Moreover, the results of the second experiment showed that efficacy of combined use of two substances depend on the interval between the injections: the longer the interval between injections the higher the TGI index. Thus, in the range of 120 minutes the TGI index was 46%.

ANTITUMOR ACTIVITY OF NOS INHIBITOR IS DUE TO ANTIANGIOGENIC MECHANISM OF ACTION

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Oncological diseases are difficult to treat despite the limited success in the fight against cancer. Therefore, the problem of creation of new pharmacological drugs and schemes of tumor therapy is very actual. One of the modern targeted approaches in oncology is the development of pharmacological agents for angiostatic therapy of tumors. The new original isothiourea derivatives (ITU), synthesized in the laboratory of radiation pharmacology of A. Tsyb MRRC, exhibit the properties of nitric oxide synthase (NOS) inhibitors. Using the ITUs as anticancer agents is relevant, because their ability to inhibit endothelial NOS largely provides the antiangiogenic activity of these substances. In this study we investigated the antitumor, antimetastatic and antiangiogenic activity of new original NOS inhibitor ITU-II.

The investigations have been done in male mice F1 [CBA×C57BL6j], 13-17 animals per group. We used epidermoid tumor model - the lung Lewis carcinoma (LLC). The studied compound ITU-II was injected daily intraperitoneally at dose 1/5 LD_{16}. The linear sizes of tumors were measured in each animal every 3 days since the 7th day of the experiment and then the volumes of the tumor were calculated. On the 21th day the animals were euthanized, lungs were removed, fixed in the acidic Bouin's fluid and the number of small and large lung metastases were counted on the following day. Tumor tissue samples were fixed and prepared in specific pattern for histological, immunohistochemical and morphological studies.

Sub-chronic administration of ITU-II caused significant antitumor activity. After 21 days of injections tumor sizes were 45% less in mice treated with ITU-II than in control mice. Marked tumor growth inhibition in treated animals was observed in the first 7-14 days. The number of lung metastases was 30% lower in treated mice than in control group. NOS inhibitor statistically significantly suppressed the growth of large metastases and reduced the number of small metastases. Histological and immunohistochemical studies have shown marked decrease in the number of blood vessels in peritumoral area and "hot spots" of angiogenesis in the LLC parenchyma, the expansion of spontaneous necrosis zones, a statistically significant decrease in the proliferative activity of carcinoma cells and stimulation of apoptosis.

Thus, a pronounced antitumor and antimetastatic efficacy of NOS inhibitor is largely due to its antiangiogenic action. The continuation of research the possibility of using the NOS inhibitor in tumor therapy is rather perspective.

PRODUCTION OF IL-12P70 CORRELATES WITH RADIOIODINE-INDUCED MICRONUCLEI FREQUENCY IN PATIENTS WITH PAPILLARY THYROID CARCINOMA

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Introduction. The aim of our study was to analyze the frequency of micronuclei (MN) and the production of cytokines in patients with papillary thyroid carcinoma (PTC) before treatment with radioactive iodine 131 (131-I) and 7 days after therapy.

Methods. The study was performed in 12 patients with PCT. Micronuclei frequency in peripheral blood lymphocytes was detected by cytokinesis-block micronucleus (CBMN) assay. Cytokine levels were determined in supernatants obtained from phytohemagglutinin (PHA)-stimulated whole blood cultures *in vitro*. The concentrations of selected cytokines: interferon gamma (IFN gamma), interleukin 4 (IL-4), interleukin 5 (IL-5), interleukin 6 (IL-6), interleukin 10 (IL-10), interleukin 12 (IL-12p70), interleukin 13 (IL-13), and interleukin 17 (IL-17A) were measured using multiplex cytokine detection systems for Human Th1/Th2/Th9/Th17/Th22.

Results. The average of MN frequency before treatment with 131-I was 18.73 ± 4.45 MN / 1000 binucleated cells (BN), whereas it was 25 ± 4.97 MN / 1000 BN cells after therapy. The concentration of IL-12p70 after treatment with 131-I is positively correlated with the difference in MN frequency (MN frequency after therapy-MN frequency before therapy) (Pearson $r = 0.627$, $p = 0.029$).

Conclusion. The increase in the frequency of MNs induced by radioactive iodine treatment is correlated with the production of IL-12p70.

Key words: Cytokines, micronuclei frequency, papillary thyroid carcinoma, radioactive iodine therapy

COMBINED EFFECT OF RADIATION AND miR-21 DOWNREGULATION ON GLIOBLASTOMA CELL FATE CHANGES

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Gliomas are the most common type of primary brain tumors in humans. Grade IV of glioma tumors, glioblastoma (GBM), is one of the most aggressive and deadly forms of cancer with the median survival of 15 months despite intensive therapeutic strategies which include surgical resection combined with radiotherapy and temozolomide chemotherapy. Therefore, the identification of more effective treatment strategies for patients with GBM is required.

Literature data indicate that microRNA 21 (miR-21) is significantly elevated in GBM and in many other tumors of various origins. Recently, miR-21 has emerged as a key omnipotent player in carcinogenesis, including development of brain tumors. It is recognized as an indicator of glioma prognosis and a prosperous target for anti-tumor therapy. One of the targets of miR-21 is *SOX2* gene which high expression is hallmark of subpopulation of cells within tumor, named glioblastoma stem cells. It has been proposed that these cells are responsible for GBM radio-resistance. Considering all these findings, our aims were to analyze whether miR-21 downregulation could sensitize glioblastoma cells to standard irradiation treatment and to analyze *SOX2* expression after downregulation of miR-21 in irradiated and non-irradiated U87 and U251 glioblastoma cell lines.

We have demonstrated that downregulation of miR-21 in U87 and U251 cell lines leads to cell death, senescence and inhibition of cell growth. The effect on cell growth was more pronounced when cells with miR-21 knockdown were irradiated, while there was no additional effect on senescence following irradiation. Furthermore, we revealed that *SOX2* gene expression is altered after irradiation of U87 and U251 cells. However, we did not detected changes in *SOX2* expression after downregulation of miR-21 expression in these cells, as well as after irradiation of U87 and U251 glioblastoma cells with downregulation of miR-21 expression.

Our results indicate that downregulation of a single oncomir, miR-21, in combination with radiation, represents a potent mechanism to target glioblastoma cells. Additionally, obtained data imply that detected effects are not mediated thorough the changes of *SOX2* expression. Further investigations are needed to delineate molecular mechanism by which combination of downregulation of miR-21 expression and irradiation determinate glioblastoma cell fate.

Environmental Chemistry

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MECHANISM OF As(III) PHOTOOXIDATION BY Fe(III) IONS AND HUMIC SUBSTANCES IN AQUEOUS SOLUTIONS

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The rising interest in arsenic chemistry in environment is caused by the toxicity and in some cases the carcinogenicity of arsenic-containing compounds. It is well known that As(III) is the most toxic arsenic species, therefore the processes of its oxidative transformation into As(V) are of a great interest. Photochemical oxidation of arsenite to arsenate plays an important role in transformation of arsenic compounds in aqueous systems. The process can be considerably accelerated by the presence of Fe(III) complexes and iron-containing clays. The formation of mixed As(V)-Fe(III)-FA(HA) complexes (where HA and FA are humic and fulvic acids, respectively) leading to the change of mobility, bioavailability, solubility and photochemical properties of arsenic-containing compounds is also possible.

This report discuss the recent findings concerning mechanistic aspects of As(III) photooxidation in the presence of Fe(III) ions and humic substances by combination of steady-state (l_{ex} = 282, 308 nm) and flash (l_{ex} = 266, 355 nm) photolysis methods with ICP-AES, ICP-AES-HG and HPLC techniques.

Photooxidation of As(III) in the presence of Fe(III) ions in acidic media was investigated in wide range of As(III) concentration. At low arsenite concentration (< 50 ppm), As(III) is oxidized by $^{\bullet}OH$ radical generated via photolysis of the $FeOH^{2+}$ complex with high quantum yield of As(V) formation (f^{308nm} = 0.1). At higher arsenite concentrations (> 500 ppm), the formation of photoactive Fe(III)-As(III) complexes occurs (f^{308} = 0.012). As(III) in solution undergoes oxidation to As(IV) through the LMCT mechanism and then to As(V) mainly by the action of dissolved oxygen with formation of white $FeAsO_4$ colloids as final photoproduct. At all arsenite concentrations, As(IV) species were detected for first time by laser flash photolysis (LFP) and their spectral and kinetic properties were determined. Solid Fe(III)–As(III) complexes are also prepared and characterized, and the photochemical transformation of As(III) to As(V) in solid Fe(III)–As(III) complexes is confirmed.

Photooxidation of As(III) by humic substances (FA H108498) was also studied. It was observed that quantum yield of As(V) formation upon 282 nm excitation is independent on pH in the range 4-8 and increase from $2*10^{-3}$to $8*10^{-3}$ with increase of As(III) concentration from 5 to 125 ppm. LFP and time-resolved luminescence techniques allows to detect two main intermediates which are responsible for photooxidation – the FA triplet state (^{3}FA) and singlet oxygen formed in quenching of ^{3}FA by dissolved oxygen. Taking into consideration FA commercial availability, this photooxidation approach seems to be perspective enough.

All aforesaid findings are important to understand the evolution of As(III) species in environmental conditions and for detoxification of As(III)-polluted water systems.

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RADIOECOLOGICAL ASSESSMENT OF THE TITANITE SULPHURIC ACID TECHNOLOGY

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The titanite mineral is incorporated in apatite-nepheline ores abundant on the Kola Peninsula. Apart from the main mineral titanite (about 90%), the concentrate obtained from the ore contains impurities of feldspar, nepheline, egirine, and perovskite minerals. The titanite concentrate also includes natural radionuclides U-238 and Th-232 partly due to isomorphic substitution of titanium (in particular, for thorium), and the perovskite impurity.

In view of envisaged processing of titanite for marketable products, it was of interest to examine the natural nuclides distribution at the main stages of the sulphuric acid process.

All the technological samples, including the feed titanite concentrate, contain natural radionuclides of U-238 и Th-232 and also K-40. No technogenic radionuclides were found.

The average values of the effective specific activity of feed titanite concentrate were 695 ± 25 Bq/kg. The material is referred to class I materials with high radionuclide concentrations (A_{eff} < 740 Bq/kg). When titanite interacts with sulphuric acid, a part of the radioactivity (up to 38%) is lost with radon and thoron. The radioactive equilibrium in the radium-radon series in by-products and target products reestablishes in about 30 days.

The average values of the effective specific activity of the target product – the titanium salt titanyl sulphate monohydrate $TiOSO_4 \cdot H_2O$ (TSM) is 125 ± 25 Bq/kg. This product belongs to class I materials (A_{eff} < 370 Bq/kg) and can be used in manufacture of building materials (such as pigment titanium dioxide) without radiation restrictions. The average values of effective specific activity of the technology's by-product (calcium-silicate aggregate) are 340 ± 30 Bq/kg and it can be used in manufacture of building and technical materials. The liquid sulphuric acid solutions are also radiation-safe and can be handled freely in a repeated technological cycle.

REMOVING CESIUM AND STRONTIUM FROM HAZARDOUS WASTEWATER BY ELECTROCOAGULATION

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Cesium and Strontium are byproducts of fission of nuclear fuel in nuclear reactors of Nuclear Power Plants. They are normally inside the fuel rods and do not pose an environmental hazard. But in case of an accident cooling water may come into contact with fuel rods and thus these radionuclides can reach into the environment.

They are known a variety of methods for removing strontium and cesium from the waters, for example: ionic exchange, adsorption or precipitation-coagulation, but all these methods have the disadvantage of generating large amounts of hazardous sludge or materials, difficult to be managed.

Electrocoagulation is a physico-chemical method of removing pollutants from wastewater using soluble anode made from aluminum or iron. Because of the use of electricity for obtaining the coagulation agent, electrocoagulation is a method that can be applied in autonomous systems base on solar energy which are need a minimal involving of human intervention, suitable for cleaning of hazardous wastewater occurring during nuclear reactor accidents.

This paperwork is a study of possibility to use the electrocoagulation for removing cesium and strontium from aqueous solution.

We will study the influence of different electrodes (aluminium and iron), electrolites (NaCl, Na_2SO_4) and electrocoagulation time in efficiency of removing of these radionuclides from hazardous waters occurring during nuclear reactors accidents.

Key words: Cesium, strontium, hazardous waters, electrocoagulation, iron, aluminium

THE APPLICATION OF NEUTRON-ACTIVATED SILVER NANOPARTICLES IN THE STUDIES OF NANOSILVER BIOACCUMULATION BY MYCELIA OF MACROFUNGI: PLEUROTUS ERYNGII AND TRAMETES VERSICOLOR

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Nanotechnology is a dynamically developing field of scientific and industrial interest across the entire world. It is estimated that, of all the nanoparticles in consumer products, silver nanoparticle (Ag NP) applications currently have one of the highest degrees of commercialization. Consequently, new potentially toxic products in the form of manufactured nanoparticles have appeared on the market. Concern stemming from the subsequent release of engineered NPs into the environment and their potential adverse effects on ecosystem as well as human health has increased. One promising method to prevent the ecotoxicity of nanoparticles is their efficient removal. A very promising alternative to chemical techniques is the application of living organisms for the accumulation (bioaccumulation) of contaminants. For the efficient removal of Ag NPs and consequently to prevent the ecotoxicity of nanoparticles fungi can be successfully applied (mycoextraction).

The main goal of the studies was an investigation of the bioaccumulation of silver nanoparticles by mycelia of edible fungi: *Pleurotus eryngii* and *Trametes versicolor*. The ability of biotechnological cultures of mycelia to efficiently remove NPs from contaminated environments was examined. For the studies neutron-activated silver nanoparticles were applied. For bioaccumulation studies, mycelia of selected macrofungi species were cultivated on liquid medium contaminated with silver nanoparticles at concentration 0 – 0.2 g/L. For determination of bioaccumulation or biosorption, quantitative analysis of accumulated or absorbed nanoparticles was performed using gamma spectrometry (^{110m}Ag, 884 keV).

The results have shown that mycelia of *Pleurotus eryngii* and *Trametes versicolor* are tolerant to the applied nanosilver concentrations and accumulate silver nanoparticles. They provide the basis for further studies into biotechnological applications of mycoextraction in nanoparticle removal from different contaminated aquatic matrixes. Finally, it was confirmed that the applied study strategy, including neutron activation of nanoparticles, is very useful technique for tracing the uptake and accumulation of NPs in organisms.

Acknowledgment. The study was supported by the Ministry of Science and Higher Education through the Faculty of Biology, University of Warsaw intramural grant DSM 2016.

MAJOR AND TRACE ELEMENTS IN SOILS AROUND IRON AND STEEL INDUSTRY FACILITIES

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Determination of elemental content in soil samples collected in the vicinity of a ferrous metallurgical enterprise was conducted in order to assess whether the potential high content of certain metals is due to anthropogenic impact on the study area, or their occurrence in soil is due to the geological peculiarities.

The soil samples were collected at sites located in the industrial area of the iron–steel plant of Galati, Romania, one of the most powerful metallurgical complexes in the South-Eastern Europe. Soil samples were randomly taken from the surface layer (0–5 cm) in each location in 20 x 20 m plots as 5–8 subsamples, which were mixed to form a composite sample. The samples have been analyzed by epithermal neutron activation analysis (ENAA) at the reactor IBR-2 of the Frank Laboratory of Neutron Physics, Joint Institute of Nuclear Research in Dubna, Russia. A total of 39 elements were determined: Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Co, Zn, As, Br, Rb, Sr, Zr, Mo, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Dy, Tm, Yb, Hf, Ta, W, Au, Hg, Th, and U.

Factor analysis revealed light and heavy crust component along with factors which elements are inherent to activity of iron and steel enterprises) (coking plant, sinter plant, blast furnaces, slag dump). The results obtained are discussed in relation with legislated permissible levels.

ENAA results for some trace elements in industrially contaminated soils are compared with those obtained by energy-dispersive X-ray fluorescence and atomic absorption spectrometry at “Dunarea de Jos” University of Galati, Romania.

MERCURY IN HIGHLY CONTAMINATED SOILS FROM A DERELICT CHLOR-ALKALI PLANT

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Mercury cell chlor-alkali plants use liquid mercury as a cathode in electrolytic cells to produce chlorine, sodium hydroxide and hydrogen by electrolysis of brine solution. The Hg emissions from these plants and contamination of surrounding soils, vegetation and aquatic ecosystems have been widely investigated in the last two decades, besides the human health impact. The Hg level in demolition materials and hazardous wastes resulted from decommissioning of chlor-alkali plants, in particular soil, was not sufficiently investigated.

In this paper the determination of mercury content in soil samples collected inside of a chlor-alkali plant in Craiova, Romania, whose process ceased in 2010, was carried out using energy-dispersive X-ray fluorescence (ED-XRF) in order to assess the anthropogenic impact on the study area and take appropriate decontamination measures.

Due to the advanced degrading state of the unit, high amounts of elementary mercury and mercury salts have been infiltrated into soil on which it was placed. The contaminated soil samples have been analyzed by employing an X-MET 5000 spectrometer at SETCAR company Braila, Romania. The Hg concentrations in investigated soils ranged in the interval 10.624 – 12.627 mg/kg, values which are comparable with the results reported in similar studies in other countries, but extremely high compared with the legislated levels. Besides Hg, the following elements were determined in soils: K, Ca, Ba, Rb, As, Zn, Cd, Th, Fe, Pb, Cr, Sn, Sb, Cu, Ti, Mn and Zr.

ED-XRF results for mercury and selected chemical elements in polluted soils from the former chlor-alkali plant are compared with those obtained by atomic absorption spectrometry at “Dunarea de Jos” University of Galati, Romania.

HYDRODYNAMIC CAVITATION-ASSISTED FORMATION OF OH-RADICALS IN AQUEOUS SOLUTION

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Hydrodynamic cavitation is an effective method for OH-radicals formation in the aqueous solutions (1,2). A novel hydrodynamic cavitator, Ventures type, has been constructed. The main technical characteristics of the cavitator have been determined: a) cavitation number as a pressure function, b) maximal bubble radius, c) maximal temperature and pressure in the bubble, d) bubble concentration and e) its energetically effectiveness. The effects of the cavitation number (KN), the temperature of the aqueous solution and the time of hydrodynamic treatment on the concentration of the formed OH-radicals were investigated. The concentration of the formed radicals has been measured by the method of iodode-iodate chemical dosimeter. Based on the results obtained it was found that a) the maximal concentration of the formed OH-radicals was achieved under the KN =0.08 at T=25^{o}C and t=10 min, b) concentration of the OH-radicals linearly increase with the duration of the hydrodynamic treatment until to t=10min, c) the increase in the temperature of the aqueous solutions leads to the decrease in the concentrations of the formed OH radicals and d) energetically effectiveness of the OH-radicals formation assisted with the hydrodynamic cavitation is as much as 10 times higher than the ultrasonically assisted one. The mechanism and kinetics of formation OH-radicals in the aqueous solutions assisted with the hydrodynamic cavitation was discussed.

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Cr(VI) REMOVAL CAPACITY OF RHAMNOLIPIDS PRODUCED BY PSEUDOMONAS AERUGINOSA NCAIM(P), B001380

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Pseudomonas aeruginosa NCAIM(P), B001380 was isolated from mineral cutting oil used as metal working fluid in the metal industry. Such extreme conditions indicate that this bacterial strain should be chromium tolerant and a producer of biosurfactant rhamnolipid (RL) with potential application in heavy metal bioremediation. Rhamnolipids (RLs) are small secondary metabolites produced by *Pseudomonas* with potential advantages such as biodegradability, less toxicity and higher selectivity to complex heavy metal ions. So, special attention is paid to the use of rhamnoplipid biosurfactants in different aspects of environmental biotechnology. Some reported data showed that rhamnolipid biosurfactant produced by *Pseudomonas aeruginosa* was used in remediation of metals from multi-metal contaminated soil confirming selectively removal of metals in the order of Cd = Cr > Pb = Cu > Ni.

High toxicity of Cr(VI) for humans and microorganisms arises from high solubility, rapid transport through the biological membranes and complexation with intracellular polymers such as proteins and nucleic acids. Some microorganisms, however, can tolerate Cr(VI) using several distinct strategies: plasmid mediated efflux system, absorbing heavy metals to their cell wall, by precipitation (including reductive precipitation) in the form of insoluble salts and binding metal ions to biological complexing agents such as exopolymers and biosurfactants. Therefore, the goal of this work was study the influence of its naturally produced rhamnolipids on Cr(VI) removal capacity with aim to provide potential application of the strain and its biosurfactants in bioremediation. Effect of two sublethal concentrations of Cr(VI) ion (50 mg/L and 100 mg/L) on growth and production of RL by *Pseudomonas aeruginosa* NCAIM(P), B001380 was investigated. Cr(VI) was shown to slightly inhibit RL production, but the maximum of RL production was found in the late-stationary phase at 72h for both Cr(VI)-amended cultures: 236 mg/L for 50 mg/L of Cr(VI) and 160 mg/L for 100 mg/L of Cr(VI), as well as the maximum of Cr(VI) removal capacity: 70 % and 57 % .

APPLICATION OF SPECTROSCOPIC METHODS IN STUDIES OF RHAMNOLIPID-Cr(VI) COMPLEX FORMATION AND INFLUENCE OF CR(VI) ON RHAMNOLIPID CONGENER DISTRIBUTION PRODUCED BY PSEUDOMONAS AERUGINOSA NCAIM(P), B001380

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The bacterial strain *Pseudomonas* has potential to metabolize chemical pollutants in the environment and a great application in bioremediation of heavy metal pollutants and numerous toxic organic compounds. *Pseudomonas* produces and excretes secondary metabolite rhamnolipid (RL), a natural biosurfactant that can show a high binding capacity and selectivity to complex heavy metal ions. Rhamnolipids belong to low-molecular mass biosurfactants and based on their chemical composition, the principal rhamnolipids are mono-rhamno-di-lipidic congeners (RL1) and di-rhamno-di-lipidic congeners (RL2). While complexation of RL with heavy metals initiated numerous investigations of the potential application of RL as environmentally compatible soil washing agents, a little is known about structural details of RL-heavy metals complexes. Previous reported data on *P. aeruginosa* also showed a significant increase in the ratio of dirhamnolipids (RL2) to monorhamnolipids (RL1) congeners produced by cultures grown in the presence of toxic metal ion Cd^{2+}. Therefore, the goal of this study was to find some structural proofs of RL-Cr(VI) complex formation, as well as to study influence of Cr(VI) metal ion *on* rhamnolipids congeners distribution using different spectroscopic methods. RL preparations obtained by *P. aeruginosa* NCAIM(P), B001380 without (control) and with Cr(VI) (100 mg L^{-1}) were analyzed by FTIR, EI/MS and NMR spectroscopy. Structural proof for RL-Cr(VI) interaction was pioneer proven by FTIR spectra that might have a pronounced importance on chromium bioremediation. An increase in a RL2/RL1 ratio of 1.11 for RL preparation with Cr(VI) compared to control (0.56) observed by ESI/MS is also in agreement that presence of Cr(VI) may influence the rhamnolipid congeners produced by *Pseudomonas* which in turn would impact metal bioavailability.

A STUDY OF LEAD CONTAMINATION IN THE URBAN SOIL OF NOVI SAD

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Soil is contaminated by lead from various anthropogenic sources. The present study is focused on investigation of lead soil pollution in the central part of the city of Novi Sad. The economic mismanagement in the last decades lead to decay or demise of once large industrial combines. One of the biggest industrial combines in the city is the oil refinery, located 3 km northeast of the city center along with the thermal power plant. It is considered that the main pollution sources in the studied area may be traffic, oil refining and combusting for home heating in some parts of the city.

Over a hundred of topsoil samples (0 – 10 cm depth) were collected near busy and less busy crossroads. The studied area (4 x 5 km^2) was divided using a square grid of 400 m x 400 m. The samples were taken in each of these squares. The soil samples were air-dried at room temperature and milled to a particle size of < 2 mm. The samples were analyzed for "pseudo-total" lead content after digesting the soil in concentrated HNO_3 and $H_2O_2$and for available Pb content after extraction with 0.05 mol/l EDTA (pH = 7.00).

The mean concentration of Pb (82.3 mg/kg) was very close to the limit value according to the Serbian i.e. Dutch quality standard values (85 mg/kg). The median was significantly lower than the mean value, which was consistent with the high skewness, showing there were some very high values (outliers). The application of the Shapiro–Wilk test ($p > 0.05$) confirmed that the original data set for Pb was not normally distributed. The available Pb concentrations showed a large variability from site to site, and the relative standard deviation value (2.24) exceeded those for pseudo-total lead content (1.35).

Variations in Pb pseudo-total content demonstrated patterns very similar to those of the most heavily contaminated areas appearing in the vicinity of major roads. As it can be seen on the distribution map, in the soils near busy roads higher Pb concentration were measured. Interestingly, there was one hot-spot of very high Pb level (999 mg/kg) in the south-eastern part of the city, at the site close to the less busy road. It was identified that the source of pollution was a small lead accumulator plant located about fifty meters from that sampling location.

CONCENTRATION OF As, Co, Cr AND Ni IN URBAN SOIL IN NOVI SAD, SERBIA

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The objective of the study was to determine pseudo-total content of As, Co, Cr and Ni in urban soil in Novi Sad and to perform statistical analysis in order to distinguish pollution sources. Soil samples (0 - 10 cm depth) were taken across the central part of the city covering a surface area of 20 km^2. Soil chemical properties were obtained following a standard procedure and soil mechanical properties were determined in the < 2 mm fraction by the internationally recognized pipette method. The soils of the study area show a sandy texture. Pseudo-total concentrations of As, Co, Cr and Ni were measured using the inductively coupled plasma - atomic emission spectrometry. Contour maps of spatial distribution of the investigated metals were obtained using ordinary kriging interpolation method.

The metals, in descending order of mean concentrations were Ni, Cr, Co and As. The largest mean value was obtained for Ni (28.7 mg/kg) and Cr (28 mg/kg). For Co and As the mean concentrations were 7.3 and 6.5 mg/kg, respectively. The means and the medians were almost the same for all examined metals showing that no high values (outliers) were identified in the dataset. In comparison with the background values in the region represented by the unpolluted agricultural soils, minimal enrichment is found for Co and Cr for all samples. A moderate enrichment is observed for 80 % of samples for As and 40 % of Ni. The concentrations of As and Cr for all soil samples were under the limit values (< 29 and < 100 mg/kg, respectively). For Co and Ni, only 10 % of the data slightly exceeded the limit values. On the maps of the metals distribution in the soil, there were no hot-spots and it could not be noticed dependence of the metal concentrations on the distance of the roads. The fact previously mentioned and a relatively low concentrations and low values of standard deviations, suggest a major natural origin of the metals from parent material (sandy alluvial deposit).

ANALYSIS OF AEROSOLS IN INDOOR WORKING ENVIRONMENT BY X-RAY FLUORESCENCE TECHNIQUE (XRF)

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In this study fine particulate matter ($PM_{2.5}$) was collected inside the metal workshop located in the suburb of the city of Rijeka, Croatia. High intensity of welding and plasma cutting is characteristic for this metal workshop and therefore high levels of very fine metal aerosols were expected. Fine aerosol sampling on thin Teflon filters and subsequent XRF elemental analysis was performed. Sampling in the workshop was conducted in two sampling periods in May and November 2016. In total, 64 samples were collected, out of which 28 were 12h-samples and 36 were hourly samples. Additionally, Trotec Optical Particle Counter PC220 was used to measure concentrations for 6 different optical sizes (0.3 µm, 0.5 µm, 1 µm, 2.5 µm, 5 µm and 10 µm) to obtain particle size distribution.

Sample analysis was carried out with X-Ray Fluorescence technique at the Laboratory for Elemental Microanalysis at the Department of Physics, University of Rijeka. Heavy metals such as Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn and Pb were detected. As expected, diurnal variations of metal concentrations are found to be well correlated with the work intensity in the workshop. The results were compared to the average daily concentrations measured in the city centre. Concentrations of all metals measured in this study were significantly higher than the corresponding average daily concentrations in the city centre. The highest indoor-outdoor ratio was obtained for Fe and Mn. Results of cluster analysis are found to be good indicators of welding and plasma cutting materials. Particle size distribution shows that sub-micron particles are present in much higher concentrations than coarse particles indicating the harmfulness of welding products.

ELEMENTAL ANALYSIS OF SEDIMENT SPECIMENS BY WAVELENGTH DISPERSIVE X-RAY SPECTROSCOPY (WDXRF) IN GULF OF IZMIR (EASTERN AEGEAN SEA, TURKEY)

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The distribution of selected toxic heavy metals, involving some radioactive isotopes and non-essential metals were determined in marine sediments in the region affected by population density, shipping and industrial activities. The drilling specimens were collected from differing depths of 1.00-14.00 m at four variant locations of Karsiyaka, Bayrakli, Inciralti and Cesmealti (Urla) in the Gulf of Izmir were investigated by considering geochemical and sedimentological properties. The elements detected in major quantities As, Br, Ce, Co, Cr, I, La, Nb, Pb, Sb, Sn, Th, U, Zn, and Zr while Ba, Cu, Ga, Mn, Ni, Rb, Sc, Sr, V, and Y identified in trace quantities. The presences of the potential pollutant sources and their impact on the environment were considered. In this study, Wavelength dispersive X-ray spectroscopy (WDXRF) with the pressed pellets method is used to find out the abundance of the dominant elements. The method offers a precise, rapid screening and high analytical accuracy results for elemental tested. Scanning electron microscopy (SEM) was also applied to provide more data on the parameters of the sediments. Based on the obtained results, Bayrakli and Karsiyaka regions are more impacted with the pollutions than Inciralti and Cesmealti locations.

Key words: Gulf of İzmir, heavy metals, sediment, SEM, WDXRF

Medical Devices

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GAMMA-RAY DETECTION SYSTEM FOR RADIOCARDIOGRAPHY

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First devices for nuclear medicine *in vivo* were gamma-ray detection systems with one or more detectors. They were based on scintillation counters with big vacuum photomultipliers. These systems had disadvantages such as big size and impossibility of real-time data processing. In 80-90s gamma camera was invented. Main disadvantages of gamma camera were restricted view field (about 50 × 50 cm^2) and a stationary location.

Evolution of microelectronics in the end of 20th century led to the creation of scintillation counters based on miniaturized silicon photomultipliers (SiPM). This devices have similar to vacuum photomultipliers gain (~ 10^6), less weight and size characteristics. In consequence of this, creation of compact multi-detector medical radiometric systems (MRS) appeared. This system can be used to survey non-transportable patients and to conduct more precise functional state diagnostics of organs in patient body. This study includes two components. The first one is the individual selection of collimating system parameters, considering patient's anatomical features. The second one is based on choosing of gamma-detector optimal orientation on the body to provide minimal errors due to hitting radiation from the nearby tissues.

One of the MRS possible applications is a radiocardiography (RCG), i.e. the heart research made by administering a radiotracer and subsequent monitoring of the dynamics of its passage through the heart chambers. In contrast with gamma camera, detectors of MRS can be positioned in arbitrary manner and located in different planes to each other.

The aim of this work is development of heart RCG study methods based on MRS. This technology can be useful to make diagnosis of various diseases. It involves analysis and subsequent modeling of heart in order to optimize parameters of the MRS collimation system and locations of detectors on the patient's body. During the research work MRS and gamma camera (MB 9100, Hungary) were used.

Both MRS and gamma camera can analyze the passage of the radiotracer through the heart chambers, large blood vessels and lungs, using digital data processing systems. As a result, it was shown that in the first radiotracer bolus pass, the following parameters determined:

1. parameters of central hemodynamic, including the ejection fraction of the left and right ventricles;
2. presence of intracardiac shunts from left to right;
3. state cavities of large vessels and chambers of the heart;
4. mobility of left ventricular wall.

On the basis of the received data, model of the radiotracer's passage in the heart chambers was developed. The next point's of research work were collimating system for MRS and justified position of gamma-detectors on the patient's body at the time of the survey. Also medical justification of measurements shows.

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Medical Imaging

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COLUMNAR RECOMBINATION IN X-RAY DETECTORS BASED ON a-Se

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Although amorphous selenium (a-Se) is the first known photoconductor with long and successful history of application in optical and x-ray imaging, some of its fundamental properties are still puzzling. The examples are mechanisms of x-ray photogeneration and recombination of electron-hole pairs in this material. The key quantity characterizing the charge carrier generation is the electron-hole pair creation energy (W_{ehp}), the quantity that describes the amount of energy needed to produce a collectable electron-hole pair upon the absorption of an x-ray photon. Although this parameter in a-Se was extensively investigated, its electric field and temperature dependences are not yet understood. In particular, the origin of recombination which governs W_{ehp} remains unclear.

It has been proven in several studies that recombination in a-Se under the x-ray generation is neither geminate, nor the bulk Langevin recombination, in which the recombination rate is limited by the slow motion of charge carriers. The columnar recombination has been instead suggested as dominant recombination mechanism for the x-ray generated carriers in a-Se [1].

Using the combination of x-ray photocurrent and pulse height spectroscopy measurements we measure W_{ehp} in a wide range of temperatures (218 – 320 K) and electric fields (10 – 100 V/μm) and show that the conventional columnar recombination model which assumes Langevin type of recombination within a column (a primary electron track) fails to explain experimental results in a wide range of electric fields and temperatures. The reason for the failure of the conventional models is revealed in this work and the theory of the columnar recombination is modified in order to account for the experimental results in the entire range of electric fields and temperatures [2]. Recombination appears columnar, though with bulk Langevin mode inside the columns only at low electric fields, while it is columnar with encounter-event-limited mode at high electric fields, when carrier mobility increases and carrier movement does not limit recombination anymore [2].

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DEVELOPMENT AND IMPLEMENTATION OF AN ALGORITHM FOR SEGMENTATION OF IRREGULAR LESIONS IN DIGITAL BREAST TOMOSYNTHESIS AND CT IMAGES

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Currently implemented EU project at the Technical University of Varna aims on creating computational models of breast lesions with irregular shapes. Along this, an algorithm for segmentation of images from Digital Breast Tomosynthesis (DBT) and Computed Tomography (CT) was developed, implemented and evaluated.

The developed algorithm includes six steps: (a) normalization of the image values; (b) filtering for reduction of the noise in reconstructed slices; (c) binarization of the area of the lesion, (d) applying of morphological operations to decrease the level of the artefacts; (e) applying a region growing technique to segment the lesion; and (f) concluding a final three-dimensional (3D) lesion model. The algorithm is semi-automatic as the initial selection of the region of the lesion and the seeds for the region growing are done interactively. Anonymized patient images obtained with Giotto Tomo and breast cadaver images, obtained with Siemens Somatom Definition CT system, were used to evaluate the algorithm.

Twenty-three different 3D models of lesions with irregular shapes were created. They were subjectively evaluated by experienced radiologists by comparing original and segmented slices and 3D lesion shapes. The evaluation showed satisfactory delineation of the lesions.

The proposed algorithm will facilitate the processing of more tomosynthesis images in further lesion modelling. An acceptable number of cancer shapes need to be collected and analyzed to develop a mathematical framework for automatic generation of computational breast cancer models for use in virtual breast imaging, e.g. phase contrast breast tomosynthesis.

RELATIONSHIP BETWEEN IMPAIRMENTS OF FEF$_{50\%}$ AND LUNG EMPHYSEMA AMONG WORKERS EXPOSED TO MINERAL DUSTS

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The aim of the study was to analyze the relationship between the decrease of FEF$_{50\%}$ - from one side, and radiologically verified compensatory lung emphysema among workers, exposed to mineral dust at the work place - from other.

Materials and methods. A case control study among 480 quartz exposed underground miners, 120 asbestos exposed workers, and 121 individuals without dust exposure was performed. The average age of examined workers was 42.82 years, and the average duration of the dust exposure was 14.01 years. A clinical examination, as well as a chest radiography (by ILO'80), and spyrometry of all persons were done. We have used SPSS software and one-way ANOVA.

Results and discussion. There was a significant decrease of the mean of FEF$_{50\%}$ in cases with lung emphysema, accounted on the chest radiography (by ILO'80). We assume that the compensatory emphysema and reduction of FEF$_{50\%}$ is associated with the formation of initial interstitial pulmonary fibrosis among workers exposed to mineral dust over a long period and in patients with pneumoconiosis.

Conclusions. 1. The decrease of FEF$_{50\%}$ is related to radiologically-established compensatory lung emphysema. 2. The investigation of FEF$_{50\%}$, combined with chest X-ray, is appropriate for periodical preventive medical check ups and assessment of health status for workers exposed to mineral dust.

Key words: Mineral dust exposure, chest radiography, emphysema, FEF $_{50\%}$.

RAD2017

MAGNETIC FIELD GRADIENTS AND THEIR EFFECTS ON THE DIFFUSION TENSOR DERIVATE MEASURES

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Diffusion tensor imaging (DTI) and the degree of diffusion weighting of the sequence, expressed as the b-factor, are useful to investigate the effect of the magnetic field gradients on the integrity of white matter in patients with temporal intracerebral hemorrhage. The healthy patients are the gold standard. The present study investigated the changes of mean diffusivity (MD) and fractional anisotropy (FA) in a brain hemisphere approach to understand the effect of magnetic field gradients on the brain hemorrhage investigation. The artifacts induced by diffusion gradients in diffusion tensor imaging affect the accuracy of the investigation, and in order to achieve the optimal image quality, strong magnetic field gradients are recommended. The artifact effect of higher magnetic field gradients is analyzed by means of the root-mean-square FA and MD difference between left and right brain hemispheres.

DETECTOR SHIFT METHOD TO FURTHER INCREASE SPATIAL RESOLUTION AT A PHOTON-COUNTING DETECTOR UNDER CHARGE SHARING

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The photon-counting detector has been developed during the past tow decades ago on the basis of its many advantages, including high X-ray efficiency and low dose image. To increase spatial resolution of images, the pixel pitch should be reduced. However, it requires new ASIC design and the reduced detector increases the quantum noise because of reduced area. Furthermore, charge sharing degrades achievable image quality form the reduced pixel pitch. Because the charge cloud generated by a single X-ray photon in a photoconductor can induce multiple counts in not only a dedicated pixel but also adjacent pixels at the ASIC. The influenced area by charge sharing at adjacent pixels dramatically increases as pixel pitch decreases. Thus, a further reduction of pixel pitch to increase spatial resolution is limited now because of charge sharing. In this work, we proposed a detector shift method (DSM) and applied DSM to the Medipix2, which are bump-bonded to 1mm thick CdTe with a pixel pitch of 55 um, for improvement of the spatial resolution without reducing the pixel pitch. To confirm the improvement of spatial resolution and noise performance, the MTF and DQE value were calculated from X-ray image using a line pair phantom and edge phantom. In addition, 2-, 3-, 4-, and 5-move DSM, which shift toward x-axis and y-axis with sub-pixel scale was taken to find the optimum shift value. The MTF value increased from 7 lp/mm to 10 lp/mm at a 0.3 MTF value by applying the 2-move DSM at the same X-ray flux and a 55 um pixel pitch detector. However, the MTF values are saturated from 3-move DSM due to charge sharing. The DQE shows a dramatic increase because of low quantum noise compared to the half-pixel detector. This study gives an alternative method to achieve high spatial resolution without a photon-counting detector redesign under charge sharing.

MONTE CARLO STUDY OF PARTICLE PACKING EFFECTS OF POWDER PHOSPHORS FOR MEDICAL IMAGING PURPOSES

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This manuscript provides a computational examination of the particle packing effects on the optical emission performance of phosphor materials employed in medical imaging. The model was based on the combination of Mie scattering theory and Monte Carlo techniques. Several conventional powder phosphors have been used during the last decades in medical imaging, however, the incorporation of a phosphor material of improved imaging capabilities requires further investigation. One of the parameters requiring further assessment is the so-called packing density, which describes the particle packing within the phosphor layer. The present study was carried out assuming packing density from 20 % up to 80 % embedded within a phosphor layer (100 μm and 200 μm). The optical emission performance was assessed through the amount and distribution of light considering grain sizes, 100 nm and 500 nm. Results showed the relation of light extinction coefficient with packing density, and, in particular, the highest variations occurred for particle size 500 nm. Finally, comparing phosphor layers with different grain size and packing density (e.g., 500 nm, 40 % - 100 nm 80 %) the most important outcome was that both cases exhibited almost identical distribution, however, the latter one showed lower optical loss.

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CREATION OF SYNTHETIC MICROSCOPIC IMAGES FOR EVALUATION OF COMPUTER AIDED DIAGNOSTIC HISTOPATHOLOGY SYSTEMS

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Introduction: Reviewing biopsy samples with the microscope is a very complex process, which may promote diagnostic misleads in traditional histopathology (McKenney et al. 2011, Lesna 1998). Computer-aided diagnostic (CAD) histopathology systems have been shown to assist expert physicians towards more accurate and reliable diagnostic decisions by providing second opinion consultations (Mosquera-Lopez 2015, Diaz et al. 2014). One of the most important steps in such systems is the segmentation stage, which aims in identifying the regions of interest (usually nuclei or cells). Many different segmentation schemes have been presented in literature (Irshad et al. 2014) with promising results; however, due to the absence of any quantitative gold standard (i.e. microscopic phantom), the evaluation and/or comparison of these segmentation algorithms is difficult to be performed. The aim of this study is to propose a mathematical model based on texture synthesis for creation of synthetic nuclei images, to be used as a quantitative gold standard for the evaluation of segmentation algorithms used by CAD histopathology systems. To the best of our knowledge, an attempt to create synthetic nuclei images is for the first time investigated.

Material and Methods: Clinical material comprised 50 tissue biopsy samples of brain cancer cases (patients) that were collected from the University Hospital of Patras, Greece. Each sample was stained with Haematoxylin and Eosin for nuclei contrast enhancement and was placed on a glass slide for observation under the microscope. Images were digitized from each case (slide) by the most representative tumor region marker by an experienced histopathologist using a light microscopy imaging system that consisted of a Leica DM2500 microscope and a DFC420 CCD digital camera. Each digitized image was segmented into nuclei and background using a pixel-based classification algorithm and morphological filtering (Glotsos et al. 2004). In this way, a library of background regions and nuclei of different size, shape, and texture was created. Background image samples were used as input to an image quilting algorithm (Efros and Freeman 2001) that produced the synthetic background image. Nuclei segmented samples were randomly selected and placed on the synthetic background image using a wavelet based fusion approach (Zeeuw 1998).

Results and Discussion: Synthesized images showed a good resemblance with real world images according to experts' visual evaluation. Since we know the exact coordinates of the regions of interest within the synthesised images, these images could serve as a 'gold standard' for evaluation of segmentation algorithms used by CAD histopathology systems.

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AUTOMATIC PROCESSING OF TEMPOROMANDIBULAR JOINT X-RAY IMAGES USING PARAMETRIZATION TECHNIQUE

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Introduction. Sensitive and objective methods of X-ray image evaluation shall be used to determine status of temporomandibular joint (TMJ) elements, particularly, to compare results in a series of studies. Human optical system of eye usually fails to determine changes in graphic (radiographic) information within 10 %.

Objective. To develop and introduce automatic processing of TMJ X-ray images using parametrization technique.

Material and methods. TMJ tomography. Analysis of imaging using parametrization technique in Matlab software environment.

Results. Parametrization technique for X-ray images of human TMJ structures is implemented within radiological protocols of TMJ examination (Slesarev O.V., 2013). Graphic radiographic information images (RII) of TMJ taken at different periods were compared. RII are highly sensitive to any changes in X-ray design. Raster images of TMJ obtained from X-ray patterns taken at different periods are considered as physical implementation of a certain dynamic system. We offer to consider square packing into S-square with upper and lower limits as a radiographic information image (RII). For this purpose, area of every square packed into S square without intercrossings is in line with a number of pixels corresponding to certain black and white chart color gradation on TMJ X-ray pattern. We had an opportunity to analyze radiographic and anatomic information previously undiagnosable by an examiner.

Conclusions. Automatic processing of X-ray images using parametrization technique excludes influence on subjective color perception of undertones by an examiner, improves analysis significance and yields economic and social effects.

LOW RADIATION AND CONTRAST MEDIUM DOSE IN 64 MULTIDETECTOR CT ANGIOGRAPHY OF THORACIC AORTA

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Objective: The evaluation of chronic aortic diseases, many protocols of low radiation dose and low medium iodined contrast dose are performed. The main aim of this study is to give a preliminary evaluation of dose reduction and iodined dose reduction.

Materials and methods: In our Hospital from February 2013 to November 2016 we selected 150 patients divided into two groups: 60 for our study and group of control of 90 cases.

All CT examinations were performed with a 64-MDCT scan. (Optima-CT GE Healthcare) Tube voltage was reduced in our study (80 kVp versus 120 in our standard) with automated current modulation system in both groups.

Concerning the iodined dose reduction, in the study groups it is strongly reduced (40 cc of 370 mg/ml versus 90 cc of 370 mg/ml): a mechanical power injector was used to administer contrast material via catheters (20-gauge) placed in antecubital vein at a flow rate of 4-5 ml/sec

Two radiologists qualitatively graded image quality of all cases defining the walls and enhancement of the lumen of the aorta. On the basis of criteria reported in the literature a five point subjective scale was used to grade image quality, from excellent (1) to non diagnostic quality(5). The reasons for degraded image quality were due to high BMI and consisted especially in low signal/noise ratio and in two cases it was due to suboptimal contrast enhancement owing to poor bolus timing.

In the cases of low signal/noise ratio a smooth filter was applied to reduce the noise.

Results: The results of this study provide useful information about reduction of radation dose and medium iodined contrast. Diagnostic quality of scan performed with low dose of iodine and radiation are overlays with the scans performed with standard protocol.

Conclusion: The study groups revealed a strong reduction dose in terms of DLP and quality of images was similar to the group of control.

RECONSTRUCTION OF MAXENT IMAGES FROM PET CAMERA

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We study here one of the imaging technique, used in nuclear medicine, called a Positron Emission Tomographic (PET) imaging that provides information about many biological processes that are essential to the functioning of the organ that is being visualized. Our emphasis is given to the application of the maximum entropy image reconstruction method called “Cambridge MaxEnt Package” (CMEM) for recovering images of the human brain from data obtained by PET camera

THERMAL IMAGING AS A TOOL FOR PATTERN RECOGNITION AND ANOMALY STUDIES: IDENTIFYING THE CHANGES IN THE CONDITION OF AN OBJECT OVER TIME BY SPOTTING A TREND OF CHANGING TEMPERATURES

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More than five decades have passed since the hypothesis of thermography in breast imaging was proposed. During this time, thermography has gone from a legitimate, promising technology to one relegated to the shadows outside conventional medicine. Thermal imaging in clinical trials is still controversial issue. However even those who discard the method due to insufficient reliability of data do not validate their arguments by clear understanding of the reasons behind the inaccuracy. While thermography is not well evidenced for use as a screening tool, its use as an adjunctive imaging procedure alongside mammography should be considered, particularly for those with dense breast tissue. It is certain that images captured by digital infrared thermal imaging support the effective recognition of irregular body patterns and that they can be used as indicators of any anomaly over the time period by spotting a trend of changes in the temperature. But data has to be not only interpreted accurately but also taken carefully and the effect of surrounding environment has to be kept minimal. The identified localized patterns have to be accurately assigned to a certain anomaly in order to be treated as diagnostic method, and the evaluation method as well as interpretation have to be standardized, and method replicable. Moreover, validation of protocols, equipment, and analytical techniques is needed to be placed in the context of large, randomized trials before its use can be considered truly evidence-based. Accurate interpretation of thermal data is largely dependent upon an experienced, knowledgeable operator who understands infrared theory and heat transfer concepts, basic anatomy and physiology, and infrared equipment operation and importantly, limitations too. In this paper we integrate theory behind thermal imaging, potential of thermal imaging in clinical research and general uncertainties and misinterpretations that lead to reduced accuracy of data interpretation and feasibility of the method.

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ESTABLISHING RADIOCHROMIC FILM DOSIMETRY FOR IMRT PLAN VERIFICATION IN RADIOTHERAPY

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Film dosimetry has been widely used for various applications in radiotherapy. Recently, radiochromic self-developing film has replaced the radiographic one in a filmless, digital environment at modern hospitals. Radiochromic film is routinely used in radiotherapy for testing geometric accuracy of linear accelerators. For dosimetry, it certainly finds its place at sites where it is impractical or impossible to perform water phantom measurements, like at the Leksell Gamma Knife. Radiochromic film also has advantages over other detectors in verification of complex techniques like IMRT (Intensity Modulated Radiation Therapy) and VMAT (Volumetric Modulated Arc Therapy). It has a much better resolution than electronic arrays of detectors and it can be placed in any direction and in any plane within the irradiated volume in a suitable phantom. Thus, it is possible to verify a treatment plan in a pseudo 3D manner. However, film dosimetry with radiochromic film has not been widely established worldwide as the method of choice for IMRT and VMAT verification. The reason might be the complex process of film handling and perhaps also its cost.

Our work aims to establish a proper methodology for EBT3 film dosimetry in IMRT plan verification. First, it is important to assess the characteristics of the film scanner in use and of the film itself, like homogeneity and reproducibility. It is important to understand the issues of improper film manipulation. Next, the film dosimeters must be properly calibrated taking into account the conditions under which they will be used for measurements. A protocol for film scanning must be set up depending on the characteristics of the particular scanner. Finally, a proper software for gamma analysis must be chosen and the user must well understand its performance with film dosimeters.

We show an example of such a methodology with EBT3 films, EPSON Perfection V700 Photo scanner, MATLAB and OmniPro I'mRT software. We validate the methodology on six clinical IMRT step-and-shoot plans created in the XiO treatment planning system and irradiated at a Siemens Artiste linear accelerator at the Thomayer Hospital in Prague.

We conclude that EBT3 film dosimetry performs well for IMRT plan verification when a proper methodology is used. We suggest that radiochromic film dosimetry could complement other verification methods at establishing new IMRT techniques in the clinic. Radiochromic film could reveal potentially hidden errors and it allows the physicists to check their plans in a pseudo 3D manner.

MULTILEAF COLLIMATOR PERFORMANCE AUDIT IN POLAND

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Purpose. The delivery of accurate intensity-modulated radiation therapy (IMRT) or stereotactic radiotherapy depends on a multitude of steps in the treatment delivery process. The proper intensity modulation depends on the proper functioning of a multileaf collimators (MLC). The aim of this audit was the control of the proper collimator leafs positioning.

Materials and Methods. The methodology of the audit of small field output performance was established within the framework of the CRP E2.40.16 project "Development of Quality Audits for Radiotherapy Dosimetry for Complex Treatment Techniques", run by the Health Section of the International Atomic Energy Agency (IAEA). The participants of the audit were obliged to irradiate provided dosimetric films, in a slab phantom, for a specific leaf arrangement, producing a pattern of five stripes, commonly called a picket fence. The participants had to programme such a pattern so that the stripes are 5 mm wide and are 3 cm distant between themselves. The Gafchromic EBT2 radiochromic films were placed in a slab phantom close to maximum dose depth. The irradiation was 250 MU per stripe.

Results. Thirty two Polish radiotherapy centres took part in the audit. They were equipped with various accelerator types and various treatment planning systems**.** In all cases the 6 MV quality beams were used. The discrepancies between measured and expected stripe positions were in the range ±1.2 mm. For particular participants, the leaf position discrepancies were in the range -0.5 mm to 0.5 mm. For particular participants, the mean opening width measured with films for each pair of leafs was between 6 and 8 mm.

Conclusion. In the audit, the best performance showed the new type multileaf collimators with 120-160 leafs, whereas the worst performance showed collimators MLC80 from Elekta**.** The results of the audit are very useful for the participants who should carefully investigate the performance of their multileaf collimators.

INNOVATIVE APPROACHES IN THE ABSOLUTE AND RELATIVE DOSIMETRY FOR THE ELIMED BEAM LINE

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Nowadays, the scientific community has shown a growing interest towards new acceleration techniques based on ultra-intense and ultra-short laser, as an alternative to conventional acceleration techniques and these could have a big impact in many applications including the multidisciplinary ones.

The peculiarities of laser-driven beams, show different characteristics respect to the conventional ones: a very high peak current (10^{10} to 10^{12} p/pulse), a wide energy spectrum and angular distribution and rather small transverse and longitudinal emittance, leding to develop specific and innovative devices to make laser driven beams suitable for any kind of applications.

In this framework, the ELIMED (ELI-Beamlines MEDical and multidisciplinary applications) beam line, developed at INFN-LNS has the purpose of realize a transport beam line for high-energy proton beams (up to 60 MeV) coupled with innovative diagnostics and in-air dosimetry devices to investigate the feasibility of using laser-driven ion beams multidisciplinary applications. This beam-line will be installed at the end of 2017 at ELI-Beamlines, in Prague, within the ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) experimental room, where a Petawatt laser will be available for users.

Furthermore, a Faraday cup (FC) prototype for absolute dosimetry, specifically designed to decrease uncertainties in the collected charge and an innovative multi-gap in-transmission ionization chamber, used for relative dose measurements have been designed and realized and tested with conventional proton beams at LNS-INFN, and with laser-driven beams at the RAL laser facility in Oxford (UK) and at the LOA laser facility in Paris (France).

In this contribution, the design and development of the dosimetric devices will be discussed.

DOSE DELIVERY QUALITY AUDIT FOR IMRT TECHNIQUE IN POLAND

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Purpose. The delivery of accurate intensity-modulated radiation therapy (IMRT) or stereotactic radiotherapy depends on a multitude of steps in the treatment delivery process. The purpose of this audit is to verify the dose delivery for an end-to-end clinical IMRT treatment executed with either a static gantry or VMAT technique. The extension of the programme to an end-to-end evaluation of advanced technology (IMRT) treatments provides an independent verification of the entire radiotherapy chain including imaging, the dose distribution calculated by the treatment planning system and treatment delivery. The methodology of the audit is presented here.

Methods. The methodology of the end-to-end clinical IMRT audit was established within the framework of the CRP E2.40.16 project Development of Quality Audits for Radiotherapy Dosimetry for Complex Treatment Techniques, run by the Health Section of the International Atomic Energy Agency (IAEA). A dedicated PMMA phantom was designed and manufactured. The phantom contains defined regions PTV (Planning Target Volume) and OAR (Organ At Risk). The phantom contains a special insert for placing radiochromic films and tubes with TLD powder. The participants of the audit are asked to CT scan the phantom, to prepare a IMRT treatment plan according to the given limitations concerning the homogeneity of the dose in the PTV, and limitation of the dose in the OAR, and finally to irradiate the phantom according to the plan.

Results. The audit in Poland is in the pilot phase. Until the end of 2016, 10 centres (out of 35) were audited. Already in this phase it may be stated that the elaborated methodology functions well in practice and makes it possible to evaluate the radiotherapy procedures in particular centres. The results are presently analyzed. It is planned that all centres in Poland will be audited until the end of 2017.

Conclusions. The audit was planned as a postal audit. However, for practical reasons it is carried out in the form of the visits to particular centres. Such form of the audit makes it possible to supervise the local staff in their and assure that the procedures are carried out correctly.

ASSESSMENT OF REFERENCE LEVELS FOR CARDIAC INTERVENTIONAL FLUOROSCOPICALLY GUIDED PROCEDURES IN ISFAHAN PROVINCE IN IRAN

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Among all complex interventional fluoroscopically guided procedures, Coronary Angiography (CA) and Percutaneous Coronary Intervention (PCI) are most frequently performed in cardiac centers of Isfahan province, Iran. Depending on patient size, equipment, technique, type and complexity of examination and operator skill, these procedures potentially deliver high radiation doses to patients. Therefore, there is a potential for developing deterministic radiation injury as well as stochastic effects in patients undergoing cardiac interventional fluoroscopy procedures. The goal of this study was to determine the local reference levels (RLs) related to patient dose and imaging parameters during cardiac fluoroscopy procedures in Isfahan province in Iran as a first approach to help in the optimization of these procedures.

Information on patient doses in terms of Kerma Area Product (KAP), Fluoroscopy Time (FT), skin dose and the number of exposures were collected. This investigation covered 4 cardiology departments in public hospitals and private clinics, and focused on 2 common examination types: 250 CA and 150 combined CA and PCI (CA+PCI) procedures.

The rounded mean values of KAP, FT, skin dose and number of exposures of all four centers were 25 Gycm^2, 2.8 min, 577 mGy, 8 for CA and 52Gycm^2, 8.6 min, 905 mGy, 17 for the combined procedure, respectively. In order to determine the local dose RL, the 3rd quartile (75th percentile) of KAP and skin dose were calculated both in each center separately and among all centers. Comparing the 3rd quartile of KAP and skin dose showed that their minimum and maximum value belonged to CA and combined (CA+PCI) procedure and it was 16Gycm^2, 233mGy and 87 Gycm^2, 1141 mGy respectively. The 3rd quartiles of KAP and skin dose among all four centers were 35 Gycm^2 and 461 mGy for CA, and 74Gycm^2 and 1222mGy for CA+PCI procedure respectively. The local RLs for effective dose were obtained as 6.3mSv and 9.36mSv for CA and the combined procedure respectively for all four centers.

The results of this research can be used to search for the problem roots and help in the optimization of cardiac interventional fluoroscopically guided procedures in this province.

Key words: Reference level, interventional radiology, CA, PCI, patient dose

RAD2017

SPECIFIC APPROACHES TO PLANNING OF PATIENTS WITH PRIMARY AND SECONDARY BRAIN TUMORS USING THE TOMOTHERAPY PLANNING SYSTEM

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Objective: Today in Ukraine there are only several medical centers with medical linear accelerators on their base, which treat their patients not only with 3DCRT methods, but also using Image-guided radiation therapy and Intensity-modulated radiotherapy (hereinafter - IGRT and IMRT). TomoTherapy Tomo HD radiotherapy system is new to our country and to the post-soviet countries at all. That is why the main purpose of this work is to define the quality of different therapeutic plans and to identify the main features of creating treatment plans for patients with primary and secondary brain tumors, using the TomoTherapy Planning System.

Materials and Methods: 25 therapeutic plans were analyzed, that were used for treating patients with brain tumors. All patients were treated using radiotherapy system TomoTherapy Tomo HD. The contours of the target (GTV, CTV, PTV (CTV + 0,3 cm)), and critical organs (eyes, lenses, optical nerve, chiasma, the brain and brain stem) were determined by radiation therapist using MIM contouring software. After that physicists created additional "logical" structures for each plan, which were used for better dose distribution control. Prescribed doses were:

D_{PTV}= 40 - 60 Gy (1,8 - 2 Gy/fr).
D_{PTV}= 30 - 40 Gy (3 - 4 Gy/fr).

All dosimetric calculations were made using TomoTherapy planning system. Medical plans features: field width 1.0 - 2.5 cm; pitch 0,287; initial modulation factor - 3,4; real modulation factor range varied from 2.1 to 3.1. Optimization options were set next way: the value of the average dose that covered V_{PTV} 100% meet the prescribed dose, the dose (D_{PTV} 99%), which covered the V_{PTV} 99% - was greater 95% of prescribed dose, in severe cases the dose that covered V_{PTV} 95% - was greater than 95% of the prescribed dose. Maximum dose in point was $D_{max} \leq 107\%$ of prescribed dose. The minimum dose at point Dmin> 90% of prescribed dose.

Results: The plan results were characterized by high uniformity of dose distribution DPTV95% = 97-100%, Dmax = 102 - 105%, Dmean = 100%, the average HImean – 0.048, HImax – 0.123, HImin – 0.0175, (a value of 0 corresponds to absolute dose homogeneity within the PTV), the average value CImean – 0.86 CImax – 0.994, CImin -0.673. (CI value can vary between 0 and 1, the value of 1 is the most accurate target coverage without the reference dose exposure of healthy surrounding tissues, a value of 0 indicates lack of conformity which may arise in the case of "miss" or when a large amount of irradiated healthy tissue). The average exposure time was 360 s. (From 170 s to 655 s). Organs at risk received a dose, which did not exceed the tolerance doses according to the QUANTEC protocols, except those plans, where these structures had common points with PTV volume. Plan verifications were performed with PTW equipment.

Conclusions: in case of using TomoTherapy planning system for creating therapeutic plans, the distribution of dose in PTV was characterized with high homogeneity and conformality, critical organs were protected as good as possible, even in cases, where organs at risk were very close to the target. The main feature of the TomoTherapy planning system plans was a high gradient within the target dose of critical organs, and the ability to control the dose maximums in those areas where a part or all critical organs had common points with target volume, which makes it possible to provide good dose covering of PTV and to maximize the protection of organs at risk.

TOMOTHERAPY IN UKRAINE – GENERAL ANALYSIS OF FIRST TREATMENT RESULTS

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Objective. General analysis of the modern radiotherapy outcomes with the TomoTherapy system (Accuray TomoHD).

Materials and methods. One of the main problems of radiation therapy in Ukraine is prevalence of old cobalt units. Implementation of linear accelerators in radiotherapy practice increases the requirements for both: radiation protection of the patient and high quality of radiotherapy. This quality is increased due to application of high-tech methods, such as IMRT, IGRT, adaptive radiotherapy etc.

Ukrainian Center of TomoTherapy (UCT) is a multi-vendor facility, which uses radiotherapy system TomoTherapy TomoHD.

Taking into account possible changes of healthy organs, tissues and tumor size, treatment plans may be adapted if needed. Adaptive radiation therapy is a process where the treatment plan can be modified and treatment dose can be routinely customized to each individual patient to achieve a safe dose escalation.

Evaluation of tumor response was carried out according to RICIST 1.1. Complications were assessed with CTCA 4.03 side effects staging. Treatments were performed according to local protocols.

Quality control of the treatment unit's characteristics was performed with set of special dosimetric equipment and phantoms. Additional automated hardware control was provided by TomoTherapy Quality Assurance (TQA) software.

Results and discussion. TomoHD machine was commissioned in 2015. Tomotherapy was created as hardware realization for IMRT and IGRT methods, which provide better cancer treatment outcomes.

Quality control of equipment parameters is a key element of patient's radiation protection.

Analysis of the periodic TomoHD checks results, which were performed in accordance to the local quality control program, showed high stability of the radiation and geometrical parameters of linac.

During 2015-2016, 257 patients were treated with TomoHD. Dosimetric analysis of plans showed uniform and conformal target coverage in majority of cases.

Organs at risk received a dose, which did not exceed the tolerable doses in accordance with the recommendations of the QUANTEC protocol excepting those, having common points with target. An average irradiation time was about 420 s.

DQA verification results were within 97% -100% (analysis of the following parameters: Gamma 3D, 3 mm distance to agreement / 3% dose difference with reference to local dose).

Analysis of treatment's early results showed that complete resorption was observed in 10%; stabilization in 25%; partial regression in 65% of cases. There were acute radiation reactions mostly not exceeding G1, G2. The most frequent reactions were dermatitis - 32%, epithelitis - 14%, leukopenia - 14%. There were no interruptions of treatment course caused by acute reactions.

Conclusions. During usage of TomoTherapy system in the UCT, the treatment unit showed high stability of geometrical, mechanical and radiation parameters. The planning system allows us to provide high quality therapeutic plans, which might be delivered with high accuracy due to application of MVCT imaging. Also mainly low grade acute toxicities were observed.

THE PROTON-BORON FUSION THERAPY: A NEW CLINICAL TREATMENT AND A POWERFUL ONLINE IMAGING TECHNIQUE

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Recently, different methods to induce an enhancement of the biological efficacy of proton therapy have been proposed [1, 2]. In [1] the use of ^{11}B is proposed, while in [2] the use of natural boron, or an optimized mixture of ^{11}B and ^{10}B is discussed through Monte Carlo simulation studies. It is based on the use of Boron atoms that, if localized inside a tumour mass, favour the occurrence of specific nuclear reactions and the consequently the production of high-LET radiation. Specifically, this approach is based on the possibility to exploit the well-known $^{11}B(p,a)2a$ nuclear reaction channel where three alpha particles, with an average energy around 4 MeV, are emitted [3]. These alphas show a sufficient range to release most of their energy in the cell nucleus and high-LET values able to strongly damage the DNA, producing an enhancement of the biological efficacy of the proton beam. In addition, various proton-boron nuclear reactions induce the emission of several prompt gamma-rays with different energies [2]. The measurement of gamma rays can potentially be a powerful technique allowing to verify the treatment online if this peaks are sufficiently intense compared to the background produced from the proton-nuclear reactions with the biological tissue. In this work a theoretical and experimental study of the gamma prompt emissions from the proton-boron nuclear reaction has been carried out with the main aim to understand and quantify the proposed 0.718 MeV peak intensity with respect to the background. A set of measurements, using a high purity Germanium detector, have been performed using two targets made by the ^{10}B and ^{11}B boron isotopes. Both analytical simulations, performed with the Talys nuclear reaction code and experimental results, seem to suggest that the boron concentration injected into a tumour mass, is a critical parameter that in some cases can produce a relatively low signal. Starting from these consideration the alternative use of the Copper labelled diacetyl-bis(N4-methylthiosemicarbazone) (Cu-ATSM) bound with the boron dipyrromethene BodiPy is proposed. Cu-ATSM, which can be also enriched with Boron atoms, can produce characteristics gamma prompts at 1.3 MeV, in a region where the background from the human body is not high. This method could be a good alternative for an imaging online during the proton therapy treatment.

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APPLICATION OF BEAM SPOILERS FOR DOSE UNIFORMITY IN ABUTTING LOW ENERGY ELECTRON FIELDS: A MONTE CARLO SIMULATION STUDY

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Introduction. In radiotherapy of superficial lesions using adjacent electron fields, non uniform dose distribution at the junction of the fields is a major concern. One method of improving dose uniformity at the field border is to broaden the beam penumbra using an electron beam spoiler. Several parameters, including physical characteristics of the spoiler material as well as the angle between abutting fields affect spoiled beam dose distribution. In this study, Monte Carlo simulation method was used to investigate the influence factors that affect dose distribution in abutting spoiled electron fields.

Methods. A Siemens Primus treatment head was simulated for a 5 MeV, 10×10 cm^2 electron beam using BEAMnrc and DOSXYZnrc, the EGSnrc user codes. Measurements were performed using a MP3-M water tank, a Semi flex Chamber and a Roos electron chamber (all from PTW, Freiburg, Germany). Using the developed beam model, different materials placed at the end of electron applicator and adjacent fields were simulated and associated isodose curves were calculated. PMMA, aluminum, titanium and chromium were used as spoiler materials.

Results. For all spoiler materials, the maximum thickness that produces clinically useful beam characteristics, including surface dose and therapeutic range (R_{90}) was determined. Compared to the open beam (without spoiler), the maximum increase in penumbra width was seen for PMMA and aluminum, 14.5 and 15 mm respectively. The maximum junction dose was lowest for PMMA, aluminum and chromium, about 108% compared to 115% for the open fields, relative to dose at depth of maximum of the open field. Titanium spoiler had the smallest effect on R_{90} and PMMA had the largest, 2mm versus 6 mm reduction. Compared to the open fields, surface dose increased for all materials and was largest for titanium.

Conclusion. Selecting an optimum spoiler depends on the treatment goal, i.e. desired surface dose, therapeutic range and dose homogeneity. The results of this research can be used to optimize dose distribution in adjacent electron fields using beam spoilers.

Key words: Beam spoiler, abutting electron fields, dose uniformity, radiotherapy

A MODEL OF ESTABLISHMENT AND IMPLEMENTATION OF THE QUALITY ASSURANCE PROGRAMME IN DIAGNOSTIC RADIOLOGY IN A MULTI-FACILITY REGION

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Quality assurance (QA) programme in diagnostic radiology is an organized effort by the staff operating a facility to ensure that the diagnostic images produced are of sufficiently high quality so that they consistently provide adequate diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation (WHO). Quality control (QC) is a part of the QA programme and QC procedures are used for testing and maintenance of the various parameters of the ionizing radiation system.

QA programme on using ionizing radiation is mandatory in all EU member states. The terms of use of ionizing radiation for medical purposes are defined by the Croatian regulatory body since 2009. However, in diagnostic and interventional radiology this is still not implemented in most facilities. One of the main reasons is a lack of medical physicists. All radiotherapy departments have a medical physicist employed, most nuclear medicine departments also, but in diagnostic and interventional radiology the situation is quite opposite. At this moment, less than 4 medical physicists are involved in diagnostic and interventional radiology.

Since 2012., when a physicist was introduced to radiology department at University hospital Rijeka, a lot of progress has been made and it is still an ongoing process. Development and establishment of quality assurance programme was set up as a primary goal at the time. Encouraged by the results of QA implementation at our hospital, we decided to make a strong effort on building awareness on the importance of such programme to both, professionals and general public, as it is also one of the responsibilities of a medical physicist.

As a result of this effort, the public health institutions in west Croatian region became strongly interested on developing and implementing a QA programme, but it was not possible since they had no medical physicist. Since the efforts of our Medical Physics Department for optimized, responsible and safe use of ionizing radiation in medicine at UH Rijeka was well publicly presented and recognized, call for help and cooperation outside our mother institution was received and accepted by hospital board.

A working group was formed with the task to find a solution for their situation. It was decided to establish a technical collaboration between institutions and agreed which actions medical physicists from University hospital Rijeka will perform in all facilities. This included 1 general hospital and 2 public health institutions with 13 facilities.

After the validation of technical performance of the equipment, our current task is the process of optimization. It is an important part of a QA programme that has a goal to find balance between satisfactory diagnostic information and the lowest possible radiation exposure.

A model of establishment and implementation of quality assurance programme in diagnostic radiology in multi-facility region will be presented.

COMPARTMENT BIOKINETIC MODEL FOR ^{90}Y-DOTATOC

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^{90}Y-DOTATOC in Peptide Receptor Radionuclide Therapy (PRRT) is used to cure the patient with neuroendocrine tumors (NET). According to standard protocols proposed by European Association of Nuclear Medicine (EANM), used activities are between 3.7 GBQ to 5.55 GBq. It is known that this kind of peptide use to bind very quickly to tumor tissue, while the rest activity is excreted through the kidneys and bladder. Certain amount of radioactivity is accumulated in kidney which can cause the significant damages and reducing the kidney function. Due to this, there is a tendency to develop personalized dosimetry in order to achieve the largest doses in tumor with smaller as possible dose in kidney.

Measurements were performed on 10 patients who were treated by this therapy in Clinical Centre Kragujevac. Patients received the activity of ^{90}Y –DOTATOC between 2.7 to 5.4 GBq. Blood was sampled at the moment when the application of radiopharmatic was terminated, then each hour in first 6 hours and after in interval of 6 and 12 hours up to 72 hours after application. Measurements were done with liquid scintillation beta counter RackBeta, LKB Wallac. Urine was also collected and measured in the period of 72 h after application.

In order to understand better biokinetic of this nuclide in human body, we developed two sets of differential equation which described behavior of used radioactive peptide in human body. Human body was considered to consist of four compartments (blood, kidneys, bladder and tumor) and differential equations describe balance of ^{90}Y in each of them. Equations were solved analytically and programmed in Fortran 90. Transfer parameters were varied and computed activity in blood was compared with measured once in order to determine the best set of parameters. This enabled determination of absorbed dose in four organs of human body due to this therapy.

ASSESSMENT OF ABSORBED DOSE IN SOME ORGANS OF ORNL AND VOXEL PHANTOM DUE TO APPLICATION OF RADIOPHARMACEUTICAL ^{99m}TC

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Nuclear medicine is the branch of medicine that deals with diagnosis and therapy by using radioactive isotopes and their compounds. One of the most commonly used pharmaceutical in nuclear medicine is ^{99m}Tc. The objective of this work was to calculate the absorbed dose in some organs of human body, when this radiopharmaceutical is incorporated in lungs. Monte Carlo simulations were done to evaluate dose due to application of ^{99m}Tc. In this work two types of phantom were used: ORNL mathematical phantom and voxel phantom-thorax. The differences between results obtained for absorbed dose values using voxel and ORNL mathematical phantom are between about 5% up to 20%.

ESTIMATION OF MEAN GLANDULAR DOSE IN MAMMOGRAPHY USING VOXEL PHANTOM AND MONTE CARLO SIMULATION

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Mammography presents one of the most precise methods for detection of irregularities inside the breast. Its most important function is discovering diseases like cancer at an early phase. Although mammography uses low dose x-ray system, examination still poses certain risk for patient. Mean glandular dose gives the best representation of risk involved for a patient undergoing mammography examination. In this study we estimated adipose, glandular and total dose to the breast using Monte Carlo simulations. For this purpose we designed a voxel breast phantom. Simulations were performed using MCNPX code. Verification of phantom design and simulations was done by comparing results with those published in similar studies.

MEASUREMENT OF ARTERIAL WALL SHEAR STRESS IN CASES OF ASYMPTOMATIC CAROTID STENOSIS AND RESTENOSIS IN HUMAN CAROTID ARTERIES IN VIVO

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We developed a system for measuring the wall shear stress (WSS) in blood vessels using Doppler ultrasonography and computational fluid dynamics (CFD). The time-dependent velocity at the center of the blood vessel was measured by phase-contrast algorithm based on Origin pro-software (Origin Lab Inc.) and was approximated by finite Fourier series, which was used for generating the velocity profile at the inlet for the boundary condition to the CFD method. To validate the CFD method, we compared the WSS obtained by the CFD method with the theoretical value in a straight cylinder with various radii for both steady and pulsatile flows. We also investigated the dependence of the WSS on the inlet velocity profile incorporated into the CFD method. For steady flow, there was a good agreement between the WSS obtained by the CFD method and the theoretical value. For pulsatile flow, there was a relatively good agreement between them when the radius of the cylinder was average diameter 1600 mm and the inlet velocity profile was given by the Womersley solution for fully developed pulsatile flow in a straight circular cylinder. When the radius of the cylinder was 1600 mm and/or the inlet velocity profile was assumed to be parabolic, large differences were observed between them, suggesting that the assumption of fully developed flow does not hold true in these cases.

Impaired endothelial function and increased carotid intima-media thickness are key events in the atherosclerotic process and predict future cardiovascular events in subjects with and without coronary artery disease. The purpose of this study was to investigate whether the vasodilator response to increased flow in the brachial artery and the presence of carotid lesions may have a prognostic significance for in-stent restenosis in patients undergoing corotid angioplasty.

The study population included 32 patients with carotid artery stenosis, 5 healthy volunteers, and 18 with restenosis within 6 years after stenting. All patients underwent ultrasound detection of brachial artery reactivity.

Working hypothesis is influence of the power of action of the stents over carotid arterial wall, as a main reason for depositing of alpha fibrils and prompt restenosis within few years.

Endothelial function can be measured in corotide arteries and in the periphery by measuring vasomotor function after intra-arterial infusion of pharmacologic substances which enhance the release of endothelial nitric oxide and with combination with Doppler ultrasound (Hitachi, Aloka-Alpha-6; Japan). Advantage of these methods is their non-invasive nature, which generally makes them suitable for studies involving asymptomatic subjects. For this reason, noninvasive tests of endothelial function have been developed. In the most widely used of these, an ultrasound-based method, arterial diameter is measured in response to an increase in shear stress, which causes endothelium-dependent dilatation (flow mediated dilation-FMD). Endothelial function assessed by this method correlates with invasive testing of coronary endothelial function, as well as with the severity and extent of carotide stenosis.

NEW MATERIALS AS TISSUE SUBSTITUTES FOR USE WITH PHYSICAL BREAST PHANTOMS DEDICATED TO X-RAY BASED IMAGING TECHNIQUES

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Introduction. Anthropomorphic physical breast phantoms play a major and crucial role in the development of new breast imaging techniques as well as they can be used as a tool for the assessment and verification of performance standards in daily clinical practice of breast imaging modalities. Although their importance, nowadays, there is limited number of breast physical phantoms dedicated to such activities. The aim of this work is to explore the available 3D printing technology and available range of materials and study the suitability of these materials for manufacturing of anthropomorphic breast phantoms for x-ray breast imaging.

Materials and methods. For this purpose, 14 materials available with currently used technology were studied: gray, clear, black, white flex, and tough resin, polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyvinyl alcohol (PVA), brick, Nylon, polyethylene terephthalate PET-G, hybrid and polymethyl methacrylate (PMMA). One step-wedge phantom per material (with 9 thicknesses: 2, 4, 5, 6, 10, 15, 20, 30 and 40 mm) was prepared by using available 3D printing technology. The resin samples were printed with stereolithography printer, while the other samples were printed with fused deposition modeling printer. Prior to going to an x-ray system, the density of these materials was carefully assessed by involving measurements on electronic scale device. The step-wedge samples were then scanned at GE Senographe SD digital mammography system Rh/Rh@28kVp, entrance dose of 2.74mGy and a detector resolution of 100 µm. In addition to the images with the samples, three dark images and one flat image were acquired. The linear attenuation coefficient for every material was calculated by least square fitting an exponential model on the attenuation data. Data were assessed against theoretical data for the attenuation coefficient for the glandular, adipose, water, polyethylene, paraffin, PMMA and BR12 from the XCOM NIST database.

Results: X-ray images were processed to obtain line integrals from intensity images with objects, flat and dark images. The absorption properties (the mass absorption and linear attenuation coefficients) of these materials were estimated from square regions of interests with size of 80 pixels. From the studied materials, the grey and clear resins show absorption properties close to the adipose tissue, while the PLA, Flex and PVA show properties close to the properties of the gland.

Conclusions: These results will be exploited in the preparation of a complex breast physical phantom. Next step is to evaluate the characteristics of these materials at synchrotron facility. The scheduled measurements will validate the results of this study and will estimate with high accuracy the absorption characteristics of the studied materials. Future work is related to studies with the refractive index of these materials.

Microwave, Laser, RF and UV Radiations

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INDOOR RF EXPOSURE ASSESSMENT IN URBAN AREA CONDUCTED BY PERSONAL RF EXPOSIMETER

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Introduction. The aim of this study was to measure the indoor microenvironmental level of RF exposure and individual personal exposure in urban area. Our main hypothesis was that the RF components of indoor exposure emitted by household wireless devices (e.g. DECT, WiFi, Bluetooth etc.) is already higher than the exposure from downlink frequency bands of mobile base stations.

Methods. In this study MVG EME Spy 200 RF personal exposimeter (PEM) was used that is a compact, body-wearable device to measure and record the ambient RF electric field strength in 20 pre-defined frequency bands between 80 MHz and 6 GHz (FM, TV3, TETRA, TV4 & 5, LTE 800-uplink/downlink, GSM-uplink/downlink, DCS-uplink/downlink, DECT, UMTS-uplink/downlink, WiFi 2G, LTE 2600 uplink/downlink, WiMax, WiFi 5G). Its dynamic range is 61,6 dB (0,005 V/m to 6 V/m). The sampling rate was 30 s. The 48 h recording was divided in two parts: in the first 24h the PEM was placed in the indoor environment of 37 volunteers' apartments while during the second 24h hours the PEM was carrying by the persons participated in the study. In each apartment a survey measurement was also conducted placing the PEM device in all rooms for recording the electric field strength during 5 minutes at least. The RF exposure from individual frequency bands, the sum of downlink bands, the sum of household wireless devices and all other sources were identified and analyzed.

Results. The total recorded electric field strengths of measured data were several times below the public exposure limits recommended by the EU (1999/519/EU). In spite of the general use and quick spread of indoor RF sources, the sum of resultant exposure from the base stations is still higher than the exposure from other indoor household wireless sources. The highest indoor RF exposure is still emitted by mobile phone bases stations in the GSM 900 downlink band. The contribution of RF frequency bands of indoor, personal or survey recording showed similar distribution nevertheless we found variation of frequency distribution of RF exposure within the rooms. The level of total RF exposure averaged over 24h from indoor household wireless devices is still less than the total exposure emitted by other sources from outdoor area.

Discussion. The ratio between the exposure levels of downlink and non downlink depends on the site of recording inside the apartment. The lower exposure levels emitted by the household wireless systems may caused by the facts that the indoor sources work low RF power and the results obtained based on 24h time average. Similar result was published by Austrian group in 2015 (Tomitsch, 2015). The exposure coming from base stations is still higher than the RF exposure emitted by indoor sources, and the GSM 900 is the highest, probably due to the new LTE technology which works also in the 900 MHz frequency band.

A PERSPECTIVE VIEW OVER THE WORLDWIDE O_3 AND NO_2 EVOLUTION DURING 2002-2016 USING UV-VIS OBSERVATIONS FROM SPACE

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In this work we present the evolution of the atmospheric ozone (O_3) and nitrogen dioxide (NO_2) over the worldwide during 2002-2016. In this purpose, two important locations from each continent were selected. The $O_3$and NO_2 remote sensing observations were provided by the following satellite UV-VIs instruments: SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric ChartographY) onboard Envisat, OMI (Ozone Monitoring Instrument) onboard AURA and GOME-2 (Global Ozone Monitoring Experiment Measurements-2) onboard Metop-A&B. Data regarding O_3 and NO_2 were obtained from the Tropospheric Emission Monitoring Internet Service (TEMIS) database. Possible correlations between NO_2 and O_3 are presented in this work.

NICOTINAMIDE RELEASE FROM PAM XEROGEL INTO WATER SOLUTION UNDER ISOTHERMAL MICROWAVE CONDITIONS: KINETIC STUDY

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The isothermal microwave heating (MWH) leads to the significant acceleration of chemical reactions, the increase in the yield of the preferred products and to the improvement of their selectivity. The isothermal kinetics curves of nicotinamide release from poly(acrylic-co-methacrylic) (PAM) xerogel into water solution, under the isothermal MWH conditions were measured in different temperatures ranging from 30°C to 50°C. The MWH experiments were carried out using a commercially available monomode microwave unit, Discover, CEM Corporation, Matthews, North Carolina, USA. The degree of kinetics complexity of the nicotinamide release under the MWH into water solution was investigated applying the isoconversion Friedman's method. Based on the found shape of the dependence of E_a on the degree of release, it was concluded that the investigated release process has one kinetically rate determining step. By application the model fitting method was found that the investigated kinetics of nicotinamide release can be described by the kinetics model of phase-boundary controlled reaction (R-3). The values of the kinetic parameters for the nicotinamide release under the MWH conditions were calculated: E_a=22±2 kJ/mol and lnA/min^{-1} = 5.0±0.5. Model mechanism of the influence of MWH on the kinetics of release of nicotinamide from PAM xerogel was considered.

HIGHLY EFFICIENT LASER ACTION FROM FREE-SHAPE DYE-DOPED SOFT MATTER SYSTEMS

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The study of electromagnetic waves propagation in periodically structured dielectrics and the linear and nonlinear optical phenomena in disordered systems doped with gain media represent one of the most challenging and exciting scientific areas of the past decade. Lasing and Random Lasers are fascinating examples of topics that synergize multiple scattering of light and optical amplification and lately have been the subject of intense theoretical and experimental studies, owing to the enormous demand for understanding the physical effects and phenomena which lie behind the confinement and moulding the flow of light. The mélange of light localization and random lasing is especially interesting because of the specific features of each distinctive lasing source, accompanied by unique emission characteristics of the localized modes. Herein we demonstrate laser emission from confined or boundary-less dye doped compact systems. The challenge was to obtain a new class of small size, versatile, free shape random laser systems by employing dye-doped soft matter systems. Ranging from confined standard wedge sandwich cell design to freely suspended thin active media films and boundary-free liquid droplets, the lasers that we introduce are ultra-compact hazard free narrow banded (FWHM ca. 0.4 nm for each laser mode) emitters that excel due to their low lasing threshold, great efficiency, long term durability, easiness in fabrication and vast variety of possible configurations. Optical emission characteristics such as spectral analysis, below and above lasing energy threshold behavior, emission efficiency, far field spatial lasing modes intensity profiling, temporal emission behavior etc confirm the light amplification and that laser emission occurs from our mirrorless devices. These materials are appropriate candidates for manufacturing small scale flexible laser systems and we predict their future employment in key areas of modern bio-medical applications, optics and photonics, and material science arena in general.

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A STUDY OF DETERMINING A MODEL FOR THE PREDICTION OF SOLAR RADIATION

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Solar energy is one of the most common renewable energy sources. Using of this energy is profited by solar radiation arriving in earth. Photovoltaic (PV) technologies using solar energy ensure a clean, renewable and sustainable energy source. PV technologies are quickly developing. Recently, PV has been used a great many large utility like photovoltaic power plants, residential systems, and irrigations. Accordingly, solar radiation model in summer season (July, June and August) is conducted by using Angstrom–Prescott linear regression. Data is gathered from meteorological measuring device. This device was established in 20 m high from the ground level. Measured data on solar radiation and sunshine duration has been recorded by a Vantage pro 2 station. In order to verify the predicted results, statistical methods as mean bias error (MBE), root mean square (RMSE), and relative percentage error are used. The new linear equation is obtained for monthly-average daily global solar radiance.

ESTIMATION OF SOLAR RADIATION MODEL USING MEASURED DATA IN SPECIFIC REGION

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Nowadays, using solar radiation is very important for some applications. Knowledge of global solar radiation distribution is needed for design of solar energy systems of these applications. But solar radiation measurements are not easily because of difficultly requirements of the measuring equipment and techniques involved. Many parameters affect the production solar energy and conversion efficiencies and location conditions of PV panels. One of the most vital parameters is the number of solar radiation. Therefore, the main objective of this study is to determine for predicting solar radiation. In this concept, two empirical models (linear and second-order polynomial equation) are analyzed according to correlation coefficients for a month.

THE PARTICULARITY OF THE THERMAL-RADIATION FACTOR IN THE WORK ENVIRONMENT AND EYE HEALTH PREVENTION AMONG BULGARIAN METALLURGY WORKERS

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Issue – Description of the problem: In the hot industrial units of metallurgical production happens significant heat radiation. As a result of fields interaction and stratify it creates a certain thermal-radiative tension workplace.

Optical radiation of technological metallurgy process is strong hazard for metallurgist vision. The visible and infrared radiation (IR)-A range 0.76-1.4 μm enters the retina and causes Retinopathy. Anterior eye segment suspend IR range 1.4 μm-1 mm and results Infrared eye cataract.

Occupational medical examination lately becomes very important both from social and economic point of view.

Material and methods: Occupational medical examination was performed on 183 metallurgy workers and included visual acuity examination, biomicroscopy and ophthalmoscopy.

Results: During occupational medical examination of 183 optical radiation exposed workers, we found pathological cataract in 3 cases (1.6 %).

There artiphakia in 5 cases (2.7%) with no proving data if the operated cataract was pathological.

In 16 cases (8.7%) there was retinal angiosclerosis.

Hypertensive retinopathy was found in 63 of examined workers. (34.4%) but it is unclear whether hypertonia was caused by the working environment.

Other vision pathological conditions that we found among this professional group included refractive errors, glaucoma, and eye injuries.

Lesson and conclusions: Diagnostics of Visual disorders in Occupational medicine must be a part of the Company Occupational medical examination system.

Quality-controlled regular organized occupational medical examination improves safety and health of metallurgy workers.

Time measurement and permissible value of exposure on workplace, at that take into account the spectral composition of radiation are very important.

Effectiveness of thermal protective aids are of practical importance for prevention.

Main message: The evaluation of individual occupational risk is of utmost importance for workers have employed in metallurgy and is closely related to timely diagnosis and proper treatment of work related eye disorders.

INVESTIGATION OF SEASONAL IONOSPHERIC VARIATIONS FROM GNSS AND IRI-2012

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Ionosphere is a layer containing a larger number of free electrons and positively charged ions within the heights from 60 km to 100 km above the earth's surface. It depends on solar activity, magnetic storms, solar cycles (every 11 years), 27-day solar rotation, seasonal variations etc. In this study, Total Electron Content (TEC) values derived from Global Navigation Satellite Systems (GNSS) and International Reference Ionosphere-2012 (IRI-2012) were produced with hourly resolutions in January, April, August and November in 2014 for a GNSS station called ZONG, and the seasonal ionospheric changes were obtained using these methods. The IRI-2012 model has produced almost the same TEC value for every hour observations for any said months while the TEC derived from GNSS measurements is a better indicator in terms of representing the behavior of the ionosphere. As a result of regression analysis, the correlations R^2 were found to be 0.895, 0.838, 0.745 and 0.936 for January, April, August and November, respectively. Although both the models have appeared to be in good agreement with each other, the IRI-2012 model has been found to underestimate the TEC values for all the days analyzed.

Neutron and Heavy Ion Radiations

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DURABILITY OF TARGETS AND FOILS IRRADIATED BY INTENSE HEAVY ION BEAMS IN EXPERIMENTS ON SYNTHESIS OF SUPERHEAVY NUCLEI

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Durability of targets and window foils irradiated by intense heavy ion (HI) beams in the experiments on synthesis of superheavy nuclei, which are carried out in Dubna with Gas-Filled Recoil Separator (DGFRS), has been viewed in various ways. High fluxes of HI and heat generations, which are realized within relatively small areas and thicknesses of these elements of DGFRS, are inherent in such long-continued experiments. The lifetimes of the targets and window foils are estimated as the result of actions of an intense HI beam such as radiation damages, sputtering and evaporation of atoms. The most critical processes determining the durability of the targets and window foils are discussed. The processes of heat transfer due to thermal conductivity, convection and radiation are also considered from the point of view of possible ways of cooling of the elements irradiated by an intense HI beam. Temperatures of the targets and window foils as a function of time can be calculated in the conditions of their pulse heating by a HI beam and corresponding cooling by radiation emitted from their surfaces. Such pulsing mode is inherent in the operation of DGFRS with the use of the rotating target and window foils irradiated by a continuous HI beam. Estimates show that radiative cooling in the conditions of pulse heating can be the most effective way of heat transfer to the surroundings at the temperature of several hundred degrees. Such temperatures can be reached on the surfaces of the target and foils irradiated by HI beams at the intensity of about 10^{13} particles/s.

NEUTRON ACTIVATION TECHNIQUE: A RELIABLE TOOL TO DETERMINE THE MINERAL COMPOSITION IN AGRO-INDUSTRIAL PRODUCTS

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Mineral composition analysis in agro industrial products is necessary for several reasons such as determination of nutritive value, assessment of product quality, detection of adulteration, compliance with legal and labeling requirements, food forensic, research and development. It is important to enhance that a variety of toxic elements in food is continuously increasing as a consequence of new agricultural practices, industrial development, and environmental pollution. For that, analytical techniques are expected to play a crucial role on chemical elemental concentration determination. Various analytical techniques are applied to provide the elemental concentration information, among them is the neutron activation analysis, a multi-element technique that analysis major, minor, trace and rare elements in a sample without been necessary chemical treatment of the sample. The technique is based on irradiating a sample with neutrons in a nuclear reactor to produce specific radionuclides. After the irradiation, the characteristic gamma rays emitted by the decaying radionuclides – indicative of a specific of the presence of a radionuclide - are quantitatively measured by semiconductor detector. Basing mainly in this information, the concentration calculation is obtained.

In this paper, the technique was applied by means of k_0-standardized method, in which instead of standards of chemical elements – relative method – neutron flux monitors, spectral parameters of the nuclear reactor, gamma system counter absolutely calibrated and k_0 constants are used. Several agro industrial samples like corn, sugar, wheat, food supplement were analysed using the 100 kW TRIGA Mark I IPR-R1 research reactor. The results were compared to legislation and/or literature in order to evaluate the values.

Therefore, the objective of this paper is to show the versatility and the efficiency of this technique on multielemental concentration determination in diversified food samples showing that several chemical elements were determined with a large range of elemental concentration. Reference materials were also analysed and evaluated statistically, pointing out the reliability of the technique.

ON THE NUCLEAR PROPERTIES OF EVEN-EVEN YTTERBIUM ISOTOPES

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Ytterbium element is used in many nuclear applications. Correct predictions of various nuclear properties of its can be important task. In the present study we have investigated ground-state binding energy, two-neutron separation energy, charge radii, quadrupole moments and deformation parameters of even-even $^{160-180}$Yb nuclei by using non-linear Relativistic Mean Field (RMF) Model. The results have been found as in agreement with the available experimental data. Furthermore obtained deformation parameters with RMF Model for stable even-even ^{168}Yb, ^{170}Yb, ^{172}Yb, ^{174}Yb and ^{176}Yb isotopes have been used for calculations of their cross-sections for neutron induced reactions in wide energy range by using TALYS code. Also, the calculated cross-sections for these isotopes have been compared with the TENDL 2015 database.

INTEGRATED ONLINE SYSTEM FOR SIMULATION AND ANALYSIS OF HIGH ENERGY NEUTRON INTERACTIONS

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Simulations in high energy physics had become a necessity in recent years as the experiments in the field are getting more and more complex. However, it is generally recognized that, despite of huge development of software, there is no standard software package which can perform simulations in complete different experimental setups. Therefore, the software for simulations is highly experiment dependent and is written almost always by the physicists for their own use. The software for analysis is even more dependent since the analysis varies from physics channel to physics channel.

In order to perform a complete simulation, we need to implement the whole geometry of the experimental setup, establish which physics process, which is characteristic of the primary beam, should be included, how to store simulated data or which is the best way to deal with event reconstruction. Mainly, this requires from the user, a good understanding of simulation package and solid knowledge of programming languages. Therefore, the user is forced to concentrate on coding and not on the physics processes which he studies.

To overcome this drawback we start to develop an integrated system, easy to use, which use Root classes for implementing the whole simulation code, geometry and reconstruction of data levels (digitization), and Geant4 simulation framework for tracking particles through matter. Analysis of the output is done using the same Root framework.

The system will have 3 basic modules: first module will ensure the system's interface and access to the other modules and it will be based on an authentification system. Second module will be the core of the system and will provides classes and member function descriptions of the software, as well as examples of use. The third module will contain analysis programs in order to obtain scientific results from simulated data. The design of the framework will allow, at first, optimizations and validations of functionality of some large area detectors used for study of high energy neutrons interactions.

Key words: High energy physics, advanced integrated system, neutrons interaction, Geant4

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NUCLEAR REACTION $^{41}K(\text{alpha},n)^{44mg}Sc$ AND ISOMERIC CROSS SECTION RATIOS

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The calculations of the excitation functions of high-spin and low-spin isomeric states production in one and the same nucleus as well as the respective isomeric cross section ratios (ICSR) were carried out for reaction $^{41}K(\text{alpha},n)^{44mg}Sc$. Measurements of ICSR allow one to obtain reliable information on angular momentum dynamics of a preceding reaction and spin dependence of nuclear level density. This dynamics depends on the properties of a target, projectile and emitted particles. Experimental studies of ICSR produced by reaction $^{41}K(\text{alpha},n)^{44mg}Sc$ in the alpha-particle energy ranges 14–32 MeV were carried out by us earlier using off-beam measurements of induced activity of members of the isomeric pair. Calculations of ICSR for the indicated reaction are performed using the codes EMPIRE-3 and TALYS. For the discussed conditions the values of ICSR calculated by EMPIRE- 3 are in disagreement with experimental ones being 20-30 % greater. At higher energies of alpha-particles calculated values of isomeric ratios significantly exceed experimental ones. As for the data obtained by use of TALYS code they turn to be in a good agreement with experimental ones over all measured region except the expressive experimental maximum of ICSR at energy 26 MeV.

OXYGEN-DEFICIENT PEROVSKITES FOR IMPROVED PERFORMANCE OF ELECTRODES IN INTERMEDIATE-TEMPERATURE SOLID-OXIDE FUEL CELLS: STRUCTURAL DETAILS

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Solid oxide fuel cells (SOFCs) have potential to become the most efficient and cost-effective system for direct conversion of a wide variety of fuels to electricity. The performance and durability of SOFCs depend strongly on the microstructure and morphology of cell components. The ceramics used in SOFCs do not become electrically and ionically active until they reach high temperature so that the operating temperatures are ranging from 800 to 1,000 °C. Nowadays, there is a great interest on reducing the operating temperatures of SOFCS. The development of new electrode and electrolyte materials with good performance at intermediate temperatures (650-800 ^{o}C) is an important prerequisite. The quest is on solid oxide materials with high ionic and electronic conductivity while preserving structural stability at high temperatures. In this direction, many of the oxides that traditionally were studied from the magnetic or electronic point of view (superconducting, colossal magneto-resistant oxides, multiferroicity…) can find applications, with subtle modifications, as electrodes in these electrochemical devices. Thus, by appropriate substitution perovskite based materials can be tailored to exhibit a host of physical properties, ranging from ferroelectricity and ferromagnetism, to superconductivity and ion conductivity.

The materials investigated and reported in this study are powder, dense and porous perovskite-related materials based on the composition $BaCe_{0.85}Y_{0.15}O_{3-\delta}$ (BCY15) tested in a novel design of single SOFC cells and defect perovskites $(PbBa(Sr))Fe_{2-x}Me_xO_5$ where Me=Co, Mn, Cr. The structural details in dependence on the anode/cathode preparation are revealed through Rietveld full profile analysis of X-ray and neutron diffraction patterns. Additional structural details of the materials were obtained because the neutron diffraction method has proven advantages over other diffraction (electron, X-ray) methods in the determination of the position of the oxygen in the structure as well as oxygen deficiency.

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PROPOSALS FOR IMPROVEMENTS OF THE SYNCHRONIZER OHM002SYNC FOR THE EASIER EXCHANGE OF THE ECG TRIGGER WITHOUT ADDITIONAL DATA MANIPULATION

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Aim. Practically tested oximetric synchronizer OHM 002SYNC (ORBIT MERRET) for acquisition synchronization with the heart beating in scintigraphic examinations has a major obstacle for easy deployment and namely the need to adjust retrospectively measured data versus data measured using a standard ECG trigger.

This relative displacement is caused by generating data synchronizing signal at intervals of a certain time point later compared to the signal based on ECG. The aim was to measure the basic physiological phenomena, which have an influence on gating, and design technical tools to optimize the signal from the synchronizer that finally influences a data shift which is below a clinical significance.

Method. The sample of 7 persons (4 women and 3 men aged from 27 to 58 years old) was measured by ECG trigger (IVY, Cardiac Trigger Monitor 3000) and oximetric synchronizer, which were connected to the oscilloscope recorder. ECG curve, pulse wave and synchronization signals were measured within each measurement. The distances between the individual synchronization signals measured by oximetric synchronizer (dependent on bottom dead-centre of pulse wave) and R oscillations from ECG trigger were evaluated on the record. Data were statistically evaluated and few suggestions based on them were made to minimize final displacement in data.

Results. It was found that R spacing oscillation and the bottom dead-centre of pulse wave can be considered as almost constant (349 ms). Signal variability among individuals is below 5% and variability through the sample of persons is below 15%.

Conclusion. Based on this findings presented above a prototype could be developed for elimination of data manipulation when oximetric synchronizer is used for gating acquisition. Some version of oximetric synchronizer will be also available for demonstrations at the congress.

COMPARISON OF GLOMERULAR FILTRATION RATE BY GATE'S METHOD WITH CKD-EPI CREATININE EQUATION IN PATIENTS WITH DIFFERENT GFR VALUES

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Objective. The aim of this research was to define the interval of glomerular filtration rate (GFR) values that showed best correspondence between the GFR values estimated by Gate's method with ^{99m}Tc-DTPA dynamic renal scan and with the CKD-EPI creatinine equation.

Materials and methods. The study was conducted at the Institute of Pathophysiology and Nuclear medicine at the Medical Faculty in Skopje. Retrospective analysis of the files of 78 patients (35 males, 43 females) that underwent dynamic renal scintigraphy with ^{99m}Tc-DTPA within the period between January 2015 and June 2016 was performed. The considered intervals for GFR values according the Gate's method were:

below 40 ml/min

between 40 – 80 ml/min

above 80 ml/min

The GFR was automatically calculated by a software in a commercially available computer according to the Gates algorithm with background region of interest between the upper poles of the kidneys. The obtained results were normalized for standard body surface area in order to be compared properly. The results were compared with the GFR values obtained by CKD-EPI creatinine formula for each patient. The statistical analysis was performed with Spearman correlation.

Results. The results have shown statistically significant correlation between two methods for the whole group of patients (r – 0.63, $p<0.05$). The results for the intervals for different GFR values showed no significant correlation in the group 1, while in the group 2 and 3 there was a significant correlation (r- 0.36, $p <0.05$ and r – 0.49, $p<0.05$).

Conclusion. Best correlation between two methods was shown in patients with GFR greater than 80 ml/min estimated by the Gate's method. The values below 40 ml/min showed no significant correlation between the methods. These results indicate that GFR values acquired by both methods should be interpreted with caution in patients with lower GFR and other more precise techniques should be employed.

A NOVEL RADIO-NANOMEDICINE PLATFORM FOR PET-MRI

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Radio-nanomedicine is an emerging nanomedicine strategy where nanoparticles are radiolabeled to enable therapeutic and diagnostic functionality (i.e. "theranostics"). In this study, we radiolabeled a Super-Paramagnetic Iron Oxide Nanoparticle (SPION) nanoparticle to extend and integrate its functionality as a detection and diagnostic imaging probe for simultaneous Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI). Hybrid PET-MRI is a relatively new, yet powerful imaging technique that combines the exquisite soft tissue contrast of MRI with the exceptional sensitivity of PET. We also radiolabeled the SPION with radio-therapeutic isotopes commonly used in nuclear medicine, thus demonstrating its potential as a versatile radio-nanomedicine platform.

We used the commercially available SPION Feraheme, which has a magnetite crystal core that acquires a strong net magnetic susceptibility when placed in an external magnetic field and can thus enhance image contrast in MRI. To make the SPION detectable with PET, we labeled it with the radiotracer ^{89}Zr using a recently developed technique, Heat Induced Radiolabeling (HIR), which offers the advantage of being chelate-free. We characterized the modified SPION before and after labeling using TEM. PD-10 analysis was used to determine the radiochemical yield and purity of the product. We prepared samples of the radiolabeled SPION for separate imaging with MRI and PET before imaging with hybrid PET-MRI. We also evaluated the HIR technique using therapeutic radioisotopes.

TEM analysis revealed ^{89}Zr and the other isotopes studied bind to the crystal core of Feraheme. We achieved a radiochemical yield and purity of ^{89}Zr-Feraheme of 92% and 98%, respectively. Similar results were obtained for the other isotopes studied. These results confirm the efficiency and robustness of the novel radiolabeling technique. The MRI and PET scans as well as hybrid PET-MRI scans demonstrate that ^{89}Zr-Feraheme can indeed be imaged by this new multi-modal technique. Our results using therapeutic isotopes further confirm that Feraheme is highly suitable as a radio-nanomedicine platform, suggesting promising applications not only for detection and diagnosis of disease, but also for targeted therapy at the molecular level.

METHODS FOR PRODUCTION AND SEPARATION OF PLATINUM ISOTOPES

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Personalized medicine is a promising and developing strategy with radionuclide diagnostics and therapy to be important part of the concept. Platinum has isotopes suitable for Auger-electrons therapy. Synthesis of a biomolecule based on platinum radionuclides would allow having smaller toxic influence on health tissue due to reducing of medication quantity required.

Due to the expedient nuclear properties of the nuclides ^{195m}Pt ($T_{1/2}$ = 4.03 days, IT = 100%, E_γ = 98.9 keV, I_γ = 11.4%) and ^{193m}Pt ($T_{1/2}$ = 4.33 days, IT = 100%) it makes possible to apply them for therapeutic and diagnostic purpose in biologically active compounds with high specific activity. Both radionuclides decay to the ground state by isomeric transition. They undergo Auger-electrons emission, average of 33 and 26 electrons per decay for ^{195m}Pt and ^{193m}Pt correspondingly.

For application of platinum isotopes in medicine, one requires significantly larger specific activity, than it can be achieved by known production methods.

In this work production of platinum radionuclides is performed by irradiation of natural platinum with bremsstrahlung at microtron MT-25 in Dubna according to the following nuclear reactions: $^{196}Pt(\gamma,n)^{195m}Pt$, $^{195}Pt(\gamma,\gamma')^{195m}Pt$,$^{194}Pt(\gamma,n)^{193m}Pt$.

To increase specific activity we tested a target, containing a mixture of H_2PtCl_6 (m = 63 mg) and nanostructured material cryptomelane (m=150 mg) as a recoil nuclei catcher. The target was irradiated for 10 hours in aluminum foil. Then separation of cryptomelane and macro amounts of platinum in a form of $[PtCl_6]^{2-}$ was done based on a different solubility of components in water solution. There was a problem of strong sorption of $[PtCl_6]^{2-}$ on cryptomelane. To overcome this drawback we used cisplatin instead of H_2PtCl_6 in the target. The sample was irradiated for 10 hours in aluminum foil. After separation of cryptomelane and cisplatin, cryptomelane was dissolved in a mixture of 1.5M H_2O_2/1M HCl, solution was evaporated, residue was dissolved in 1 ml 0.1 M HCl. Separation of Mn and Pt was performed on CIX resin (Dowex 50WX8, 200 mesh). Radiochemical yield of ^{195m}Pt was 32 %. Overall yield of platinum reached was $\approx 5\cdot 10^3$ Bq/ (μA·mg·h).

Pharmaceutical Sciences

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REDOX-ACTIVE NICKEL(II) COMPLEXES WITH 1,2-DIHYDROXYBENZENE DERIVATIVES

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Demand for metallotherapeutic drugs in contemporary medicine is a matter of common knowledge [1], although the discovery and wide use of antibiotics as well as the toxicity and low bioavailability of salts of transition metals were the reasons for the limited possibility and range of their functioning. A promising way to fight multi-drug resistant bacteria strains is to enhance chemotherapy efficiency through the use of antibacterial agents affecting simultaneously several biotargets. We demonstrated that among these compounds are metal complexes with redox-active ligands – cycloaminomethyl derivatives of 1,2-dihydroxybenzene [2]. They are able to reduce cytochrome *c* (Cyt *c*), the key component of bacterial electron transport chain, and to act as low-molecular SOD mimics. In view of the above findings and as a continuation of our effort to identify new candidates that are potent antimicrobials we have initiated the study of Ni(II) complexes with the above-mentioned ligands. Nickel is an element of expanding biological interest, because diverse Ni(II) complexes have shown antibacterial, antifungal, antimicrobial and antiproliferative activities [3]. Ni(II) complexes with 5-*tert*-butyl-3-(pyrrolidine-1-ilmethyl)-1,2-dihydroxybenzene (HL^{I}), 5-*tert*-butyl-3-(piperidine-1-ilmethyl)-1,2-dihydroxybenzene (HL^{II}), 5-*tert*-butyl-3-(azenone-1-ilmethyl)-1,2-dihydroxybenzene (HL^{III}), 5-*tert*-butyl-3-(morpholine-1-ilmethyl)-1,2-dihydroxybenzene (HL^{IV}), and 5-*tert*-butyl-3-(methylpiperazine-1-ilmethyl)-1,2-dihydroxybenzene (HL^{V}) have been synthesized. Potentiometric titration showed that in the water-organic medium Ni(II) ions form the complexes M(II):L=1:2 with the compounds HL^{I}–HL^{V} ($\beta=7.9\cdot10^{14}$–$1.6\cdot10^{15}$). According to the data obtained from elemental analysis, TG/DTA, IR, ESR, UV-Vis spectroscopy and conductivity measurements the complexes have the composition described by the general formula ML_2. The compounds HL^{I}–HL^{V} coordinate in their singly deprotonated forms in an *O,N*-bidentate fashion. The Ni(II) complexes are characterized by distorted square planar geometry of their coordination cores [NiO_2N_2]. The reducing properties of the ligands and their Ni(II) complexes were examined by cyclic voltammetry. Using the method of superoxide generation from alkaline DMSO solution, superoxide dismutase activity (IC_{50}) of the complexes synthesized was determined, which was equal to 1.6-6.2 $\mu mol\cdot l^{-1}$. The results obtained give grounds to characterize Ni(II) complexes with cycloaminomethyl derivatives of 1,2-dihydroxybenzene as potential inhibitors of oxidation processes involving superoxide radicals.

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SOD-LIKE ACTIVITY OF SULFUR-CONTAINING ORTHO -DIPHENOLS AND THEIR METAL COMPLEXES

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The public health problems demand searching and synthesizing a new class of antimicrobial compounds effective against pathogenic microorganisms that developed resistance to the antibiotics used in the current regimen. It is common knowledge that active oxygen forms which are generated in phagolisosome and are involved in bactericide mechanisms can produce an antimicrobial effect. But some microorganisms, being active producers of extracellular superoxide themselves, are able to prevent their action [1]. Superoxide dismutases (SOD) are oxidoreductases catalyzing transformation of superoxide into hydrogen peroxide and oxygen. SOD are demanded as pharmaceuticals, but the use of native SOD in medicine is limited by their thermolability, low ability to penetrate cells and others [2]. Many of the limiting factors could be overcome by developing synthetic, low-molecular-weight mimics of the SOD enzyme [3]. Redox-active sulfur-containing *ortho*-diphenols 2-[4,6-di(*tert*-butyl)-2,3-dihydroxyphenylsulphanyl]acetic acid (HL^{I}), 2-[4,6-di(*tert*-butyl)-2,3-dihydroxyphenylsulphanyl]propanoic acid (HL^{II}), 4,6-di-*tert*-butyl-2,3-dihydroxybenzaldehyde isonicotinoyl hydrazone (HL^{III}), 4,6-di-*tert*-butyl-2,3-dihydroxybenzaldehyde thiosemicarbazone (HL^{IV}) and their Ag(I), Zn(II) and Cu(II) complexes have been synthesized. Using non-enzymatic method of superoxide generation employing alkaline DMSO assay [4], the SOD-like activity (IC_{50}) of the ligands was determined, which was equal to 0.7 – 6.9 $\mu mol \cdot l^{-1}$. The results obtained on the SOD-like activity allow one to consider them as promising hit-compounds to produce new effective antioxidants – traps for superoxide. The Zn(II) complexes with the compounds HL^{I}–HL^{IV} synthesized also demonstrated a high level of the SOD-like activity (IC_{50} = 0.4–16.9 $\mu mol \cdot l^{-1}$). But the complexes of these ligands with the ions-oxidizers Cu(II) and Ag(I) are characterized by a lower ability to neutralized superoxide (IC_{50}>59.1 $\mu mol \cdot l^{-1}$). Thus, the redox nature of the metal ion determines the level of the SOD-like activity of their complexes with *ortho*-diphenols, which is likely to be due to the intermolecular redox interaction between the metal ions and *ortho*-diphenol fragments of the ligands proceeding in water-DMSO medium.

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THE INFLUENCE OF SILVER NANOPARTICLES ON MAMMAL BEHAVIOR

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It was previously demonstrated that nanoparticles (NPs) with the average size less than 20 nm are able to penetrate through blood-brain barrier. However, the recent research shows that the silver NPs with the average size of 30-35 nm functionalized with polyvinylpyrrolidone can get through blood brain-barrier as well. By the means of the Instrumental Neutron-Activation Analysis it was found that such functionalized NPs accumulate in mammal brain as a result of long-time exposure to NPs and remain there quite sustainably. Therefore, it was a challenge to understand whether such a phenomenon as accumulation of silver NPs may influence on cognitive, behavioral or physiological functions of mammals.

For this purpose, 4 groups of male mice C57Bl/6 as a mammal model were checked in the two-stage experiment: feeding and testing. These groups included 10 mice, which were orally exposed to 50 μg of NPs daily for 30 days, 10 mice orally exposed to the same amount of NPs during 60 days and 20 reference mice, which were not exposed to NPs. Each animal was contained in an individual cage and received balanced food. After first stage of the experiment, mice were tested in the Open Field Test, in the Elevated Plus Maze and in the Light-Dark Box. After that, the animals were put into the individual PhenoMaster cages for 1 week for analyzing of their physiological conditions and these cages became so called home cages for the given period. During this time, each initial group of mice was divided into 2 groups such as the Active control (AC) and the Fear conditioning (FC). All the groups were trained once in the so-called Freezing cell for the development of the long-term memory. AC groups were placed into the experimental Freezing cell where they freely explored the new environment. FC groups were placed into the experimental Freezing cell where they were exposed to the foot shocks induced by electric pulses, which is normally accompanied by the fear. In 24 h after the training, animals were tested for the long-term memory. Thus, the series of cognitive, behavioral and physiological functions as anxiety, locomotor activity and long-term memory was tested. In the experiments mice had to choose between their natural instinct to hide in a dark and safe place and the space research instinct. Each test was video recorded and analyzed by the modern automatic analytical equipment.

As the main results, we should note increasing of the anxiety, decreasing of the locomotor activity and no changes in the long-term memory. The negative effects became more pronounced with the increasing of NPs exposure period. We suppose these phenomena are caused by the silver NPs exposure, their accumulation in brain influencing the behavioral functions of the key mammals.

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GENERATION OF NUCLEOGENIC PHENYL CATIONS - NEW APPROACH FOR THEIR APPLICATION IN ORGANIC CHEMISTRY, BIOCHEMISTRY AND PHARMACEUTICS

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Review of undertaken investigations in the field of nuclear-chemical method has been presented. Nuclear-chemical method allows a new approach for generation of free nucleogenic cations via tritium beta-decay in hydrocarbons. Application of nucleogenic phenyl cations opened the horizons for the previously unknown reactions with one-step synthesis of even unpredictable by traditional chemistry structures, together with the high sensitive way for investigation of chemical and biochemical reaction mechanisms with the use of tritium label. Ion-molecular reactions of nucleogenic phenyl cations with a wide range of six ring nitrogen containing heterocyclic derivatives (azines and diazines) have been carried out. New pathways of electrophilic reactions with heterocyclic compounds were revealed. Perspective tritium labeled biomarkers containing heterocyclic fragment with quaternary nitrogen atom have been synthesized.

Generation of new fluorine substituted nucleogenic phenyl cations led to the expansion of unique opportunities of the elaborated nuclear-chemical method for synthesis of previously unknown biomarkers with heterocyclic scaffold containing simultaneously tritium label and fluorine atoms at the quaternary nitrogen fragment.

PRIMARY PHOTOCHEMICAL PROCESSES FOR HEXACHLOROPLATINATE(IV) AND HEXACHLOROOSMATE(IV)

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Potential applications of photochemistry of the noble metals complexes are photocatalysis and oxygen-free photodynamic therapy of malignant tumors. Electronic configurations of these complexes ensure the existence of a rich photochemistry. However, the information concerning their photochemical properties is not complete. In many cases, mechanisms were put forward based on the results of the stationary experiments; these mechanisms should be verified by application of modern time-resolved methods.

In this work, photochemistry of $PtCl_6^{2-}$ and $OsCl_6^{2-}$ was studied by means of ultrafast kinetic spectroscopy (with a 100 fs time resolution), nanosecond laser flash photolysis and stationary photolysis.

Primary events for $PtCl_6^{2-}$ in CH_3CN was found to intersphere electron transfer form a Cl^- ligand to the central ion with the formation of an intermediate identified as the primary Adamson radical pair (RP) [$PtCl_5^{2-}$...$Cl^{\cdot}$]. In the reaction with a solvent molecule the RP yields a long-living Pt(III) intermediate, which is responsible for the chain photosolvation of the initial complex. As a result, the quantitative mechanism of $PtCl_6^{2-}$ photosolvation in acetonitrile from absorption of a light quantum to formation of final reaction products was put forward.

For the case of $OsCl_6^{2-}$ complex photochemistry was found to be solvent-dependent. In aqueous solutions, the only process is photoaquation, which is fully completed within 100 ps. No chain processes are developing. In ethanolic solutions parallel processes of photosolvation and photoreduction were observed.

Finally, the quantitative mechanisms of photochemical reactions for $PtCl_6^{2-}$ and $OsCl_6^{2-}$ in different solvents were studied from absorption of a light quantum to formation of final reaction products was put forward.

BASE-PAIRING EFFECT ON UV-INDUCED ADENINE RADICALS IN DNA A-TRACTS

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Absorption of UV photons by DNA induces chemical reactions damaging the genetic code. For long, it was considered that DNA cannot be ionized by absorption of one single photon of 4.66 eV (266 nm), as this energy is significantly lower than the ionization potential of the bases (>7.0 eV). However, experiments performed by Marguet *et al.* [1] showed that, contrary to its monomeric constituents, single and double strands of DNA can be ionized in a monophotonic process at 266 nm. In order to understand the origin of this observation and to describe the subsequent reaction steps leading to the final photoproduct, we have investigated the UV-induced photoionization of DNA by combining time-resolved spectroscopy, mass spectrometry and theoretical calculations.

By detecting the transient absorption signals of hydrated electrons in nanosecond flash photolysis experiments, we characterized the ionization quantum yields of several single, double and quadruple DNA strands with various base sequences.

We studied the ionization of adenine-containing sequences (A-tracts) and found that the adenyl radicals generated by one- and two-photon ionization by 266 nm laser pulses in single and double strands, $(dA)_{20}$ and $(dA)_{20}\cdot(dT)_{20}$, decay at 600 nm with half-times of 1.0 ± 0.1 and 4 ± 1 ms, respectively. The four-fold increase of the lifetime of the adenly radical in the double helix indicates a clear base-pairing effect, proving that helix conformation plays a key role in its reactivity. [2]

In case of $(dA)_{20}$ we also examined the UV-induced dimerization of adenine which is not triggered by ionization. We identified the reaction intermediates and showed that the adenine dimer formation is controlled by the ground state conformation. [3]

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STUDY OF RADIATION-THERMAL EXTRACTANT STABILITY BASED ON DIAMIDE 2,6-PYRIDINEDICARBOXYLIC ACID IN FS-13

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Study of external accidents causes, resulting in explosions and fires on nuclear facilities, is an important component in ensuring nuclear and radiation safety due to considerable impact on the personnel, population and the environment. For one of the most dangerous nuclear facilities are SNF reprocessing companies, which currently use such processes as PUREX, UNEX, which consists in extraction / re-extraction of target components by the organic solution from nitric acid environments. This combination of organic reductant and nitric acid oxidant presents a potential danger in regard to uncontrolled chemical exothermic reactions, which more than once led to explosion at the radiochemical enterprises both in Russia and abroad.

Our work has shown that fenyltrifluormethylsulfone has a high rate of flash temperature and is enough thermal and radiation resistant. The purpose of this work was to investigate the explosiveness and radiation stability of extraction mixture based on diamide 2,6-pyridinedicarboxylic acid in fenyltrifluormethylsulfone (FS-13). Ionizing radiation of radionuclides was simulated with the help of samples irradiation on a linear electron accelerator UELV -10-10 C70 with vertical scanning electron beam to absorbed doses 0.5; 1 and 2 MGy. Experiments were carried out in closed vessels. The temperature of the autoclave during the experiments was 170 and 200°C.

The results of experiments to determine the nature of irradiation effect on outgassing from 0.1 mole/l diamide 2,6-pyridinedicarboxylic acid in FS-13 with an aqueous phase 14 mole/l nitric acid, showed that at a temperature of external heating 170°C outgassing in a mixture of extractant with 14 mole/l HNO_3 begins at a temperature about 120°C and proceeds at a constant speed until the mixture temperature becomes ~160°C, by which the self-heating occurs (exothermic process). However, the exothermic process is relatively weak and short-lived, after which the temperature of the mixture and the pressure in the vessel stabilizes. It was determined that exposure to dose 0.1 MGy dramatically increases the total amount of released gases from the system.

The obtained data allows us to make a preliminary conclusion - conducting the technological operations of highly radioactive waste fractionation by the extractant based on diamide 2,6-pyridinedicarboxylic acid in the diluent FS-13 at the investigated conditions, is fire- and explosion-safe.

Acknowledgement. The study was financially supported by the Russian Science Foundation (project 16-19-00191).

PRODUCTS OF THE EXTRACTION SYSTEM DESTRUCTION BASED ON DILUENT FS-13 IN THE CONDITIONS OF RADIATION, CHEMICAL AND THERMAL LOADS

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For the radiation safety, an important task in the development of high-level waste fractionation technology of UNEX process is to ensure explosion safety – reducing the risk of uncontrolled chemical reactions that occur in the interaction of the organic extractant with concentrated nitric acid. To the issues on preventing of explosions of extraction systems, in which the extractant is tributyl phosphate in light hydrocarbon diluent, a significant number of scientific publications are devoted, including the recent time, much lesser other extraction systems are considered using in heavy FS-13 as the diluent. Any extraction system during operation is exposed to radiation and chemical stress. Therefore, its behavior during SNF reprocessing affects both the efficiency and safety of the process.

We have studied the extraction system consisting of trifluoromethylphenylsulfone (FS-13) containing 0.02 mole/l of biphenyl N-dibutylcarbamoylmethylenephosphine oxide (CMPO) in terms of radiation, chemical and thermal loads. Radiation loads are simulated by the beam of accelerated electrons of a linear electron accelerator UELV-10-10-S-70. Chemical loads - the contact with 14 mole/l HNO3 and thermal – holding at t = 170oC. During the gas chromatographic research and HPLC/MS analysis of the products structures were established which are formed in the extraction system under such loads.

It is found that the diluent FS-13 at t = 200oC thermally decomposes. In the gas phase the presence of FS-13 is fixed, trifluoromethyl benzene and sulfur dioxide in a ratio of 1:1. By irradiation of diluent FS-13 and its mixture containing 0.02 mole/l of extractant to the doses of 1MGy, up to 14 compounds there in formed. The most of their structure was found (these products are caused by the formation of the cation-radical, which decays with the phenylsulfonyl-cation and trifluoromethyl radical formation, which is consistent with the published data). For FS-13 irradiated sample, containing CMPO, is most typical the formation of dimeric products, including a hydroxy group in the aromatic ring.

By the contact of the irradiated sample of diluent FS-13 and FS-13 with 0.02 mole/l extractant with 14 mole/l HNO3, followed by holding at t=170oC, character of found structures does not change much. There is a partial nitration of the aromatic ring preferably in the meta position. The extractant when exposed to ionizing radiation and contact with HNO3 partially decomposed to dibutylamide glycolic acid and 2-phenylphosphineoxide acetic acid.

In the studied system, by the impact of radiation, chemical and thermal loads, diluent FS-13 degrades to 40%.

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THE STABILITY OF GUANINE ADSORBED IN A CLAY MINERAL UNDER A HIGH RADIATION FIELD

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An important step toward the origin of life on Earth is the transition from inorganic molecules to the compounds that are part of a living organism. An approach to answering this question has been to simulate the possible processes that may take place on the primitive Earth that lead to the formation of complex molecules, and finally a living organism. These physical and chemical processes are called chemical evolution. A simulation of the possible relevant environments to the primitive Earth may require the participation of a multi-faceted system, as a mineral surface and aqueous solution of biologically relevant organic compound under the influence of an energy source

In spite of the importance of nucleic acid bases in the prebiotic environment, there are few reports on the stability of these type of compounds. In this context, the behavior of guanine, a nucleic acid base, under irradiation adsorbed in a mineral surface was studied. The attempt of this work is to present some results related to the stability of guanine (nucleic acid base) adsorbed in a mineral (sodium montmorillonite) and exposed to a high radiation field to highlight the importance of ionizing radiation in prebiotic processes. To this end, guanine ($1x10^{-3}$ aqueous solution, oxygen-free), was adsorbed in sodium montmorillonite, a clay mineral, and the clay-guanine system was irradiated with gamma radiation and the guanine was analyzed by UV spectroscopy and high-performance liquid chromatography.

The results presented in this paper show that guanine in an aqueous medium was relatively stable under gamma radiation, especially when it is adsorbed in sodium montmorillonite.

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RADIOLYSIS OF ALPHA KETO-GLUTARIC ACID IN AQUEOUS SOLUTION

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The alpha-keto acids, like alpha keto-glutaric acid, are compounds involved in metabolic processes in all living systems. An important aspect of chemical evolution, a step that is proposed for the presence of organic compounds of biological importance before the appearance of life, is related to the stability of such molecules under primitive conditions, especially in the presence of constant energy sources. To this end, the aim of this work is to study the radiolysis of oxygen-free aqueous solutions of alpha keto-glutaric acid (akg) simulating the primitive Earth conditions. The samples were irradiated at different irradiation dose with a fixed dose rate. The analyses of alpha-keto-glutaric acid and its radiolytic products were performed by gas chromatography and gas chromatography-mass spectrometry. The akg was very labile under irradiation and it formed other carboxylic acids by decarboxylation reactions, like succinic acid.

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IN SEARCH FOR BETTER PROBES FOR THE DETECTION OF THE SUPEROXIDE RADICAL ANION IN BIOLOGICAL SYSTEMS – A PULSE RADIOLYTIC STUDY OF ONE-ELECTRON OXIDATION OF HYDROETHIDINE DERIVATIVES

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Superoxide radical anion is a product of one-electron reduction of molecular oxygen. The main *in vivo* sources of superoxide radical anion are the family of NADPH oxidases, xanthine oxidase and mitochondrial electron transport chain. Superoxide radical anion is a precursor of a broad range of biologically relevant oxidants like hydrogen peroxide, hydroperoxides, and peroxynitrite, hence it is important to know when and in what quantity it is produced in biological systems. This radical species rapidly reacts with various biological molecules (e.g. nitric oxide) or undergoes spontaneous dismutation, therefore its detection and quantitation is difficult and demands special techniques. One of the approaches is the use of profluorescent probes, the compounds which themselves are not fluorescent but during the reaction with superoxide molecule form the fluorescent products that can be directly quantitated. Among various profluorescent probes available on the market hydroethidine seems to be a gold standard for detection of superoxide in biological milieu. This probe reacts with superoxide radical anion forming a diagnostic fluorescent product, 2-hydroxyethidne. Nevertheless this probe possesses some limitations and its reaction mechanism with superoxide radical anion is still not fully understood. Here we present a pulse radiolytic characterization of one-electron oxidation products of two new analogues of hydroethidine, hydropropidine and tetramethylhydroethidine. The obtained result will be discussed in relation to the mechanism of the reaction of hydroethidine with superoxide radical anion. The reactivity of these probes toward biologically relevant radicals will be determined, e.g.: glutathionyl radicals ($GS^{\bullet}$), $^{\bullet}NO_2$, and $CO_3^{\bullet-}$. Additionally the oxidation product profile of the tetramethyhydroethidine will be investigated by LC/MS technique.

THE PULSE RADIOLYTIC STUDY OF ONE-ELECTRON OXIDATION OF HYDROETHIDINE, THE PROBE FOR THE DETECTION OF THE SUPEROXIDE RADICAL ANION

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Hydroethidine (HE) is a fluorescent probe widely used for the detection of superoxide radical anion ($O_2^{\bullet-}$) both *in vitro* and *in vivo*. In the systems generating $O_2^{\bullet-}$, HE undergoes oxidative transformation into 2-hydroxyethidium (2-OH-E^+), a specific marker of $O_2^{\bullet-}$ production. The proposed mechanism of that transformation includes one-electron oxidation of HE, followed by the reaction of transient HE radical cation ($HE^{\bullet+}$) with $O_2^{\bullet-}$. Here we present the spectroscopic characterization of HE radical cation using a combination of steady-state radiolysis of cryogenic organic glasses and time-resolved pulse radiolysis experiments. The radiolytic characterization of the $HE^{\bullet+}$ has been accompanied by quantum mechanical DFT calculations, suggesting that the high spin density of $HE^{\bullet+}$ is located at the C-2 carbon atom, where the hydroxyl group is attached in the 2-OH-E^+product. With the use of pulse radiolysis, we determined the kinetics of HE reaction with biologically relevant one-electron oxidants: nitrogen dioxide ($^{\bullet}NO_2$) and carbonate radical anion ($CO_3^{\bullet-}$). We also show, that glutathionyl radical ($GS^{\bullet}$) are also able to oxidize HE to $HE^{\bullet+}$. To evaluate the value of the rate constant of the reaction of HE with hydroperoxyl radical ($HO_2^{\bullet}$) we have studied the kinetics of oxidation of HE by peroxyl radicals. The rate constants of HE reaction with $HO_2^{\bullet}$ estimated from the dependence of the kinetics of oxidation of HE by chloromethylperoxyl radicals on their one-electron reduction potentials.

LEMNA NINOR L. (DUCKWEED) – ANTIOXIDANT AND ANTIRADICAL ACTIVITY CAUSED BY GAMMA RADIATION

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Lemna minor L. Lemnaceae (Duckweed) is a widespread, continuous flow, free water aquatic macrophyte. It grows quickly and reproduces faster than other vascular plants. *Lemna minor* L. is a suitable plant model for the toxicity evaluation of many substances, it possess defenses against oxidative stress and shows immunomodulatory properties, namely the ability to enhance phagocytosis. There is a lot of studies about activities of antioxidant enzymes in duckweed, and it has been widely used as a raw material for the production of analgesic and antipyretic remedies.

The aim of the present study is to determine the antioxidant and antiradical, activities of *Lemna minor* L. by using different *in vitro* methodologies after gamma radiation from 5 till 30 Gy. For evaluation of antioxidant and antiradical activities, was used 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) ($ABTS^{\bullet+}$) radical scavenging, 1,1-diphenyl-2-picryl-hydrazyl ($DPPH^{\cdot}$) free radical scavenging, total antioxidant activity by ferric thiocyanate, total reducing power by potassium ferricyanide reduction method, superoxide anion radical scavenging, hydrogen peroxide scavenging, ferrous ions chelating activities and Lipid peroxidation were calculated. To evaluate the antioxidant and antiradical activity the extracts of *Lemna linor* L were used. The plant extracts were irradiated by using ^{60}Co source at doses 5, 10, 20, and 30 Gy (Gamma cell 5000, India; 1.4 Gy/h). Immediately the irradiated samples were stored at laboratory conditions (humidity 40 %). The EPR experiments were carried out in triplicate at 23°C on an X-band EMX^{micro}, spectrometer Bruker-Germany (simulation was performed with WIN-EPR and SimFonia) and compared with spectrophotometric studies.

The spectrophotometric studies (EDPA, DPPH, $ABTS^{+}$, $OH_{\cdot}$, LP, NO, $O_{\cdot 2}^{-}$) of the γ-irradiated *Lemna minor* L.samples with a 30 Gy dose were significantly increased compared to those of the nonirradiated samples. It was found, that antioxidant activities, radio-modulatory and free-radical scavenging properties of *Lemna minor* L. are statistically significant increase with increase the γ-radiation doses.

The study has been repeated 30 days after irradiation, and the EPR spectra were with almost the same intensities in the γ-irradiated samples, which indicated that the radical structures formed after irradiation of Lemna minor L. were quite stable, and it could find application as a good antioxidants/radioprotective agents.

Radiation Detectors

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THE DETERMINATION OF GAMMA IRRADIATION RESPONSE OF Gd_2O_3 MOS CAPACITORS AT A LOW FREQUENCY

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The MOS based radiation sensors have been used in many application areas such as high energy physics laboratories, radiotherapy, space radiation modules etc. The silicon dioxide (SiO_2) is usually used as sensitive region of these type dosimeters. However, the higher charge storage capability of the high-k dielectrics compared to SiO_2 (~ 3.9) makes them attractive for the gate oxide (sensitive region) of this dosimeter. Therefore, investigation of the radiation response of the MOS structure composed of high-k dielectrics is quite important to produce the sensor with broader measurable dose range and higher sensitivity compared to traditional SiO_2-pMOS.

The rare earth oxides among the high-k dielectrics are quite important due to their large conduction band offset over 2 eV and large band gaps ~ 5.4 eV. Our results on the radiation response of the MOS capacitors composed of the rare earth oxides of Er_2O_3 and La_2O_3 showed that their sensitivities are higher than SiO_2-MOS capacitor [1-2]. Therefore, we tried the Gd_2O_3 from the rare earth oxides as gate dielectric in the MOS capacitor and investigated the gamma response of this capacitor. For this purpose, Gd_2O_3 films were deposited on the p type Si wafer (100) by RF magnetron sputtering. The films were annealed at 800 ^{o}C under N_2 ambient. The films thickness was measured as 254 nm by Angstrom Sun Spectroscopic reflectometer. The front surface Al contacts with 1.5 mm diameter and back contacts were formed by RF-sputtering. The samples were fabricated at Class 100 Cleanroom Laboratories of the Center for Nuclear Radiation Detectors Research and Applications, Abant Izzet Baysal University. The capacitors were irradiated by ^{60}Co radioactive source in the dose range of 0.5–100 Gy. All of the Capacitance-Voltage (C-V) and Conductance-Voltage (G/ω-V) measurements were performed at 100 kHz-frequency. The series resistance correction was made on the C-V data. The obtained results showed that the C-V curves shifted to less negative voltages with respect to C-V curve of the non-irradiated MOS capacitor. The sensitivity of the Gd_2O_3 MOS capacitor was found as 49.86 mV/Gy. The density of the oxide trapped charges was found in the range of 3.46×10^{11} – 2.15×10^{12} cm^{-2} in the studied dose range. The density of the interface states was obtained at around 10^{10} eV^{-1} cm^{-2} and not much change was observed between these values. These results showed that an important deterioration in the device did not occur in the studied dose range.

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NEW HEAVY TL-BASED ELPASOLITE SCINTILLATORS FOR RADIATION DETECTION

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In recent years, more attention is devoted in the discovery of new scintillators. Recently, new Ce doped elpasolite halide scintillators with best scintillation properties have been extensively studied by various scientists. Elpasolites are represented by chemical composition X_2YRZ_6 (where X = Cs, Rb,Tl; Y = Li, Na; R = rare earth and Z = F, Cl, Br, I) in which R^{3+} site is located at the center of a regular octahedron of halide ions, and offer well suited environment for the doping of Ce^{3+} and other trivalent ions. In this report I will present our work on the new $Tl_2LiReCl_6$ (Re = Gd, Y, Lu, La) single crystal with different mole% of Ce-concentration (0 to 10 mole%). This material belongs to Chloro-elpasolite crystal family and was grown by two zone vertical Bridgman technique. Also, like other inorganic halide scintillators, it is very hygroscopic.

Luminescence and scintillation characterization under X-rays and γ-rays excitation at room temperature are reported. X-ray excited luminescence spectra of the subject crystals showed broad emission peaks between 350 and 500 nm, with two overlapping peaks. This emission is caused by transitions from the lowest 5d excited state of Ce^{3+} to the two spin orbit split $^2F_{5/2}$ and $^2F_{7/2}$ ground state levels. Since the transition is favored, we expect fast decay time and high light output. We compared energy resolution and decay time of grown crystals by using gamma radiation source. Under 662 keV γ-rays excitation, the light outputs of the investigated samples are found to be < 60,000 photons/MeV for various Ce-concentrations and different materials. Decay time of those crystal scintillators usually were fitted with three components (fast, medium and slow).

Since they contains high Z material, Tl, they can be used to efficiently detect gamma rays or x-rays in many applications such as radiation detection, computerized tomography (CT), positron emission tomography (PET), single photon emission computed tomography (SPECT) and homeland security. Also Li and Gd contained crystals could be promising candidates for neutron detection.

MOSFET RADIATION SENSORS FOR THE QB50-URSA MAIOR CUBESAT

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QB50 is a European FP7 project for facilitating access to space. The QB50 mission will demonstrate the possibility of launching a network of 50 CubeSats (low-cost and miniaturized satellites) designed and built by Universities Teams all over the world as a primary payload on a low-cost launch vehicle to perform first-class science in the largely unexplored lower thermosphere (90-380 km). URSA MAIOR (University of Rome la Sapienza Micro Attitude in Orbit testing) is an 3U-CubeSat participating in the QB50 project. As a payload for QB50, the satellite carries a multi-needle Langmuir probe sampling the electron density of the space around it. The estimated duration of the orbital mission is around two years.

The URSA MAIOR designers are also interested in measuring the ionizing radiation inside the CubeSat and they proposed to us to develop a printed circuit board (PCB) containing radiation sensors. This PCB will be controlled and its information will be read and transmitted by the motherboard of the satellite. Some design constrains are the low area available, I/O bus was fixed by the motherboard capability, high thermal stress in each orbit and high vibrational stress during the satellite launching. To face these challenges, we have designed, fabricated and tested a compact PCB with different MOSFET-based radiation detectors.

Different prototypes were designed, with ten, five and four dosimetric sensors. Due to area and fabrication constrains, the four sensors version was the final design with a pMOS 3N163, a pMOS transistor from a CD4007 chip from Texas Instrument and two 400 nm RADFET transistors in one SOT chip (the latter provided by Tyndall National Institute, Cork, Ireland). All of them are biased at I_{ZTC} current with the temperature-stabilized adjustable current source LM134. The sensors have protection JFET transistors to have all terminals short-circuit during the cycles of radiation. These JFETs will be cut-off during the reading period.

Three identical prototypes were manufactured: for thermal and radiation test, and the final one to be sent to the mission. A temperature sweep from 0 to 40 ºC was carried out. The absolute thermal coefficient for every dosimetric sensor were below 0.4 mV/K. Moreover, different irradiation sessions were applied to a clone of the PCB to study the radiation response up to 110 Gy of accumulated dose. The setup for irradiation used a LINAC with field of 20x20 cm^2 a phonon beam of nominal energy of 15 MV and a build-up layer of 3 cm over the PCB. The output source voltage shifts were measured with the multichannel switch 34970A from Agilent Technologies. The measured sensitivities were between 5 and 20 mV/Gy. The final tested prototype was mounted over the mother board of the satellite. It has been sent to Rome, where the vibration tests were passed. It is programmed to be sent to the space around December 2016.

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A PORTABLE RADIOACTIVE PLUME MONITOR BASED ON A SILICON PHOTODIODE

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After the Fukushima Daiichi Nuclear Power Plant (FDNPP) accident, the System for Prediction of Environmental Emergency Dose Information (SPEEDI) was not well functioning at that time. The Nuclear Regulation Authority (NRA) in Japan decided not to use the SPEEDI any longer when judging whether evacuation is needed or not. From such circumstances, many measuring devices for radioactive plume detection need to be widely deployed around nuclear facilities. Thus, a compact and inexpensive radioactive plume monitor needs to be developed. In this study, we developed a portable radioactive plume monitor using a silicon photodiode. The system consists of a silicon photodiode, a bias supply, a pre-amplifier, a linear amplifier and a multi-channel analyzer. In fact, it is well known that most of artificial radionuclides, such as ^{131}I, ^{134}Cs and ^{137}Cs, emit beta particles as well as gamma radiations. So in our future plan, the system developed in this study will accommodate filter holder which accommodates the detector for continuous air sampling. The background counts caused by gamma-rays for the system were evaluated at 11 sites in Fukushima Prefecture. Gamma-ray pulse height distributions were obtained using a 3 × 3 inch NaI(Tl) scintillation spectrometer (EMF-211, EMF Japan) at the same site as the system background evaluation to evaluate the ambient dose equivalent rates. The background counting rates of the system caused by gamma-rays were directly proportional to the ambient dose equivalent rates. This result suggests that the detection limits for the beta-particles measurements might be increased. However, the system developed in this study may be available to use for a gamma-ray monitoring. Furthermore, the detection limits in 20 μSv h^{-1} as an ambient dose equivalent rate, which was decided by the NRA for early protective measures, were evaluated using the methods of ISO11929. The NRA decided the detection limit as 100 Bq m^{-3} for the radiation monitoring in the emergency situation, however, the detection limit of the system in 20 μSv h^{-1} was found to be approximately 180 Bq m^{-3}. This result suggests that the detection limit for the system be able to decrease effectively by the shielding with lead optimized for the thickness.

A SILICON PHOTO-STRIP DETECTOR COUPLED WITH A CsI(Tl) CRYSTAL

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We developed a radiation detector consisted of a photo-strip sensor detector and a CsI(Tl) crystal. The crystal is sandwiched between a set of the photo-strip sensors which are optically coupled with a crystal scintillator. This detector concept provides not only two-dimensional position information, but also depth of interaction by measuring a signal ratio between the first and second photo-strip sensors. This device makes possible to measure simultaneously energies and positions of incoming particles. The single-sided strip sensors with light entrance window were manufactured using a high resistivity, 5 inch n-type silicon wafer. The photo response of the fabricated photo-strip sensors were measured for the wavelength of 350~1000 nm. The energy resolution of the photo sensor optically coupled with the crystal was measured to be 13.8% using a radioactive gamma source. Two-dimensional position information of a LED light source was obtained by using the scintillator sandwiched between two photo-strip sensors. A study for measurement of the depth of the interaction by varying position of a light source is under way.

RESPONSE OF DIFFERENTLY DOPED LITHIUM MAGNESIUM PHOSPHATE CRYSTALS TO NEUTRONS, PROTONS AND ALPHA PARTICLES

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Nowadays, the optically stimulated luminescence (OSL) becomes a standard method in the modern radiation dosimetry. However, this method did not come into use until the excellent luminescent properties of crystalline Al_2O_3:C have been discovered. Since then, the OSL properties of the Al_2O_3:C crystals have been extensively studied. Although the OSL method has been very popular for more than the past 10 years, the number of commercially available OSL phosphors is still limited (Al_2O_3:C and BeO). Such a situation stimulates efforts for seeking new OSL materials usually in the form of complex oxide crystals.

A lithium magnesium phosphate ($LiMgPO_4$, LMP) is a relatively new and promising dosimetric material, which nowadays undergoes extensive studies. The $LiMgPO_4$ compound exhibits good dosimetric properties that potentially may allow to compete with commercially available TL and OSL phosphors based on LiF (TL) or Al_2O_3:C and BeO (OSL). In general, the Li-containing OSL materials are always of interest, because of the possible application in the neutron fields, where both the Al_2O_3:C and BeO are difficult to exploit. Recently, a micro pulling down (MPD), a relatively new method for single crystal growth, has been also utilized to prepare the LMP crystal samples. This process has been further optimized in order to obtain the crystals of desired luminescent properties.

A high radio-sensitivity of the LMP compound as well as a wide linear dose-response range were repeatedly confirmed for photons and beta radiation (mostly $^{90}Sr/^{90}Y$). However, there are no published papers describing response of this material to other radiation qualities. Therefore, in order to fill the gap, this work presents preliminary studies on differently doped LMP crystals regarding its response to thermal neutrons (moderated $^{239}Pu/Be$), protons (AIC144 cyclotron at the IFJ PAN, Krakow) and alpha particles (^{241}Am) comparing the obtained characteristics with those well known for beta radiation. Changes of TL/OSL curves, dose-response and relative efficiencies are also discussed. These studies allow for concluding whether the LMP compound may be considered as a promising material for applications in radiation dosimetry.

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NFC TAG FOR READOUT OF MOSFET DOSIMETERS

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In the present work an NFC tag has been developed as an ultra-compact reader system to measure the dose absorbed by a MOSFET dosimeter with the help of a smartphone. The Near Field Communication protocol (NFC) is a technology based on Radio Frequency Identification (RFID) according to the ISO14443 standard. The RFID/NFC tags can be supplied by the energy harvested by the tag antenna (passive tags), or by other power source such as batteries or solar cells (active tags). In our case, an NFC-enabled smartphone is used to power up the tag and read the dosimetric parameter. The tag consists of:

- Antenna.
- RFID chip: SL13A from AMS (Premstaetten, Austria).
- Charge pump to increase the regulated voltage provided by the SL13A.
- Current source for biasing the MOSFET dosimeter.
- Analog conditioning to adapt the signal level to the SL13A analog-to-digital converter input range.

A passive NFC tag has been designed, therefore no battery is needed. The electromagnetic field provided by an NFC-enabled smartphone is enough to power up the tag. The power harvested by the antenna is rectified and regulated into the RFID chip. This voltage is doubled by a charge pump IC to bias the MOSFET dosimeter with a current source. The MOSFET dosimeter is connected to the tag through a socket. A set of three DMOS transistors model ZVP3306 (Zetex diodes, USA) has been irradiated with photons of 6 MV generated by a linear accelerator Siemens Artiste (Siemens AG, Germany). It is common to use the increment of threshold voltage (V_T) as dosimetric parameter in MOSFET-based dosimeters. To validate the NFC reader, the increment of threshold voltage of irradiated MOSFETs has been measured and compared with the values obtained by means of the dosimetry system previously developed by our research group [1]. The global sensitivity, calculated as the slope of the linear fit of source voltage accumulated shift and the accumulated dose (up to 20 Gy), was obtained using both dosimetric systems. For the conventional reader the value obtained was (4.80 ± 0.06) mV/Gy, while a value of (4.75 ± 0.15) mV/Gy was obtained using the NFC reader showing a very good agreement.

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EVOLUTION OF GAN-BASED SENSOR CHARACTERISTICS DURING PROTON IRRADIATION

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High response speed sensors made of thin GaN-based structures can be important for the optical readout in harsh radiation environment at Large Hadron Collider (LHC) and other collider facilities. In this work, the metal-semiconductor-metal structure sensors formed on the MOCVD grown GaN heterostructures have been studied. The proton induced luminescence (PI-L) and the microwave probed photoconductivity (MW-PC) transients have simultaneously been recorded during 1.6 MeV protons emitted by a linear particle accelerator Tandetron 4110A. The PI-L and MW-PC measurements allowed for tracing the evolution of the parameters of radiative and non-radiative recombination. Characteristics of carrier lifetime and charge collection efficiency dependent on irradiation fluence have been examined. The dominant radiation defects introduced by 1.6 MeV proton beam have been unveiled.

RESPONSE OF DIFFERENT ELECTRICAL PARAMETERS OF IRRADIATED pMOSFET

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Interface and fixed oxide trapped charges are produced on MOSFET when they are exposed to ionizing radiation. This irradiation influences on the electrical parameters and characteristics of transistors. Traditionally, the threshold voltages shift (ΔV_t) in the saturation region has been used as main dosimetric parameters when pMOS transistors are used as dosimeters. However, not only threshold voltage is modified by radiation, but also other parameters are modified. This work presents a study where the influence of dose on electrical parameters of commercial and specific pMOS (RADFETs) is analysed.

As commercial transistors 3N163 (Linear Technology) and CD4007 (Texas Instruments) were selected and as specific transistors the RADFET of 400 nm model W5 was chosen, provided by Tyndall National Insitute, Cork, Ireland. The irradiation facilities were at the Hospital Universitario "San Cecilio" in Granada (Spain), using a linear accelerator Mevatrons KDS (Siemens). A semiconductor parameter analyser, B1500 (Agilent Technologies) was used to measure the current-voltage curves of the MOSFETs. The irradiation conditions of dosimeters were with all the terminals grounded and in electronic equilibrium.

Several tests were carried out to measure the electrical parameters before and after irradiation. The transistors were studied in subthreshold, triode and saturation region and also with the charge pumping technique. The most important parameters studied are:

- Subthreshold swing.
- Current substrate-gate, interface traps charge and oxide traps charges.
- Threshold voltage with different process: linear fit, constant current, Fowler-Harstein, maximum transconductance, etc.
- Transconductance and derivate transconductance.
- Early voltage.

Some preliminary results of this experimental study show, as it was expected, a tendency of change in the parameters with the dose. For example, the subthreshold swing of the 3N163 with a sweep of source-bulk voltage between 0 and 5 V has a value between 0.42 mV/dec*Gy and 0.29 mV/dec*Gy respectively. In the case of CD4007 this parameters shift between 0.28 -0.19 mV/dec*Gy also with V_{SB} between 0 and 5 V, and in both cases up to 20 Gy of accumulated dose. Our aim with this work is to provide a comparative study and discussion of the parameters calculated in each region for every transistor. We are expecting different response to the radiation of them related to the transistor fabrication process.

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PULSED OSL READOUT OF DETECTORS BASED ON $YAlO_3$:Mn CRYSTALS

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Application potential of Mn^{2+}-doped $YAlO_3$ (YAP) for thermoluminescent (TL) dosimetry of ionizing radiation has been shown previously (see [1] and references herein). For this purpose, one of two types of detectors can be used. The first type produces green emission near 530 nm (caused by Mn^{2+} ions) in the main TL peak at 200 °C, whereas the second type produces an orange emission around 640 nm in the TL peak near 350 °C. Detectors of the first type have a considerable daylight effect on fading (bleaching effect), and optical stimulation by blue-green light can be used for their readout.

Main features of the $YAlO_3$:Mn^{2+} detectors are as following: high thermochemical and time stability, high resistance to radiation damage, high sensitivity to ionizing radiation (up to 40 relative to TLD-100 for ^{60}Co), extremely wide range of linearity (from few mGy up to few kGy), high effective atomic number (Z_{eff} = 31.4) and consequently high energy response (about 40 for photon radiation of 55 keV/^{60}Co), low thermal fading of single crystalline detectors (<20%/year for 200 °C peak and <5%/year for 350 °C peak). In such a way the material is a good candidate for wide-range dose measurements, especially when tissue equivalence is not required, as well as for a purpose of the radiation quality determination if used alongside with other low-*Z* materials.

In the case of the CW-OSL readout of detectors of the first type, it is required an effective spectral separation of wavelengths of optical stimulation and registration. Even if such spectral separation will be provided (e.g. stimulation by blue light and registration in green range), the Mn^{2+} photoluminescence as a background signal reduces essentially the possibility of detection of low doses.

The possibility of pulsed OSL readout of the detectors was shown by us recently [2]. For this purpose, stimulation with green light (525 nm) and an optical registration in a close spectral range (~490 nm) were tested. The characteristic OSL decay time for the studied detectors was found to be about 80 ms independently on irradiation dose applied from 50 mGy to 1 kGy. The pulsed OSL technique offering a time resolution allows to eliminate the Mn^{2+} photoluminescence with a much shorter lifetime (3.5 ms) and in such a way to decrease considerably a detection threshold of these OSL detectors. In the measuring conditions used in [2], the detection limit was a little bit lower than 50 mGy. A possibility to decrease the detection limit by variation of wavelength and power of stimulation light and accumulation time is discussed in this work.

References:

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CONSTRUCTION AND FIRST TESTS OF A PET-LIKE DETECTOR FOR HADRONTHERAPY BEAM BALLISTIC CONTROL

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We present the first results obtained with a detector, called Large Area Pixelized Detector (LAPD), dedicated to the beam ballistic control in the context of hadrontherapy. The purpose is to control the ballistics of the beam delivered to the patient by in-beam and real time detection of secondary particles, emitted during its irradiation. These particles could be high energy photons (prompt γ), or charged particles like protons, or 511 keV γ from the annihilation of a positron issued from the β^+ emitters induced in the patient tissues along the beam path. These methods require being able to detect with a huge efficiency, and with a minimum dead time, these secondary particles emitted when the beam hits the patient. The LAPD is similar to a conventional Positron Emission Tomography camera. The 511 keV γ are detected and the reconstructed line of responses allow to measure the β^+ activity distribution. Nevertheless, when trying to use γ from positron annihilations for the ballistic control in hadrontherapy, the large γ prompt background should be taken into account and properly rejected. This detector is made of two half-rings of 120 channels each. Each channel consists of a 13*13*15 mm^3 LYSO crystal glued to a PMT. The PMT signal is sent to an Analog Sampling Module (ASM board). This VME 6U board is based on the DRS4 chip technology (Switch Capacitor Array) from the Paul Sherrer Institute and was specially designed for the LAPD detector. This board receives up to 24 differential analog input signals, with maximum amplitude of 600 mV, digitized by 12 bits - 33 MHz ADC. The sampling rate varies between 1 and 5 GHz, for a maximum buffer size of 1024 samples. The first part of the talk is devoted to the description of the detector and its electronics. Then, we describe the various trigger strategy, and the on-going upgrade of the VME-based acquisition system to a μTCA-based technology. The selection of the coincident 511 keV γ is also discussed, and the reconstruction using an iterative MLEM algorithm is presented. In the last part of the talk, few results from an experiment with one third of the detector, using proton and carbon ion beams at the Heidelberg Ion-Beam Therapy Center in 2014, are also described, and the Coincidence Resolution Time and energy resolution are given. First reconstruction results, obtained with a phantom filled with a high intensity FDG source at the cancer research center of Clermont-Ferrand in 2015 are also shown. This detector is now characterized, and will be installed at the Lacassagne hadrontherapy center (Nice, France), on the 65 MeV line (Medicyc) in December 2015 first, and on the future 230 MeV line (S2C2 from IBA) in 2016. The capability of this detector and its associated electronics to measure the ballistic of the proton beam in real clinical conditions with a sufficient precision will be evaluated.

RAD2017

CHARACTERIZATIONS OF Co-60 GAMMA IRRADIATION OF HfO_2 NÜRFETS

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Novel studies have been focused on the exploring new high-k dielectric materials as alternative gate oxides to overcome the scaling limit of SiO_2 due to high tunneling and reliability concerns. Among the various high-k dielectrics materials HfO_2 is considered as one of the most promising materials exhibiting the desirable properties including a high dielectrics constant, high density, large bandgap, and a good thermal stability in contact with silicon relative to the other high-k materials. Beside potential usage of HfO_2 for state of the art MOS based technologies; It has also high potential to be use in a new dielectric layer for radiation dosimetry, due to higher effective atomic number, density and lower band gap energy than conversional SiO_2 gate dielectrics. Hence in this study, we have fabricated Nuclear Radiation Sensing Field Effect Transistor (NürFETs) with 100 nm- thick HfO_2 gate dielectrics and Co-60 gamma irradiation effects on the device characteristics were investigated. The obtained results were compared with RadFETs having conversional 100 nm- thick SiO_2 gate dielectric layers.

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AN ANALYTIC METHOD FOR IN SITU NUCLIDE IDENTIFICATION IN MOBILE GAMMA SPECTROMETERS

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Decommission of nuclear reactors, nuclear accidents or terroristic attacks may lead to large-area contamination with radionuclides. Environmental radiation security and safety at transport of nuclear materials, in industry, mining, nuclear medicine or isotope laboratories are civil fields where radiation protection is required and fast in situ methods of nuclide identification are necessary to quickly estimate the extent of possible radioactive contamination. We present the mobile gamma spectrometer NucScout which is based on a 2”×2”NaI(Tl) scintillation detector. The device is equipped with the necessary electronics and a special software package including nuclide libraries for mobile and autonomous application. When expensive gamma spectrometers and computer aided nuclide identification methods are appropriate for laboratory use only, NucScout may automatically identify the basic nuclide vector, calculates and visualizes the corresponding activities and provides the local dose power for a homogeneously assumed radiation source within rather short time intervals. For instance, a ^{137}Cs activity of 200 Bq/kg located at a distance of 1 m is identified within 10 s. Nuclide identification is realized by means of a new peak-shape verification method which does not need background subtraction. It is based on nuclide library information, automatically determines peak parameters such like peak position (mu) and standard deviation (sigma) assuming a spectral Gauss distribution and calculates the relevant peak areas to determine corresponding nuclide activities. For NucScout calibration, a given nuclide vector measured in chosen geometry is used to calculate the detector specific polynomic dependencies mu(E) and sigma(E) where E denotes known gamma transition energies. The NucScout registration efficiency for typical (but arbitrary) energy ranges between about 100 keV and 2 MeV is approximated by the function eta(E) = A*EB where the parameters (A, B) are found from a best fit to the peak areas of registered nuclide gamma lines of known transition probability. The presented algorithm is also applied in the LabScout device (www.sarad.de).

THERMOLUMINESCENCE (TL) DOSE RESPONSE CHARACTERISTICS AND REUSABILITY PROPERTIES OF NATURAL MUSCOVITE MINERAL

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In this study Thermoluminescence (TL) glow curves of natural Muscovite mineral were studied in respect of dose response and reusability properties. Muscovite is a common rock-forming silicate mineral within the mica group, and it is a secondary mineral result from the alteration of quartz, feldspar etc. that are used as natural TL dosimeter. It is generally found in white colour, classified according to crystallographic criteria in dioctahedral, and has the approximate chemical formula $KAl_2(Si_3Al)O_{10}(OH,F)_2$. All TL measurements were carried out by using Lexsyg Smart Thermoluminescence Reader which has Sr-90 beta source with 1.85Gy activity. 3 cups (each 20 mg) of Muscovite powder samples have been exposed to beta radiation between 0.115-414Gy for the part of dose response experiment, detected with the wideband blue filter and heated from room temperature (RT) to 400°C with the heating rate 2°C/s for TL readout. Results showed that glow curve had a mean peak at around 230°C and two shoulder peaks at around 84°C and 164°C for the relatively low doses i.e. between 3.45-138 Gy. In addition, mean peak of glow curve shifted to lower temperatures at about 164°C and that made the other two peaks -at around 84°C and 230°C-became shoulder peaks for the higher doses i.e. 276-414Gy. Furthermore, in this study we have pointed out the reusability properties of the samples. Muscovite samples in powder form were exposed to 103.5Gy and 207Gy, detected with the wideband blue filter and heated from RT to 400°C with the heating rate 2°C/s for TL readout and same manner repeated 10 times in order to evaluate the reusability of the mineral. Outcomes showed that all 10 cycles have the same 3 peaks at the same temperatures -approx. 81, 166, 215°C- for the 103.5Gy irradiation and again all 10 cycles have the same 3 peaks at the same temperatures -approx. 86, 164, 197°C- for the 207Gy irradiation. Experimental results indicated that crystal structure of the natural Muscovite mineral is not degenerated by heating up to 400°C for at least 10 times and exhibits very gratifying reusability.

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STRUCTURAL AND OPTICAL PROPERTIES OF CdTe THIN FILMS OBTAINED BY ELECTRODEPOSITION

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Thin films of CdTe have been obtained by electrodeposition in presence of tartaric acid on fluorine-doped tin oxide (FTO)-coated glass substrates, under constant voltage of 1.40 V. In order to determine the deposition parameters of CdTe, cyclic voltammetry has been performed. The films were thermally annealed at T= 200 °C, T= 300 °C, T= 400 °Cand T= 450 °C, in air atmosphere. The X-ray diffractograms show that the films obtained at 90 °C are nanocrystal with cubic structure and with grain size of 6 nm. The thermal annealing treatment of CdTe films contributes to grain growth and obtaining polycrystalline films. Atomic Force Microscope shows that the films are smooth and uniform with spherical grains. The optical properties of the CdTe films have been investigated by measurements of wavelength-dependent transmission. The optical bandgap of as grown films is 1.48 eV and is decreasing up to 1.45 eV, for films annealed at temperature of 300 °C, and increasing again at temperature of 450 °C. Lastly, SnO_2-CdS-CdTe-grafite type photochemical solar cells have been made, using the 0.1 M NaOH-0.1 M Na_2S_x electrolyte. From the measured current-voltage characteristics, open-circuit voltage of V_{oc}= 500 mV and short circuit current of I_{sc}= 1.2 mA/cm^2 have been determined.

RADIATION RESPONSE OF TWO TYPES OF COMMERCIAL RADFETs

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We have studied radiation response of Radiation Sensing Field Effect Transistors (RADFETs) produced by two commercial vendors – Tyndall National Institute (Cork, Ireland) and REM (Oxford, UK).

Two Tyndall device types, differing only in post-oxidation anneal parameters, show different trends during irradiation with zero and positive bias. Regarding the comparison between Tyndall and REM RADFETs, Tyndall samples are significantly more sensitive at zero bias, while the sensitivities of the two types of samples are comparable at the positive bias. We observe the Enhanced Low Dose Rate Sensitivity (ELDRS) effect for both Tyndall and REM samples at very low dose rates, but employ Monte Carlo simulations and additional experiments to show that these effects may be due to experimental setup and are not the real effects.

Finally, we re-analyse historical flight data based on the results of these radiation experiments.

Radiation Effects

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IRRADIATION RESISTANCE OF ELASTOMERS BASED ON TERNARY RUBBER BLENDS REINFORCED BY NANO FILLER

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Elastomers based on ternary rubber blends are industrially very important materials as they achieve the best compromise of different network precursor properties. In structuring of multi-phase material, characteristics of individual components can be partly preserved or significantly changed due to the effect of intermolecular interactions. In order to design the compound composition for elastomers, which will have good properties from technological aspect it is necessary to select a representative combination of network precursor. In this investigation, the irradiation resistance of elastomeric composites based on natural rubber (NR), butadiene rubber (BR) and styrene butadiene rubber (SBR) reinforced with carbon black (size of primary particles 28-36 nm) were studied. The sulfur curing behavior of compounds was estimated using the oscillating disk rheometer. All elastomeric composites were subjected to gamma irradiation different absorbed dose (100, 200, 400 kGy) with irradiation rate 10 kGy h^{-1}. The mechanical properties (hardness, modulus at 100% elongation, tensile strength, and elongation at break) were determined before and after irradiation of samples. It was assessed that tensile strength, modulus at 300% elongation and hardness increased, but elongation at break decreased with increasing irradiation dose. SBR as network precursor influenced appropriate toughness. NR as ternary blend component provided superior resilience. Prepared composites can be used in many industrial applications such as radio controlled model race car tires to footwear applications.

GAMMA IRRADIATION AGEING STUDY OF ELASTOMERS BASED ON ETHYLENE/PROPYLENE/5-ETHYLIDENE-2-NORBORNENE RUBBER

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Elastomers based on ethylene propylene-diene-monomer rubber (EPDM) as network precursor have lot of applications. This materials are used as a medium for water resistance in electrical cable-jointing, roofing membranes (since it does not pollute the run-off rainwater, which is of vital importance for rainwater harvesting), in glass run channels, and appliance hose, o-rings, solar panel heat collectors, belts, electrical insulation, plastic impact modification, and many other applications. The most common use is in vehicles. It is used in door, window and trunk seals. EPDM granules can be mixed with polyurethane binders and troweled or sprayed onto concrete, asphalt, screenings, interlocking brick, wood to create a non-slip, soft, porous safety surface for wet-deck areas. The goal of this project was to study the effect of gamma irradiation on the properties of carbon black reinforced elastomers based on EPDM (ethylidene norbornene content 3.8 mass %) in combination with other network precursors (CSM or NBR). The compounds were cross-linked either with peroxide or sulfur. It was assessed that elastomers obtained with different curing systems have different sensitivities to gamma irradiation. It was estimated that the values for tensile strength, hardness, and modulus at 300% elongation for peroxide cross-linked elastomers were higher, but elongation at break values were lower when compared with sulfur cross-linked rubbers. Peroxide cross-linked samples were more stable at low doses, as their properties were maintained constant, whereas at higher doses, they showed severe degradation.

THE ASSESSMENT OF GAMMA IRRADIATION AGEING OF ELASTOMERIC MATERIALS FILLED WITH RECYCLED RUBBER POWDER

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Technological development of reclaiming scrap waste rubber process is of great interest due to its significant influence to the environment. The recycling of waste rubber by mechanical or chemical methods is the ultimate approach to solve the problems. Transforming bulk rubber to powders using mechanical process is the most preferable procedure of reclaiming rubber and it is more economical compared to chemical process. Recycled rubber powder (RRP) can be used as filler for elastomers and as modifiers for asphalt. Blending of two or more rubbers as network precursors is a useful technique for preparing material with properties superior to those of individual constituents. Moreover, each kind of rubber has its own advantages and specific application due to its chemical configuration. Elastomers based on chlorosulfonated polyethylene (CSM) are used for cable jacketing materials and have excellent radiation resistance needed in nuclear power stations. Gamma irradiation is a powerful means for rubber crosslinking, however, exposure to higher dosage degrades the polymer network chains. It is well known that during irradiation several processes take place (main chain scission, crosslink formation and crosslink breakage). The extent of crosslinking and chain scission depends on network precursor structure. The focus of this work was to study the gamma irradiation resistance of sulfer elastomeric nano composites based on two quite different network precursors (nonpolar natural rubber and polarCSM) and different content of RRP. The irradiation dose was varied. Natural rubber is categorized as a radiation crosslinking type of polymer as it contains a double bond in its basic cis 1, 4 polyisoprene units. It was estimated that the tensile strenght for all prepared elastomeric materials increased with increasing gamma irradiation dose reaching its maximum value at 200 kGy as a consequence that the crosslinking process was the dominating one up to this dose, whereas the degradation process has apparently prevailed for higher doses.

AN OVERVIEW OF THE CURRENT MODELS FOR THE CIRCUIT-LEVEL SIMULATIONS OF SINGLE EVENT TRANSIENTS

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A common source of malfunction in advanced nano-scale CMOS integrated circuits are the single event transients (SETs), induced by the interaction of high energy ionizing particles with the sensitive volume of the target device. The SETs are manifested as a pulsed current flow through the struck device, causing a disturbance of the corresponding voltage level, and consequently leading to data corruption. For this reason, evaluation of the SET effects and application of appropriate techniques for their mitigation are fundamental tasks in the design of radiation-tolerant circuits and systems.

SET analysis is generally based on the multi-scale modeling and simulation approach comprising three main phases: device-level modeling and simulation, circuit-level modeling and simulation and logic-level modeling and simulation. Performing all aforementioned characterization phases for every design would be costly and time-consuming. In order to reduce the time and cost of the design process, the focus is on the development of efficient circuit-level modeling and simulation methodologies with a good trade-off between the complexity and speed of simulations.

The typical approach for the circuit-level simulations of SETs is based on the use of appropriate current source connected to the target node. Numerous models for the SET-induced current have been proposed, and they can be classified into five major groups:

(1) Models based on single voltage-independent current sources (e.g. double exponential, rectangular, trapezoidal),

(2) Models based on multiple voltage-independent current sources (e.g. two double exponential current sources connected in parallel),

(3) Voltage-dependent current models (consider the dependence of node voltage on SET current),

(4) Piecewise linear interpolation models (derived by linear interpolation of the SET current pulse obtained from device simulations or experiments),

(5) Look-up table models (SET current waveforms obtained from device simulations or experiments, for different design and operating conditions, are stored in the form of table).

As an alternative to the current injection concept, an approach employing a switch with a series resistor has been proposed for SET simulations. Unlike current-based models, the switch-based concept reproduces the SET voltage pulse (close duration of switch determines the SET pulse width and series resistor controls the pulse amplitude).

All aforementioned modeling and simulation approaches have specific advantages but also certain drawbacks which limit their accuracy or make it difficult to apply them in the circuit simulators. Hence, it is necessary to consider the key features of each approach and determine to what extent it could be applicable for evaluating a particular design. In that regard, this study analyzes the benefits and shortcomings of the common SET modeling and simulation approaches, providing useful guidelines for the selection of a suitable approach for a particular design.

EFFECT OF CHRONIC γ-IRRADIATION ON RI-TRANSFORMANT AND HAIRY ROOTS OF DIGITALIS PURPUREA L. IN VITRO

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Previously we analyzed small doses of acute γ-irradiation on the formation of the radio adaptive reactions in intact plants, regenerated Ri-transformed plants and hairy roots of *Digitalis purpurea* L. under *in vitro*conditions. It was established that the adaptive stress response differs in plants and cell cultures.

In the present work the effect of chronic gamma-irradiation (total dose of 3 cGy and 20 cGy) on the main components of non-enzymatic antioxidant defense of *D. purpurea in vitro* was studied.

Adverse biotic and abiotic factors lead to increase in substances production in plant cells which eliminate the harmful effects of the stressor. Chronic γ-irradiation of *Digitalis purpurea* caused changes in flavonoids and pigments content in plants and flavonoids content in hairy roots (HRs) culture. After a month of irradiation an increase of chlorophylls, carotenoids and flavonoids content was observed in transformed and not transformed plans, though the increase in transformed plans was higher. Roots exposed to the minimal doses of 3 cGy also synthesized higher amount of flavonoids than the non-irradiated control. Ri-transformed roots synthesized an order of magnitude less flavonoids per wet weight unit than plants, but nevertheless the mechanism of adaptation to chronic exposure in roots as well as in plants was activated. After irradiation of transformed plants with 20 cGy an increase in carotenoids, flavonoids, chlorophylls content was observed which is approximately equal to the stimulating effect of acute irradiation with 1-3 Gy described earlier. Thus, we have shown that the accumulation of phenolic compounds as one of the manifestations of the stimulation effect of radiation has a threshold and probably based on the principle “all or nothing”. Also, our data indicate the antioxidant role of chlorophyll b, which protects chlorophyll a in a light-gathering complex of photosystem II from oxidative damage.

Based on the presented study we can assume that Ri-transformation of *D.purpurea* itself causes an increase of the flavonoids and carotenoids content in the transformants tissues and the chronic γ-irradiation with stimulating doses induces pigments and flavonoids production in the intact and Ri-transformed plants as well as flavonoids in the HRs, that is a sign of the radio adaptive response to chronic γ-irradiation.

POSITRONICS OF RADIATION EFFECTS IN CHALCOGENIDE SEMICONDUCTOR GLASSES

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The experimental techniques exploring phenomena of positron-electron interaction, namely the positron annihilation lifetime spectroscopy (PALS) and Doppler broadening of annihilation radiation (DBAR), are presented as informative tools to study radiation- and thermally-induced effects in chalcogenide semiconductor glasses (ChSG).

At the example of three types of ChGS samples of archetypal As-S system (affected by high-dose gamma-irradiation from ^{60}Co source, annealed after gamma-irradiation and finally rejuvenated), the time-dependent processes of free-volume voids agglomeration (expansion), fragmentation (refining) and discharging (contraction) are identified as main stages of physical ageing in S-rich As-S glass compositions, while a competitive channel of coordination topological defects (CTD) formation associated with free-volume voids charging becomes significant in a vicinity of near-stoichiometric As_2S_3 glass. The data of combined PALS and DBAR measurements are correlated well with radiation-induced shift of fundamental optical absorption edge of the studied glasses (serving as optical signature of radiation effect). Comprehensive approach applied allows an unambiguous distinguishing the effects of structural relaxation near glass-transition (physical ageing) and gamma-induced CTD formation. The free-volume evolution in As-S glasses associated with below glass-transition relaxation is shown to be consistent with void fragmentation-agglomeration processes, while gamma-induced CTD formation is caused mainly by void charging.

The meaningful model for gamma-induced radiation and relaxation-driven evolution in atomic-deficient free-volume void structure of As-S ChSG giving a unified insight on their structural-chemical nature is proposed.

EFFECTS OF IN VIVO PROTON IRRADIATION ON MOUSE SPLEEN CELLS

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One of the major problems derived from the exposure to ionizing radiation is the impairment of the immune system. The consequent immune-depression increases the risk of infections and may lead to immune-mediated disorders. Intensity and duration of the immune-compromised phase and its recovery depend on dose, dose-rate and quality of radiation. In recent years, there has been a great interest on the effects induced by protons, both for a better assessment of the health risks associated to space flights in astronauts and for a better understating of their effects in radiotherapy for oncologic patients.

In the present study we investigated the effects of the *in vivo* exposure to 2 Gy integral dose absorbed by medium energy proton beams on mouse lymphoid spleen cells. A proton accelerator under construction in the framework of the Italian TOP-IMPLART project was used. The facility consists of a low radiofrequency (425 MHz) and low energy (7 MeV) injector and linear structures operating at high radio-frequency (3 GHz) to accelerate protons to medium (35 MeV) and high energy (150 MeV). Irradiations were performed with pulsed (3.4 ms, 10Hz) proton beams emerging with energy of 27 MeV (in vacuum), choosing a particular setup to have a uniform (98.5%) coverage of the selected area at 100 cm from the accelerator in air with 24.5 MeV protons penetrating 6 mm in tissue. During the exposure mice were anesthetized in order to keep them in the right position. Sham-exposed anesthetized age/gender/strain-matched mice were used as controls. Twenty-four hours after irradiation each mouse was individually analyzed for several parameters (5 mice/group). Results showed that spleen cell number was partially affected by the exposure whereas flow cytometry analyses revealed that the frequencies of helper and cytotoxic T cells, identified by CD4 and CD8 markers respectively, were not altered. Also the frequency of B cells, as identified by the expression of CD19, was not affected. Spleen cells were stimulated with an anti-CD3 antibody or LPS to induce T cell and B cell proliferation, respectively. In spite of the observed unchanged frequencies, both T and B cells were functionally impaired by the exposure. T cell proliferation indeed was reduced by 50% in exposed mice compared with controls. B cells also displayed reduced cell proliferation in response to the mitogenic stimulus (-33%). Experiments are in progress to assess the effects on cytokine secretion (of Th1/Th2/Th17 type) by T cells and antibody production by B cells.

This first study allows us to conclude that after 24 hours, in vivo local exposure to protons induces a small reduction in spleen cell number, leaving unaltered the frequencies of T and B cells but drastically affecting their ability to proliferate in response to mitogenic stimuli.

Acknowledgments. the present study was partially supported by the Italian Space Agency (ASI) project BIOxTREME.

EFFECTS OF DIFFERENT SPECTRUM LED-LIGHTING ON SEVERAL MEDICAL PLANTS

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A grate amount of pharmaceuticals are produced with a use of plant components which have certain benefits: low toxicity, the complexity of the impact and the ability of its long-term use without any significant side effects. Therefore, applying of biotechnological methods for increasing secondary metabolites production in plants and cell cultures is highly promising. In vitro plants and cell and tissue culture grows are regulated by several factors, and the light is highly important among them. Illumination system for *in vitro* culture should provide light of the specific spectral region that is involved in photosynthesis and in the photomorphogenetic responses (Seabrook 2005). Fluorescent lamps have been the most popular in the tissue culture room, but it consumes a lot of power when generating heat in the tissue culture laboratory. Light emitting diodes (LEDs) have been proposed as a new light source for plant research chambers and a potential alternative light source for in vitro plant growth and development (Yeh and Chung 2009).

The LED-lighting of different spectrum and intensity effect study was conducted on several medical plants: *Catharanthus roseus* G. Don – a medicinal plant which accumulates pharmacologically important anticancer terpenoid indole alkaloids; *Aerva lanata* L – a producer of indole alkaloids; *Digitalis purpurea* L. – a natural source of cardiac glycosides.

A significant growth stimulation of *C. roseus* plants cultivated under different ratio of the blue and red light in LED spectrum was revealed (in comparison with fluorescent lighting). The ratios of blue and red light in the spectrum that lead to flowering, stimulation of biomass accumulation along with indole alkaloids accumulation were established. Blue lighting slows down stem, leaf and root growth that leads to compact plants with thicker leaves formation allowing better light absorption and usage. This newfound feature is highly important in seedlings cultivation. Blue lighting also leads to the decrease in the amount of the pigments, though it is known that blue-violet part of the light spectrum is almost entirely absorbed by the chlorophyll which create conditions for the maximum photosynthesis intensity. Conducted research allowed us to conclude that lighting only by red and blue part of the light spectrum is not optimal for biosynthesis and pharmacologically valuable metabolites accumulation in plants. Based on the data resaved we assumed that it is advisable to include green and UV parts of the spectrum for the plant lighting purpose which is scheduled in our further works.

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CHANGES IN HAEMATOLOGICAL PARAMETERS OF FISHES IN THE GRADIENT OF RADIOACTIVE CONTAMINATION OF WATER BODIES WITHIN THE CHERNOBYL EXCLUSION ZONE

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During the 2010-2016 we studied hematologic parameters in the peripheral blood of fish, inhabiting water bodies with different levels of radioactive contamination within the Ukrainian part of the Chernobyl exclusion zone (CEZ). The leukograms and rate of abnormal red cells as different type of invaginations, ramifications, micronuclei, amitosis etc. was analysed in peripheral blood of the perch (*Perca fluviatilis*), the common rudd (*Scardinius erythropthalmus*) and the Prussian carp (*Carassius gibelio*). The analysis of the quantitative characteristics of the individual leukocytes pools in the peripheral blood of fishes showed the significant differences between the same cells of the fish that inhabit the water reservoirs with different level of radioactive contamination. These fish differ from those of the reference reservoir in low values proportion of lymphocytes and high neutrophils, eosinophils, basophils, as well as in the presence of foam cells. The comparative analysis of morphometric parameters of erythrocytes in peripheral blood of the common rudd showed that corpuscular volume of fish from the reference lake characterised by the homogeneous structure – a high quantity of cells has a similar volume. As to water bodies with medium and high levels of radioactive contamination, we can observe here an increased tendency of heterogeneity of studied parameters with formation of so-called double-humped curve, which can testify to the anaemic processes in blood of fish. We registered a high rate of red cells aberrations and abnormalities in peripheral blood of fish from the stagnant water bodies within the CEZ, where the absorbed dose rate on the fish organisms due to internal and external sources of irradiation have reached 270 μGy h^{-1} that is more on three orders higher in comparison with water bodies with background level of radioactive contamination, making a point of the amount of red cells with deformed shape of nucleus as different type of invaginations and ramifications as well as formation of double-nucleus cell, schistocytes (cells without nucleus), parietal nucleus, microcytes, nucleus and cytoplasm vacuolization, micronuclei etc. Our studies in peripheral blood of fish from water bodies within the CEZ have shown an increased level of abovementioned morphological damages of erythrocytes, which is generally for pray fish in 4-16 times and for predatory fish in 7-15 times was higher in comparison with fish from the reference water bodies with background levels of radioactive contamination. Data analysis of the dynamics of structural defects and disorder of the cell proliferation in peripheral blood of fish that habitat water bodies with high levels of radioactive contamination, allows us to assume a genome instability and increase the accumulation of chromosomal and genetic defects in organisms of fish that can be transmitted to future generations.

BEHAVIOR OF THE MODERN INTEGRATED CIRCUITS AFTER THE LATCH-UP PARRYING

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This work is devoted to research of the impact of single and multiple latch-up on subsequent behavior of modern ICs.

Nowadays, a huge amount of research and investigation on latch-up effect in integrated circuits is available. Several methods, as well as specialized ICs and electronic blocks, for latch-up parrying have been developed. Physical models of "latent damage" from single event latch-up with following IC failure during exposure in latch-up state, have been discussed. However, a question is constantly left out of consideration - how can successfully parried single (or multiple) latches change the subsequent behavior of IC?

In this work, results are introduced from:

- the analysis of latch-up studies for more than 100 modern IC types;

- the consideration of the impact of multiple latch-up on subsequent radiation behavior, based on the example of SRAM IC;

- the consideration of obtained dependence of IC's durability from the time of its exposure in latch-up state.

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SUBLETHAL DOSE OF X-RAY IRRADIATION INDUCES GENETIC INSTABILITY IN ENDOMETRIAL MESENCHYMAL STEM CELLS AT THE KARYOTYPIC LEVEL

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We aimed to study the karyotype structure of human adult stem cells after X-ray irradiation. The object was cultured endometrial mesenchymal stem cells (eMSC) isolated from desquamated endometrium of menstrual blood of the healthy woman. eMSC at the 9th passage were irradiated with the sublethal dose 5G. Irradiated cells were cultivated under standard conditions and at the 13th passage they were underwent to karyotyping assay with G-banding technique. The cytogenetic analysis revealed that the progeny of irradiated cells exhibited genetic instability. Most cells (more 80%) had chromosomal abnormalities. Most types of karyotypic changes were aneuploidy (chromosomal copy number) and chromosome breaks (near-centromeric and terminal). Within a particular karyotype various chromosomes may be involved in breaks. Chromosome 1, 4 and X were involved in chromosomal rearrangements not randomly. According to literature data chromosome 1 and 4 exhibited morphological instability in liquidators of the Chernobyl nuclear power plant accident underwent radionuclide exposure but their dosimeter interpretation is unclear. Not irradiated eMSC at the 13th passage (80%) had standard karyotype. Deviations from normal karyotype were random. Chromosomal breaks were not registered.

Our findings show that sublethal X-ray irradiation of eMSC results in multiple disorders of the genetic apparatus structure at the karyotype level.

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COMPARISON OF X-RAY AND HEAT SHOCK EFFECTS ON GENETIC STABILITY OF STEM CELLS IN CULTURE

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The aim of this study was the comparative cytogenetic analysis of endometrial mesenchymal stem cells (eMSC) in vitro after exposure to different types of exogenous stress - sublethal dose of X-rays (5 Gr) and sublethal heat shock (45 ° C for 30 min). For analysis of chromosomes we used the G-banding technique.

It was found that both stresses induced changes in the structure of eMSC karyotype. In both cases more 80% of the analyzed cells had karyotypic abnormalities. The main types of chromosome rearrangements were aneuploidy and chromosomal breaks. **C**hromosomes 1 and 4 were involved in breaks more often than other chromosomes both after heat shock and irradiation. The number of chromosomes involved in rearrangements as a result of heat shock was larger than after X-ray. In both cases chromosomal breaks were found in centromeric and distal loci.

Overall, karyotype destabilization in stem cells exposed to a heat shock and X-ray was similar. It is typical for cells with disturbed cell division program. X-gal assay showed that cells after shock entered to replicative senescence which prevents their immortalization/transformation.

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THE EFFECT OF ACCELERATED CARBON IONS WITH AN ENERGY OF 450 MeV/n ON THE COGNITIVE FUNCTIONS IN MICE IN VIVO

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Humans are exposed to ionizing radiation under a variety of conditions, primarily associated with medical treatment. While the risks related to those situations are well established, there is considerable uncertainty with respect to other types of human radiation exposure such as during space travel and radiotherapy. The health risks for people exposed to high-LET radiation include possible cognitive deficits. The pathogenesis of radiation-induced cognitive injury is unknown but may involve loss of neural precursor cells from the subgranular zone (SGZ) of the hippocampal dentate gyrus.

The aim of this work was to investigate the accelerated carbon ions effect on cognitive functions in mice.

Experiments were performed on male outbred albino SHK mice at age of two months. The animals were caged under the standard conditions in animal facility of the ITEB RAS (Russia). Mice were irradiated with U-70 particle accelerator at IHEP (Russia) in a dose of 70 cGy by accelerated carbon ions with an energy of 450 MeV/n in the Bragg peak. The gafchromic EBT3 films (USA) and neutron monitor were used to verificate the carbon beam profile and to control the dose. Non irradiated animals were exposed to the same handling procedures, but the machine was not active for them. In order to avoid undesirable behavioral side effects of different anesthetizing agents we used non anesthetized animals as control in the present study.

Two months after irradiation mice were tested to assess total activity, spatial learning, long-term and short-term hippocampal-dependent memory (open field, Barnes maze, novel object recognition). After evaluation of cognitive activity the histological analysis of dorsal hippocampus was carried out to assess its morphological state (Nissl staining) and to reveal late neuronal degeneration (Fluoro Jade-B staining).

It was found that in irradiated mice the total activity was significantly reduced in “open field” test compared to control animals, indicating the development of the anxiety. Both groups of the animals demonstrated a good learning to the final day of training in a maze Barnes, however, in long-term memory test, the control animals showed fewer errors locating the escape box compared to the experimental group. The Nissl staining method revealed a reduction of the number of cells in the dorsal hippocampus of the irradiated mice, with the most pronounced reduction in cell density observed in the dentate gyrus hilus of the experimental animals. In addition, the length of the CA3 field of dorsal hippocampus was significantly reduced, and the number of cells in it was slightly reduced. Experiments with the use of FJB-staining have not shown the FJB-positive staining in the dorsal hippocampus in animals two months after irradiation. Thus, the presence of morbid cells in irradiated as well as in control groups was not detected.

MODELING OF THE BIPOLAR STRUCTURES UNDER PULSE IONIZING RADIATIONS

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Significant radiation tolerance is one of the main requirements for integrated circuits operating in extreme environment. We have created a 2D- model of the bipolar structure using a general-purpose software platform COMSOL Multiphysics. We have modeled an impact of different pulse ionizing radiations on the semiconductor devices taking into account the ionization distribution over the structure cross-section.

The electron/hole pairs under pulse radiation are generated simultaneously however their spatial distribution may significantly different. In the case of gamma-radiation, we have the practically uniform carrier distribution over the volume. The X-rays create non uniform ionization connected with attenuation in surface metallization and additional electron emission from heavy metal (if it exists). The laser photons with energy of more Si bandgap can ionize the device; however, its distribution is sufficiently non-uniform due to surface metallization reflection.

As a result we have described the transient radiation effects of bipolar structure under gamma-, X-rays and laser irradiations. We have found that carrier distributions are different for each type of radiation. This led to the sufficient different of ionizing current amplitudes. However, the ionizing current forms are not very sufficiently different.

By using Comsol 5.1., it is shown again that pulse gamma and X-ray ionizing dose rate bipolar structures reaction may be modeled by pulse laser radiation with appropriate energy.

STUDIES REGARDING $CuInS_2$ POWDERS PREPARED BY ULTRASOUND-ASSISTED PRECIPITATION METHOD WITH DIFFERENT Cu/In RATIO

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Metal chalcogenides have been largely studied over the last decades because of their excellent physical and chemical properties. However, the focus of early work has largely been on Cd- or Pb-based metal chalcogenides. But these are toxic heavy metals, and have a limited application in commercial applications. Therefore, chalcogenides with similar properties but less toxic constituent elements are desirable.

Copper-Indium sulphide (CIS) represents a promising “green” and “safer” alternative to the II–VI systems. It has a direct band gap in the visible region (Eg = 1.5 eV), a large optical absorption coefficient ($\alpha > 10^5$ cm^{-1}), and high photostability.

The physical, chemical and luminescence properties of CIS powders are exceptionally dependent on the particle size, morphology and coper/indium molar ratio, which in terms depend on the synthesis methods and conditions. CIS powders usually are obtained by precipitation in organic compounds, under inert gases.

Here we report a new air-stable synthesis of copper-indium sulphide powders. The used method is ultrasound-assisted precipitation in ethylene glycol with the reagent simultaneous addition technique (SimAdd). The reagents used are sodium sulphide and different molar ratio of copper and indium chloride.

The CIS powders were characterized by thermal analysis, FT-IR and UV-Vis spectrometry, SEM, EDX, X-ray diffraction and photoluminescence spectroscopy. A correlation between the Cu/In ratio, the photoluminescence and morpho-structural characteristics of CIS powders was established.

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RADIATION ENVIRONMENT ON BOARD OF THE DESCENT MODULE AND ROVER OF "EXOMARS 2020" SPACECRAFT

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The main scientific objectives of the Russian-European mission "ExoMars 2020" are: search for signs of life on Mars in the past of the planet and now, study the water and geochemical environment on the surface and in the subsurface layers, research of gas impurities in the Martian atmosphere, and others. These ambitious scientific problems are solved by the delivery of Descent module (DM) developed by Lavochkin Association (Roscosmos, Russia) and Rover (ESA development), equipped with scientific instrumentation complex, on the surface of Mars.

During flight the Descent module equipment is exposed to the damaging effect of space ionizing radiation and of 17 radioisotope heat units (RHU)) based on plutonium-238 dioxide and placed on DM and Rover.

Moreover, the contribution to total absorbed dose from RHU radiation (as the calculations show) substantially dominates compared with the space ionizing radiation contribution especially for devices, placed in close proximity to the radioisotope sources.

The dose calculations were performed using of a licensed software package "LocalDose & SEE" (developed by Lavochkin Association), which allows to calculate of various radiation effects on the spacecraft three-dimensional model and is modified taking into account the location and impact of radioisotope RHU.

The report presents the spacecraft 3d-model and the results of dose calculations from external (space) and internal (RHU) radiation sources for specific groups of devices that are part of the DM and the Rover.

INFLUENCE OF ELECTRON IRRADIATION ON OPTICAL AND ELECTROPHYSICAL PROPERTIES OF $La_3Ga_{5,5}Ta_{0,5}O_{14}$ CRYSTALS

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Lanthanum - gallium tantalate ($La_3Ga_{5,5}Ta_{0,5}O_{14}$, langatate, LGT) is one of the crystals from langasite family, LGT belongs to the class of symmetry 32. Langatate crystals are currently used in the field of piezo electronics and are promising materials for laser and nonlinear optics. The main problem that still limits application of these crystals is undetermined. A comprehensive study of the properties of these crystals grown in different conditions, before and after the post growth treatments can clarify origin of defects. The defect origin data will allow to affect their concentration to reduce it to an acceptable level. For instance, the transfer of charged particles, primarily point defects, determines conductivity and, consequently, the resistance of the crystals. Point defects in crystals are observed in the transmission spectra as absorption bands.

Here we present results of our study of optical and elecrophysical properties of LGT crystals before and after electron irradiation. All investigated samples were cut from crystals grown in “Fomos-Materials” using Czochralski method in iridium crucibles, growth atmosphere – Ar and Ar + (2%) O_2.

Electron irradiation was performed using a linear accelerator of the LU type which emits electrons with a narrow-band energy spectrum (~ 6 MeV) in a short-pulse (~ 5 ms). The electron radiation doses were 10^{11}, 10^{12}, 10^{13}, 10^{14} and 10^{15} cm^{-2}. Optical transmission spectra were measured using UV-Vis-Nir spectrophotometer «Cary-5000» with the accessory UMA (Agilent Technologies) at non-polarized light, *p*- and *s*- polarization and at different angles of sample. The luminescence was excited at T = 300 K and T = 95 K by second (λ_{ex} = 532 nm) and third harmonic of YAG:Nd^{3+} (λ_{ex} = 355 nm). Investigation of the defects was carried out by the X-ray diffuse scattering (XRDS) method using the X-ray diffractometer D8 Discover (Bruker-AXS, Germany) in three-crystal scheme. Electro physical properties and their temperature dependences were measured using Keithley 6517 A electrometer (USA), work range 10 to 2×10^{14} Ω, DC.

INFLUENCE OF IRRADIATION ON INTERFACE STATE AND SERIES RESISTANCE CHARACTERISTICS OF Sm_2O_3 MOS CAPACITORS

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Various dielectrics such as, TiO_2, HfO_2, Al_2O_3 etc., have been studied to replace to conversional SiO_2 gate dielectric layers for state of the art MOS based technologies. However, very little of them have knowledge in the literature about their radiation responses. Charge trapping and relevant irradiation responses of the devices are important for qualification of high-k devices for a long-term reliability of high-k materials. Hence, we investigate irradiation effects on the series resistance (R_s) and interface state (D_{it}) characteristics of the Sm_2O_3 MOS capacitors. The influences of the radiation were studied from analysis of the C-V and G/ω-V curves. The results demonstrate that both R_s and D_{it} characteristics critically changed with Co- 60 gamma irradiation. Positive $Sm^{+2}$and Sm^{+3} atoms ionized by irradiation, is the possible reason of the generated trap densities in the devices. In addition, it is also found that the R_s correction should be performed for accurate calculation.

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THERMAL DEGRADATION OF GAMMA IRRADIATED ELASTOMERS BASED ON DIFFERENT NETWORK PRECURSORS

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In rubber industry fillers are used to enhance specific properties of elastomeric materials based on different nano particles have gained attention due to their ability to improve the properties and irradiation resistance. The uniform filler distribution in the cross-linked material is desired. It is a challenge to create a favorable interaction between different network precursors, and thus avoid agglomeration of the nano particles. The main focus of this work was to investigate thermal degradation of carbon black reinforced elastomers based on two network precursors: chlorinated copolymer of isobutylene and isoprene (CIIR) and chlorosulphonated polyethylene (CSM). Both used rubbers are categorized as predominantly irradiation cross-linkable types. It is well known that materials based on CIIR have very good properties including the compression set, good adhesion, the compatibility to other rubbers, good thermal and oxidative stability, excellent moisture resistance, and low gas permeability. It has been used for inner tubes, hoses, tank linings, friction pads, pharmaceutical stoppers, tyres, and conveyor belts. Elastomeric materials based on CSM are using in many applications such as sheeting cable and membrane, cable jacketing, flexible magnets due to its outstanding resistance to degradation by the heat, ozone and oxidation. Properly formulated CSM compounds offer strong adhesion to various substrates and good dynamic properties. The curing of rubber blends was carried out in an electrically heated laboratory hydraulic press. The size of carbon black primary particles was 40–48 nm. The samples CIIR/CSM (50/50 mass %) were irradiated in air at ambient conditions using 100, 200 and 400 kGy doses by the Co-60 irradiation unit. Thermal stability of materials was assessed by thermogravimetry (TGA). The sample mass losses (0.5; 10; 30 %) were calculated for the respective TGA curves. Radiation-initiated reactions can be classified as: (a) scission and (b) cross-linking. Cross-linking during irradiation does not require unsaturated or other more reactive groups, and the mechanism generally varies with the network precursor concerned. The preliminary observation in this work leads to conclude that stability of prepared elastomeric nano-composites increases with irradiation up to 200 kGy dose after that it decreases. The results show positive synergistic influence of gamma irradiation and carbon black particles on the thermal stability of composites. Obtained materials may be suitable for industrial applications requiring elastomers of good thermal stability and radiation resistance.

RADIATION-INDUCED OPTICAL EFFECTS IN CHALCOGENIDE SEMICONDUCTOR GLASSES

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Radiation-induced effects in chalcogenide semiconductor glasses (ChSG) deal with destruction of covalent chemical bonding following structural relaxation (radiation-induced physical ageing) towards novel state. Destructed bonds can be renewed intrinsically via direct interaction of bond-constituting atoms with nearest neighbors forming a channel for intrinsic bond switching, or extrinsically due to interaction with some impurities. In the first case, the diamagnetic pairs of over- and under-coordinated atoms possessing an excess of positive and negative delectrical charge appear in ChSG. In the latter case, some kinds of impurity products can be formed at the surface, the most essential being induced by interaction with oxygen, which replace chalcogen in its bonding within glassy network. Thus, the intrinsic radiation-induced effects occur to be permanently admixed with extrinsic impurity-related ones, forming complicated picture of competitive input in the overall balance of radiation-induced effects. Under such conditions, the methodology allowing unbiased observation of "pure" radiation-induced effects attains vital importance, especially from viewpoint of practical implementation of induced functionality. In this work, we present an adequate methodological solution of this problem exemplified by high-dose gamma-induced effects in glassy arsenic sulfide.

Two types of experimental measuring protocols can be utilized to study gamma-induced optical changes, these being realized in direct and backward measuring chronology. In the former, the optical transmission spectra are recorded ex-citu for the the same ChSG in before-irradiated and after-irradiated states. The second measurements are performed in-situ giving optical spectra for the same irradiated and annealed sample. The smallest inaccuracies are shown to be provided within the latter measuring protocol owing to elimination of errors associated with (1) sample reinstallation in a spectrometer chamber and (2) time separation between subsequent cycles of optical spectra recording for initial and gamma-irradiated samples. As a result, the impacts of impurity-related and intrinsic effects on the optical transmission spectra can be effectively separated. It is shown that impurity-related processes (connected mainly with surface oxidation) depress optical transmission in near-band-gap region, while intrinsic ones shift optical absorption edge towards larger wavelengths.

Effects of Gamma-Ray Irradiation on Characteristics of Al/ZrSiO$_4$/p-Si (MOS) Capacitors

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In this work, the effects of gamma radiation on the electrical characteristic, incorporating interface state density D_{it} and series resistance (Rs) characteristics of Al/ZrSiO4/p-Si (MOS) capacitors have been studied. MOS samples were irradiated by a Co-60 gamma-ray source from 0 to 12 grays at a dose rate of 0.0055 Gy/s in order to examine gamma radiation response. Capacitance–voltage (C–V) and conductance–voltage (G/ω–V) measurements were recorded at 1 MHz. The effects of the radiation were determined from analysis of the C-V and G/ω-V curves. A slight chance in the capacitance curves were noted while an enhancement in conductance characteristics is found with increasing irradiation dose. In addition, for both the capacitance and conductance curves, flat band voltages were shifted with increasing radiation dose. Slight changes in the series resistance (Rs) and interface state density (D_{it}) values were observed with increasing irradiation dose.

SURFACE IRRADIATION OF CHICKEN EGGS BY NANOSECOND ELECTRON BEAM

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The irradiation experiments on chicken eggs were lead on a pulse repetitive nanosecond accelerator URT-0.5. Biological samples were exposed by electron beam with energies up to 500 keV, 50 ns pulse duration, pulse repetition rate of up to 200 pps. To determine the allocation of absorbed dose (AD) in the depth in the polyethylene we conducted by a gray wedge. Using the film dosimeter measurement AD electron beam on the surface of the shell (removed from the eggs) and under the shell and beneath the absorber (polyethylene 80 microns thick) was performed. To determine the distribution of the bremsstrahlung AD inside chicken eggs used thermoluminescent dosimeters (TLD-500). These researched allow us to conclude that the irradiation of an electron beam with AD 5 kGy sufficient to complete disinfection on the surface of an egg, inside the AD by bremsstrahlung will not exceed 800 Gy.

SPACE RADIATION EFFECTS AND IRRADIATION TESTS OF SEMICONDUCTOR DEVICES IN TURKEY

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Effects of space radiation on semiconductor devices can be classified in three groups: Total Ionizing Dose (TID) effects, Single Event Effects (SEEs) and Displacement Damage (DD) effects. TID is the cumulative effect of the deposited dose in the semi-conductor device during the mission duration. TID tests can be performed with a photon or electron beam. SEEs are caused by deposited energy when a high energy particle passes through the semi-conductor device. SEEs can be soft, which can be corrected with the reset of the device or hard, which results in device malfunction. SEE tests can be performed with a proton or ion beam. Unlike TID and SEE, DD is not an ionization effect, but is the result of changes of atomic positions in the lattice due to inelastic scattering of a high energy particle. DD can only be tested with an ion beam.

Semiconductor devices must be developed and qualified according to the space radiation environment in their destined orbit. Simulations in SPENVIS [1] are carried out to estimate the worst-case radiation environment during mission time. Irradiation tests must be performed according to these results.

Turkish Atomic Energy Authority (TAEA) Sarayköy Nuclear Research and Education Center (SANAEM) has a ^{60}Co source in the Gamma Irradiation Facility with an activity of 250 kCi [2]. This source can be used for TID tests according to ESA ESCC No. 22900 standard. TID tests for Solid State Power Amplifier (SSPA) modules developed by ASELSAN in Turkey were performed in 2016 [3]. TID tests for DDA3 pin diodes developed by TÜBİTAK BİLGEM UEKAE in Turkey were also performed at this facility and tests of MOS devices are underway. First, these results will be presented.

Currently, SEE tests cannot be performed in Turkey. METU-Defocusing Beam Line (METU-DBL) project aims to construct a beam line to perform SEE tests for the first time in Turkey. METU-DBL aims to perform SEE tests for solar panels, multi layer insulation, Lithium-ion battery and its control card for IMECE satellite which is an experimental satellite foreseen to be launched after 2020. The project was funded in 2015 by Turkish Ministry of Development. METU-DBL will enable to having a beam that conforms to the ESA ESCC No. 25100 standard. Construction of METU-DBL has been started at the TAEA SANAEM Proton Accelerator Facility. METU-DBL will serve space, particle, nuclear and medical physics communities starting from 2018. While the studies are going on, a preliminary setup is being constructed towards first tests in March 2017. Solar cells, DDA3 pin diodes and newly developed materials in Turkey will be tested at the preliminary test setup of METU-DBL.

In this talk, simulation of space radiation environment and radiation effect test results will be presented. The status of the METU-DBL project as well as the results of the TID and preliminary SEE tests will also be reported in this talk.

Key words: Space radiation, radiation effects, irradiation tests

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RADIATION INDUCED LUMINESCENCE OF CARBON-DOPED Al_2O_3 NANOPOWDERS PRODUCED BY PULSED ELECTRON EVAPORATION

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Carbon doped Al_2O_3 (Al_2O_3:C) has exceptional optically stimulated luminescence (OSL) and thermoluminescent (TL) properties for application in ionizing radiation detection. Al_2O_3:C ceramics are already used in the commercial TLD and OSL dosimeters; however, potential of the enhanced performance of these materials is still widely studied. Particularly, the use of nanostructured counterparts is considered.

In this study, optical properties of the Al_2O_3:C nanopowders prior and post irradiation were studied. Al_2O_3:C nanopowders with different carbon concentration have been produced by the method of pulsed electron evaporation [1]. This method allows the production of nano-powders of high melting temperature oxides with high specific surface area. Moreover, the process is conducive also to high concentrations of structural defects in the nano-particles which have a significant role in the luminescent properties of the materials. Irradiation with 5MeV electron beam was performed with the dose range from 1Gy up to 100kGy. Optical properties were studied by the means of Dark field micro spectroscopy system which allowed also to measure individual spectrum for different phases in the material if present. Additionally thermal properties of the powders were studied by the means of TG/DTA system.

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NATURAL AND RADIATION-INDUCED PHYSICAL AGEING IN Ge-As-Se CHALCOGENIDE GLASSES

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A recent progress in the field of chalcogenide glasses (ChG) makes possible a wide usage of these disordered materials for xerography and lithography, CD-erasable media, chemical sensors, low-loss IR transmitters, memory-switching devices, photo- and radiation-sensitive recording elements, etc. Nevertheless, it is known that atomic structure and, consequently, physical properties of ChG (as well as any other melt-quenched solids) are changing with time, essentially limiting their practical application. The above processes are known as natural physical ageing. Different external influences (like photo- or γ-irradiation, high temperature, pressure, etc.) could be effectively used for resolving of the natural physical ageing problem by accelerating of this process.

We examined the ability of ternary $Ge_xAs_xSe_{1-2x}$ ChG ($0.05 \leq x \leq 0.30$) to be subjected by natural and radiation-induced physical ageing, using conventional differential scanning calorimetry (DSC) applied in a so-called backward-rejuvenation chronology. It was shown that 2 years of natural storage, as well as high-energy gamma-irradiation (the absorbed dose was near 1 MGy), led to significant ageing effect in the glasses with $x < 0.14$. The observed gamma-irradiation induced changes are much higher than natural storage-induced once. Within $0.14 < x < 0.25$ domain, no changes were detected in the glass transition peak parameters testifying in a favour of possible optimally-constrained phase. This result contradicts to the conclusions on self-organization in this system within $0.09 < x < 0.14$ range followed from temperature-modulated DSC measurements [*P. Boolchand, D.G. Georgiev, T. Qu, F. Wang, L. Cai and S. Chakravarty, C.R. Chimie 5 (2002) 713*], but it is in a good agreement with previous data extracted using high-resolution x-ray photoelectron spectroscopy [*R. Golovchak, O. Shpotyuk, M. Iovu, A. Kovalskiy and H. Jain, J. Non-Cryst. Sol. 357 (2011) 3454*].

DENSITY ASSESSMENT OF DIFFERENT METALS AND ALLOYS BY GAMMA-RAY TRANSMISSION TECHNIQUE USING Co-60 RADIOACTIVE SOURCE

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In this study, density measurements were observed by using gamma transmission technique. Co-60 gamma emitter was used as gamma radioisotope source. Regarding the gamma-ray transmission method, initial radiation intensity (I_o) and radiation intensity (I) determined experimentally and [I/I_o] rates were calculated and then density of materials could be determined by using Beer-Lambert Equation. Experimental application performed on widespread industrial metals or metal alloys e.g. lead, copper and steel, brass. With this study, it is shown that gamma transmission technique can be used for density measurements. There were acceptable differences obtained between the measured densities and given densities of them. In hence, the minimum difference is obtained as 0.26% and 1.11% *up* for steel and copper, near by 5.07% and 5.73% *down* for brass and lead. Another point, these difference ratios would be referenced for next studies about another material density measurements, too.

ELECTRON BEAM IRRADIATION-INDUCED STRUCTURAL CHANGES OF CNT FIBER

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Highly strength CNT fibers are useful structural materials for space, aviation, electricity and potential future applications. In space applications, it is important that CNT fiber used in space are able to retain good properties during the expected lifetime of space vehicle. In this study, the effects of electron beam irradiation on structural changes on CNT fiber were investigated. The CNT fiber was supplied by KIST (Korea Institute of Science and Technology, Jeonbuk Institute Advanced Composite Materials). Irradiations were carried out using an ELV-4 accelerator at an acceleration voltage of 1MeV and a beam current of 4mA. The dose rate was 10kGy/pass. The samples were irradiated up to 10,000 kGy. The structural changes of CNT fiber throughout different radiation dose has been studied by Raman spectroscopy, scanning electron microscopy, scanning transmission electron microscopy and X-ray photoelectron spectroscopy. Specifically we investigated on possibility of endurance of CNT fiber to survive the high energy irradiation in space environments.

Radiation in Medicine

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IRRADIATION ACTIVITY WITH THE TOP-IMPLART PROTON LINEAR ACCELERATOR

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A proton linear accelerator devoted to protontherapy application, is under construction in the "Particle Accelerators and Medical Applications Laboratory" at the ENEA Frascati research center in the framework of the TOP (Terapia Oncologica con Protoni) - IMPLART (Intensity Modulated Proton Linear Accelerator for RadioTherapy) project funded by the regional government of Lazio in Italy.

The proton linac is composed by a modular sequence of RF linear accelerators designed to reach the energy of 150 MeV. The beam features, particularly useful for very conformal irradiation of tumours in complex anatomical regions, can be likewise translated to other situations. Therefore, during the process of commissioning of the TOP-IMPLART accelerator, the beam has been also made available as a versatile proton source for ancillary experiments in the framework of other projects.

Presently, indeed, the maximum TOP-IMPLART beam energy is 35 MeV and this section delivers a 3 usec pulsed beam at maximum repetition frequency of 25 Hz with a variable charge in each pulse in the range 5-100 pC. This beam is used for pilot experiments to simulate cosmic conditions on the ground and PIXE (Particle Induced X-ray Emission) analysis for the determination of elemental composition of archeological and old painting samples.

This work presents an overview of these activities, describing in detail the different set up adopted to perform the tests and the main achieved results.

THE BR2 REACTOR AND OTHER FACILITIES AT SCK•CEN – USAGE FOR SCIENCE, TRAINING, EDUCATION AND MEDICAL APPLICATIONS

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SCK-CEN, Mol, Belgium

The Belgian Nuclear Research Centre was founded in 1952. Ever since SCK•CEN has been playing a pioneering role with unique achievements and groundbreaking work in nuclear science and technology. About 700 people work on the development of peaceful industrial and medical applications of ionising radiation and study the impact on man and the environment.

Each year we offer newly graduated scientists and engineers the possibility to undertake their doctoral or post-doctoral research at SCK•CEN, on a subject covered by one of our priority research areas. Our experts also advise those taking bachelor and masters diplomas on their dissertations. Our laboratories and installations are made available to them.

The Belgian Reactor 2 or BR2 is one of the most powerful materials testing reactors in the world. Together with four other reactors, BR2 is responsible for the production of 90 % of the radioisotopes that are used worldwide in nuclear medicine for diagnosis and treatment. Other radioisotopes are used in industry, for example in sensors used to determine the density and moisture content of materials. Ionising radiation can affect the materials in a reactor, cause small cracks and weaken components. In order to deal with this issue, SCK•CEN irradiates materials (metallic, organic, all types of materials) in extreme conditions in the BR2 reactor. The damage and ageing processes are analysed in our Laboratory for High and Medium level Activity (LHMA). Material compositions and chemical processes are analysed in specialist radiochemical laboratories.

After refurbishing the reactor for a new 10 years of operation, we introduce a system of open user facility, allowing to share part of the facility for scientific purposes. We have also a long experience in sharing reactor irradiation channels by several Universities, to distribute the cost while allowing to use one of the most interesting facility for neutron irradiations.

In 2004 SCK•CEN opened its radiobiology, radioecology and space exploration laboratories, which are used for various research into the impact of ionising radiation on mankind and the environment.

The SCK•CEN is looking for all kind of partnerships, in science, education and training for the advance of scientific understanding of the effects of radiation on matter, living species and environment. The presentation will focus on some typical examples of partnership and on the use of the unique facilities to reach these objectives in a very international environment.

TARGET DEVELOPMENT FOR MEDICAL RADIONUCLIDE PRODUCTION AT RADIOISOTOPE COMPLEX RIC-80 AT PNPI

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At PNPI NRC KI (Petersburg Nuclear Physics Institute of National Research Center "Kurchatov Institute") a high current cyclotron C-80 has been put into operation lately. External beam of the energy 70 MeV and intensity 100 μA has been obtained. Presently the work is being carried out to obtain the planned external beam parameters: the proton beam energy up to 80 MeV and the current up to 200 μA. The main goal of the C-80 is production of medical radionuclides for diagnostics and therapy. One of the cyclotron beams is intended for treatment of ophthalmologic diseases by irradiation of malignant eye formation. The radioisotope complex RIC-80 (Radioactive Isotopes at cyclotron C-80) which is constructed at the beam of C-80 will allow obtaining sources of a high activity practically for the whole list of radionuclides produced at accelerators. An essential peculiarity of the RIC-80 is the use an on-line mass-separator connected to one of the target stations that will allow the production of separated radionuclides of a high purity. The target prototypes intended for the production of different radionuclides at the RIC-80 target stations are being studied and developed. The results of different target material tests for production of radioisotopes ^{67}Cu, ^{82}Sr and others are presented. A new method of a high temperature separation of the target materials and produced radioactive isotopes has been discussed.

USE OF TELE-ROENTGEN-DIAGNOSTIC COMPLEXES FOR IMPROVING MEDICAL CARE OF PATIENTS

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Objective. The transfer to family medicine in Ukraine has actually resulted to distancing of patients from X-ray rooms, which are not in clinics of family doctors. This led to a significant increase in the time between the patient's direction on radiological examination and the receipt by the doctor of its result. In addition, experience of rendering medical aid in conditions the fighting in the East of the country has shown efficacy of digital radiodiagnosis use for operative sorting of injured and rendering them timely surgical aid. The aim of this work is to demonstrate the possibilities of improving medical care to patients thanks to the use of teleroentgendiagnostic complexes (TRDC).

Materials and methods. Portable X-ray unit (output power from 2.0 kW) with mobile stand, digital receptor with the working field of 40×40 cm and spatial resolution of 4.0 lp/mm, mobile tripod devices needed for execution of X-ray examinations, and the operator workstation based on the laptop makes up the TRDC. Total weight of the complex does not exceed 100 kg. When necessary it can be promptly delivered to the place of examinations by any the ambulance. The TRDC does not require the presence of a radiologist: the review and the interpretation of x-ray images are performed remotely.

Results. The TRDCs in the military field hospitals have been used mainly for diagnostics of the injured with frag wounds with followed by radiographic control of the surgery. Average annual load per complex is 4953 exams, average number of images on one exam – 2.1. Average annual load in 2015 per one X-ray machine in Ukraine was 2126 exams, average number of images per exam – 1.65. In the private medical centres the TRDCs were used mainly for chest examination and extremities. Average annual load per such complex made 19788 exams, average number of images per exam – 1.46. Average annual load in 2015 per one fluorography machine in Ukraine was 9159 exams. The above data prove to that TRDC can be used with high intensity.

Conclusions. The TRDC can be used effectively for providing medical aid to the suffered at the sites of large scale incidents and emergencies of civil or military nature. Use of TRDC in the field hospitals allowed to raise the efficacy of surgical aid provision to the injured. The equipment of family medicine offices by TRDC allows minimizing the time of reception of the necessary diagnostic information on the patient and allows the family doctors to take correct treatment decisions of patients.

Radiation Measurements

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EVALUATION OF PULSE STRETCHER FOR DETECTION OF VERY SHORT SINGLE EVENT TRANSIENTS

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Single event transients (SETs), resulting from the interaction of high energy ionizing particles with the target device, are a serious reliability issue for modern CMOS integrated circuits employed in hostile radiation environments. In order to evaluate the sensitivity of a particular technology or design to SETs, it is necessary to characterize experimentally the SET response of the target circuit or system. A common approach for the SET effects characterization is based on measurement of the SET voltage pulse width using appropriate measurement circuitry implemented in the target chip.

In general, the width of the SET pulses ranges from dozens of ps up to several ns, depending on the processing technology. However, very short SET pulses (< 200 ps) cannot be measured by the conventional on-chip measurement systems because of the limitations posed by the propagation delay of the standard logic gates. A typical solution for this problem is to stretch the detected SET pulse, i.e. increase its width, and then feed it to the measurement circuitry for further processing. To achieve this, it is required to use the well designed and well calibrated pulse stretching circuits.

The basic configuration of a CMOS pulse stretcher used for SET pulse width measurement consists of two cascaded asymmetrically sized inverters, such that in first inverter the NMOS transistor is wider than the PMOS transistor and in second inverter the PMOS transistor is wider than the NMOS transistor. Therefore, larger pulse widths at the output of a pulse stretcher can be achieved by increasing the sizing ratio of the inverters which constitute the pulse stretcher.

Although several papers have reported on the use of pulse stretchers in SET measurement systems, to the best our knowledge there is no any report which thoroughly analyzes the dependence of the output pulse width on the sizing of the pulse stretcher. Moreover, the effect of load sizing on the pulse stretcher's functionality has not been studied. In that regard, this work investigates through the SPICE simulations the impact of the sizing of pulse stretcher and the corresponding load on the pulse width at the output of the stretcher.

Obtained results indicate that the two-inverter pulse stretcher with fixed sizing and predefined load provides a constant pulse stretching for the input pulse widths from 100 ps to 1 ns, whereby the pulse stretching is linearly proportional to the size of transistors which constitute the pulse stretcher. Moreover, increasing the load sizing results in the linear increase of the output pulse width, but the impact of load sizing is moderate compared to the stretcher sizing. Therefore, in the design of a pulse stretcher it is necessary to consider the sizing effects of both the stretcher and its load, in order to ensure high accuracy of the SET pulse width measurement.

CARBON STABLE ISOTOPE ANALYSIS OF ARCHAEOLOGICAL PLANT REMAINS

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The method commonly used to measure carbon and nitrogen isotope ratio is isotope-ratio mass spectrometry interfaced with elemental analyzer (EA IRMS). This is a well-established analytical tool for investigating archaeological materials and has become increasingly important for understanding ancient diet and agricultural practices.

Radiocarbon dating using Accelerator Mass Spectrometry (AMS) measures the ratio of radiocarbon to stable C in a sample and determines the sample's age with quantifiable precision. Nowadays AMS simultaneously measures ^{14}C and $\delta^{13}C$ in archaeological-charred plant material. The differences between IRMS- and AMS-measured $\delta^{13}C_{plant}$ values for the same material could arise from different laboratory preparation protocols and the resolution of the instruments used. In IRMS analysis, $\delta^{13}C$ values are directly evaluated from CO_2 produced by combustion of the sample, while the AMS protocol involves graphitization of CO_2 from the sample by using hydrogen in the presence of a metal catalyst – a process which may include C fractionation and affect the C natural isotopic values.

We explored differences in C isotopic values obtained using EA IRMS and AMS for archaeological-charred plant remains by measuring ^{13}C /^{12}C ratio of a 6800-year old charred Cornelian cherry stone from the Neolithic settlement of Vinča near Belgrade, Serbia. EA IRMS values were compared to the $\delta^{13}C$ values previously obtained through AMS for the same type of material originating from the same archaeological site. The AMS-derived $\delta^{13}C$ values of Cornelian cherry stones from Vinča were produced at two different laboratories and they varied both within and between the two datasets. Our results from EA IRMS were not comparable with AMS $\delta^{13}C$ values. In order to glean some possible reasons for the observed variations and differences, we also measured (using EA IRMS) $\delta^{13}C$ values of modern and modern-experimentally charred Cornelian cherry stones collected from three locations in Serbia. The results showed significant variation in the C isotope values for cherry stones from different locations, potentially due to differential environmental and geographical conditions of growth. For instance, the archaeological material had similar $\delta^{13}C$ to the modern material collected at a similar altitude. Also, it was observed that isotopic composition is likely affected by charring, as indicated by higher $\delta^{13}C$ values for heat-treated specimens in comparison to the untreated material. The dataset is too small for definite conclusions and further experimental studies are necessary to evaluate whether IRMS-measured and AMS-derived $\delta^{13}C$ values in charred plant remains can be compared.

THE DEVELOPMENT OF A NEW TYPE OF RADIATION SENSITIVE MATERIAL ON THE BASIS OF SUCROSE FOR SOLID STATE/EPR DOSIMETRY

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In the last years several materials have been studied as radiation sensitive detectors for Electron paramagnetic resonance (EPR) spectroscopy. Among them the table sugar or sucrose shows very good results and it was considered as one of the most promising radiation sensitive materials for EPR dosimetry. A table sugar is cheap, widespread in the everyday practice materials. Moreover, it is important as involved in the DNA structure. The sucrose has been studied for a long time as a dosimeter in radiation accident and in high-dose dosimetry by using not only EPR spectroscopy but also and other analytical techniques. Up to now the alanine/EPR dosimetric system has been accepted by International Atomic Energy Agency as a secondary of transferring type system. In the last years the scientist aims to increase the sensitivity of the materials used in the EPR dosimetric systems.

In the current study, an attempt to improve the sensitivity of sucrose as a material for EPR dosimetry is made. In view of this a new dosimetric material on the basis of sucrose and ascorbic acid are developed. It was prepared following mixtures: sucrose and 2% ascorbic acid; sucrose and 5% ascorbic acid. The technology of their preparation included addition of ascorbic acid to a saturated solution of sucrose and consequent co-precipitation of the solution. The resulting crystals were grounded in a mortar and powdered samples were irradiated with gamma rays with a dose of 0.5 to 25 kGy. The obtained dosimetric materials were studied with EPR spectroscopy in view of stability of radiation induced EPR signal, dosimetric response and possible to determine the absorbed dose of ionizing radiation received once or accumulated under normal conditions in the irradiation process.

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RAD2017

SPACE RADIATION DOSES AND FLUXES MEASURED ABOARD ON THE EXOMARS TRACE GAS ORBITER DURING THE TRANSIT AND IN MARS ORBIT

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Since April 2016, the dosimetric telescope Liulin-MO has been conducting radiation environment investigations aboard the Trace Gas Orbiter (TGO) of the joint ESA-Roscosmos mission ExoMars. Liulin-MO is a part of the Fine Resolution Epithermal Neutron Detector aboard TGO. Presented are data for the ionizing radiation dose rates and particle fluxes measured during the cruise to Mars and in Mars orbit. Data obtained are compared to the data of other radiation measurements in the interplanetary space.

DETERMINATION OF DETECTION DISTANCE AND MINIMUM DETECTABLE ACTIVITY FOR RADIATION MONITORING SYSTEM IN WATER

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Water has to be monitored and prevented from contaminations including artificial radioactive materials which could be produced by any accidents of neighboring nuclear facilities or terror. Especially, since Fukushima nuclear facility disaster, the national security interests for radioactive materials and nuclear facility accidents happened by terrors, natural disasters, and so on has been increasing. Researchers in Korea Atomic Energy Research Institute (KAERI) have been developing the radiation monitoring system for national urgent emergency system. In this study, we have determined the marine detection distance and minimum detectable activity in water experimentally for the radiation monitoring system.

The radiation monitoring system is composed of 2 EA NaI(Tl) detectors which is 3 inch in diameter and 3 inch in height based on the cost-benefit comparison research. So all the experiments has been carried out with the NaI(Tl) detectors. For measuring the marine detection distance, we used the acryl water tank of which the water volume including radioactive materials can be controlled. So, we injected ^{99m}Tc (140 keV), ^{68}Ga (511 keV), and ^{137m}Ba (662 keV) generated from radioisotope generator into the tank, and then measured the marine detection distance with changing the volume. The minimum detectable activity has to be measured in real place where the monitoring system will be placed because it is calculated based on the radiation background in water. For this, we measured the radiation background using the NaI(Tl) detector with the water-proof housing in river, and the minimum detectable activity was then determined as a function of energy. The marine detection distance and minimum detectable activity values will be considered to operate the radiation monitoring system.

THE TRANSFER OF RADIONUCLIDES FROM THE RESERVOIR ROCKS TO THE GROUNDWATER ON THE EXAMPLE OF MT. ETNA VOLCANO

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The radiological survey was carried out in the eastern flank of Mt. Etna volcano in Sicily. Activity concentrations of uranium $^{234,238}U$ and radium $^{226,228}Ra$ isotopes in the reservoir rock and water samples were determined with the use of different nuclear spectrometry techniques.

In this work, a model was established based on soil-to-water transfer factor TF for mentioned radionuclides. For the purpose of the methodology the transfer factor was defined as the ratio of the activity concentration of a radionuclide in water to the activity concentration of a radionuclide in soil. Assuming both activity concentrations given in the same units, i.e. Bq/kg of dry mass, TF would be a nondimensional value:

$$TF = A_{water} / A_{rock}$$

where:

A_{water} is the activity concentration of the isotope in TDS in water [Bq/kg dry mass],

A_{rock} is the activity concentration of the isotope in reservoir rocks [Bq/kg dry mass].

Dry mass in water is defined as total dissolved solids (TDS), i.e. all mineral substances in the form of real and colloidal solutions present in 1 L of water sample.

The values of rock-to-water transfer factors for natural radionuclides cannot be found in the literature. TF in this case denotes the degree of radionuclides dissolution from rocks encountered by water flowing through them. The area of water flow is much harder to define then in rock-to-plant relation.

The activity concentrations of $^{226,228}Ra$ and $^{234,238}U$ isotopes for underground water intakes samples present in the area of reservoir rocks were re-calculated from [Bq/L] to [Bq/kg d.m.] taking into account total mineralization TDS of underground water.

The transfer factor TF for rocks-to-underground water for each mentioned radionuclide was obtained. Detailed description of the results will be presented at this work.

DUST EFFECT ON OPTICALLY STIMULATED LUMINESCENCE DOSIMETRY

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Optically stimulated luminescence dosimetry (OSLD) has been used for dose measurements in many different radiation fields for personal monitoring and medical and industrial applications. One of the most important advantages of the OSLD is the light source used to stimulate crystal compared to thermoluminescence dosimetry (TLD). On the other hand, it has discrimination problem between the light used in stimulation and the luminescence light obtained as a result of stimulation. To measure correct dose value, the stimulation and luminescence light has to be discriminated very well by using different optic filters such as UV blocking, long and short band filters. In addition, the OSL readers are calibrated under fixed conditions (normal operating condition of optic filters, light source and photomultiplier tube, etc). The measured dose values are very sensitive to changes in normal operating conditions. In this work, the dust buildup factor on the optic filters is studied to analyze the response of BeO OSL dosimeter system. The elemental composition of suspended dust was determined by using the literature given for samples obtained from different indoor locations in Turkey and abroad. The light transport algorithm is used to simulate BeO OSL dosimeter system's response with and without dust buildup by means of Monte Carlo photon transport technique. The Coherent and incoherent scattering of the light as well as other photon interaction mechanisms explicitly modeled in Monte Carlo simulations. The dust buildup effects on OSL spectrum was investigated in detail as a function of dust thickness on the optic filters and elemental composition of the dust.

GROSS ALPHA AND GROSS BETA ACTIVITIES FROM NATURAL SUPPLEMENTS

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The specialists' concern from the health point of view is prevention. Given the fact that to treat is more expensive than to prevent, people usually prefer to use natural supplements. With the intake of natural supplements, different problems can be prevented and some of the human capabilities can be amplified. The consumption of natural supplements represents at the same time a way of ingesting the natural radionuclides existing in their ingredient components.

This study aims to make a general screening of the gross activity from natural supplements and to assess their contribution to the effective dose. Gross alpha/beta activity of the samples was measured using low-background MPC-2000-DP system (Protean Instruments Corporation). 13 samples of natural supplements have been analysed. The gross alpha activity and the gross beta activity ranged from 0.25 to 94.49 mBq g^{-1}, and from 2.18 to 769.59 mBq g^{-1}, respectively. In addition, in order to make a comparison, 7 drugs samples have been analysed and in this case the gross alpha and gross beta activity ranged from 0.37 to 25.51 mBq g^{-1}, and from 1.70 to 169.08 mBq g^{-1}, respectively.

The assessment of the effective dose due to ingestion of natural supplements/drugs was carried out in this way: the gross alpha activity and the gross beta activity had been assigned to the most radiotoxic alpha and beta emitters, which are ^{210}Po and ^{228}Ra, respectively. Thus, the effective dose due to ingestion of natural radionuclides from natural supplements varied from 0.36 to 442.21 nSv (daily dose)$^{-1}$, assigned to the ^{210}Po, and from 1.11 to 666.02 nSv (daily dose)$^{-1}$, assigned to the ^{228}Ra. These values were compared with the daily dose value recommended to the current EU legislation.

Key words: Natural supplements, drugs, gross alpha/beta activity, effective dose.

STUDY OF INFLUENCE OF RADIONUCLIDIC IMPURITIES IN RADIONUCLIDE METROLOGY

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The absolute standardization of radionuclides is complex in the case of mixture radionuclides, such as it is the case with the existence of impurities. The difficulty is still amplified in the case of radionuclides decaying in different modes. One example is Co-57, a radionuclide decaying by electron capture, accompanied by the emission of low energy Auger electrons and x-rays, impurified with Co-56 and Co-60, beta decaying radionuclides. Even low contents of such impurities, can influence in a significant way the final result, activity of the measured radioactive source. In the present paper, an example of treatment of this mixture within the participation in the key comparison code BIPM(II)-K1.Co-57, where the influence of impurities was underlined, will be presented.

DIRECT METHOD FOR GROSS ALPHA/BETA DETERMINATION IN WATER SAMPLES BY LSC

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Gross alpha/beta measurements in drinking waters enable radiochemical composition analysis in environmental studies providing efficient screening method that indicates whether water sample contains elevated levels of any radionuclide. Routine gross alpha/beta activity monitoring in drinking waters has been carried out in laboratory for low-level radioactivity measurements in Novi Sad for a few years according to ASTM D 7283-06 method on liquid scintillation counter Quantulus 1220™.

Development of rapid and efficient screening method for gross alpha/beta measurements has been presented. This method is modification of conventional ASTM method and assumes direct mixing of water samples with liquid scintillation cocktail Ultima Gold AB, without any sample preparation. Optimization of the method involved determination of optimal sample-to-scintillation cocktail ratio based on the achieved detection limit and quench level of sample. Optimal value of Pulse Shape Analysis (PSA) discriminator was investigated for different sample: cocktail ratios to ensure accurate and reliable alpha/beta spectra separation. Calibration experiments have been carried out with ^{241}Am, and ^{90}Sr/^{90}Y aqueous standards for different sample: cocktail ratios, which included efficiency, MDA (Minimal Detectable Activity) and optimal PSA parameter determination.

Method's accuracy and validity has been tested on few water samples and spiked samples with various radionuclides and obtained activities have been compared to results obtained with ASTM D 7283-06 method. Presented method for direct alpha/beta measurements offers some advantages over conventional ASTM method, since it is ultra fast, simple and inexpensive test for efficient screening of water samples.

Key words: Alpha/beta spectroscopy, Quantulus 1220™, optimization

COMPARISON OF MEASUREMENT OF NORM BY GAMMA-RAY SPECTROSCOPY USING DETECTORS OF Ge, CsI, NaI AND BGO

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We made a study to determine the concentrations of some radionuclides considered as NORM (Naturally Occurring Radioactive Materials) between them the radionuclides ^{238}U, ^{232}Th and some of their decay daughters as well as the ^{40}K concentration. An experiment with a high resolution γ-ray detector (HPGe) was conducted in order to compare and delimit the regions in the spectrum to determine the concentrations of each radionuclide. We measure several samples using detectors of Ge, CsI, NaI and BGO. The determination of concentrations was conducted by comparing the spectra of the samples and reference materials RGU-1, RGTh-1 and RGK-1 [1]. Thereby we determine the concentrations, accuracy and detection limits produced by measuring with the different detectors. The advantages of using each detector in the measuring of NORM are discussed.

Key words: NORM, natural radioactivity, decay chain, gamma-ray spectroscopy

BIOGENIC COMPONENT DETERMINATION IN LIQUID FUELS – COMPARISON OF DIFFERENT LSC METHODS

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There are few novel methods for biogenic component determination in liquid fuels by direct measurement of ^{14}C via liquid scintillation counting (LSC) technique. The basic idea of all used methods is the same: different ^{14}C signatures of the biogenic and the fossil components – in the case of biogenic component there are a presence of modern ^{14}C activity from the atmosphere and in the case of fossil fuels there should not be ^{14}C activity in the sample. This paper presents inter-laboratory comparison between two different methods used in Laboratory for Nuclear Physics from University of Novi Sad, Serbia and in Laboratory for Low-level Radioactivities from Rudjer Boskovic Institute, Croatia. Both laboratories used the same samples, the same detectors – liquid scintillation counter Quantulus 1220 but different calibration methods. Laboratory for Low-level Radioactivities is using quenching properties of modern liquids for calibration (I.Krajcar Bronic et al, 2016) and Laboratory for Nuclear Physics is using two step method for calibration (I.Stojkovic et al, 2017).

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THE EXTENDED SOURCE EFFICIENCY CORRECTION AND OPTIMIZATION OF THE SAMPLE POSITION TO MEASURE THE CONCENTRATIONS USING A HPGE DETECTOR

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An experiment using several calibrated γ-ray sources located at different positions around a HPGe detector was conducted. The efficiency calibration curve for each position was obtained. More than 15 γ-ray energies for each position point were used. The efficiency calibration curves help us to determine the concentration of radionuclides in an extended source. The resulting efficiency curves and their interpretation will be shown. A validation of the efficiency correction for extended sources was carried out. Extended sources of different geometries were prepared using reference materials and the efficiency correction was applied to determine the previously known concentration of the radioactive material.

A TIME-DEPENDENT MONTE CARLO APPROACH FOR THE DETERMINATION OF CHANCE COINCIDENCE EFFECTS ON THE HPGe SPECTRUM AT HIGH COUNT RATES

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Coincidence summing for a germanium spectroscopy system is the generation of single output pulse from simultaneous detection of two or more photons. If these photons are originating from a single nuclear disintegration it is called true coincidence. Otherwise, it is called chance coincidence and can be neglected at low count rates. But at high count rates, count loses due to chance coincidence also become important and should be corrected as in the case of true coincidence summing.

In this study, the effect of chance coincidence on a HPGe spectrum at high count rates and CCCF (chance coincidence correction factor) for full energy peak efficiency are determined theoretically by using time dependent Monte-Carlo approach and results are compared with the experimental calculations. For experimental calculations, spectra of low activity and high activity point sources which contain same single-line gamma emitter radionuclide are obtained by using a geometrically well-defined HPGe detector and CCCF is calculated by comparing two spectra. For theoretical calculations, same experiments are modeled using MCNPX and probability and cumulative distribution functions for energy deposition at detector are obtained. These functions are used in an interface program which randomly distributes the energy deposition of gamma rays on time base according to the activity. Theoretical determination of spectra for high and low count rates are performed by this program and again CCCF is calculated by comparing two spectra. Also the contributions of energy deposition at detector and pulse pile-up at electronic devices are examined by using a random pulse generator and results are given.

^{90}Sr AND ^{137}Cs ACTIVITY DETERMINATION IN WATER FROM SPENT FUEL STORAGE BASINS USING MONTE CARLO SIMULATION

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During repackaging of spent nuclear fuel elements of research reactor RA it was necessary to determine the daily activities of the main fission products ^{90}Sr and ^{137}Cs in water taken from the reactor storage pools. For this purpose, a fast and reliable methodology using MCNP-5 geometry model of semiconductor Si detector for beta spectrometric measurements and Ge semiconductor for gamma spectrometric measurements was developed. Both detectors were numerically and experimental calibrated using Monte Carlo simulation for standard sources and good agreement between these results were achieved. Also, derived results show that geometry model of Ge detector allows the accuracy of determining efficiency for point-source geometry of ± 6% in the investigated energy range. By this, geometry model is valid and verified for its use for problems with complex geometry. In the case of semiconductor Si detector the measured and simulated energy response functions were compared and a good agreement of ± 7% was found in the entire range of interest. Verified models were used for non-destructive determination of radionuclides ^{90}Sr and ^{137}Cs in the water without chemical separation. Measurements were conducted every day for one year and are presented graphically. The results of ^{137}Cs activity determination using gamma and beta spectrometric methods show good matching within ± 10%. Based on them it can be concluded that developed methodology is low-cost, fast and reliable and can be used for samples from nuclear power plants and environment.

MONTE CARLO SIMULATIONS OF THIN FILMS LOADED WITH OSL DETECTORS

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The transport and interactions of gamma-rays in a thin film loaded with optically stimulated luminescence (OSL) nanoparticles (NPs) were studied by Monte Carlo (MC) simulations with the Particle and Heavy Ion Transport code System (PHITS). In the MC input file, the geometry of the thin film was treated as a virtual space using a cubic voxel structure with a lattice of variable size nanoparticles (NPs) of OSL Ca_2F:Ce. The Polyvinyl chloride (PVC) film matrix was treated as two-dimensional and three-dimensional arrays simulating a 10 μm thick layer. For the irradiation simulations, a point source of Cesium-137 with an emission of 10^7 monoenergetic gamma-ray of 0.66 MeV and a pencil beam with radius 0.001 cm were considered. Moreover, the thin film (detector) was centered on the front face of an ISO water phantom which consists of a 30 cm x 30 cm x 15 cm water slab with PMMA walls (front wall of 2.5 mm thick and other walls 10 mm thick). The source-to-film distance was 100 cm and the film was placed perpendicular to the incident beam. In the MC simulations, we followed the radiation tracks and calculated the dose due to energy deposition from the tracks of electrons produced by the interaction histories of the photons crossing thin film. The results show that dose increases at about 32 (MeV/cm^3/source) increasing the diameter of Ca_2F:Ce grains varying from 50 nm to 600 nm. This research will support the design and development of films loaded with OSL–NPs for application in in-vivo dosimetry.

Key words: Dosimetric film, optically stimulated luminescence, Monte Carlo simulation

BACKGROUND DOUBLE COINCIDENCES AT A MULTIDETECTOR GAMMA SPECTROMETER

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Double background coincidences at two multidetector spectrometers having 6 and 32 NaI(Tl) detectors and registration geometry close to 4π (PRIPYAT-2M and ARGUS), are considered as a sum of true and random ones. They have been analyzed together with energy resolution and efficiency of ^{137}Cs, ^{65}Zn and ^{40}K (photons with energy of 662 keV, 1116 keV and 1461 keV, respectively) detection in the full absorption peak (individual detectors and the whole spectrometers). Number of detector-duplet combinations registering double coincidences was 15 and 496, respectively (an angle from the spectrometer centers to the detector centers ranged from 37.38° to ~180°). Double background coincidences in the whole energy range (from 200 to 1500 keV, and from 200 to 2000 keV) in dependence on detectors arrangement, as well as double coincidences caused by monoenergetic sources – in the whole energy range, and in the energy windows corresponding to the photo-peak regions (Eg±2DEg/Eg), showed that main contributors to the background double coincidences at the spectrometers PRIPYAT and ARGUS are coinciding photons which were scattered from detector to detector. In the 32-detector system, minimum, maximum, arithmetic mean and standard deviation of the background double coincidences counting rates in the energy range (200-1500) keV were found to be 0.034 (detector pairs at 79.19°), 0.142 (detector pairs at 37.38°), 0.066, 0.033 cps, respectively. The same values for the background double coincidences counting rates coming from monoenergetic sources and photons of different energies, were found to be 0.974 (63.43°), 4.646 (41.81°), 3.0724, 1.167 cps, respectively (^{137}Cs), and 0.389 (63.43°), 18.696 (~180°), 2.794, 5.294 cps, respectively (^{65}Zn). At the same time, minimum, maximum, arithmetic mean and standard deviation of the background double coincidences counting rates in the photo-peak regions were found to be 0.003 (63.43°), 0.0114 (41.81°), 0.0074, 0.0029 cps, respectively (^{137}Cs), and 0.0056 (63.43°), 0.0241 (37.38°), 0.0148, 0.006 cps, respectively (^{65}Zn).

Key words: Multidetector spectrometer, background, double coincidences, Cs-137, Zn-65, K-40

THE REGISTRATION OF Cs-134 BY GAMMA DETECTOR PAIRS AT AN ANGLE OF 90°

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Four NaI(Tl) detectors and five pairs of NaI(Tl) detectors at an angle of 90° – from the six-crystal spectrometer PRIPJAT-2M (Faculty of Natural Sciences and Mathematics, University of Montenegro, Podgorica), were used to determine registration efficiencies for the most intense gamma rays in de-excitation of ^{134}Ba, following beta minus decay of ^{134}Cs. The ^{134}Cs liquid calibration standard was used for acquiring spectra over 18 000 s real time in the energy range (200-3000) keV – in the integral, non-coincident and mode of double gamma-gamma coincidences. All the spectra from individual detectors and detector pairs in all the counting modes clearly showed peaks at the 605 and 796 keV, i.e., detection of gamma rays with relative intensity of 97.6 % and 85.5 %, respectively. Experimental registration efficiency of the 605 keV gamma ray by individual detectors in different modes of counting was found to be in the range from 0.018 to 0.071 (integral), 0.008 to 0.039 (non-coincident) and 0.007 to 0.024 (double coincidences), whilst in the case of detector pairs – from 0.048 to 0.113 (integral), 0.026 to 0.069 (non-coincident) and 0.019 to 0.045 (double coincidences). In regard to the 796 keV, detection efficiencies of individual detectors were from 0.011 to 0.046 (integral), 0.006 to 0.028 (non-coincident) and 0.004 to 0.013 (double coincidences), and in the case of sum spectra from detector pairs – from 0.021 to 0.064 (integral), 0.012 to 0.043 (non-coincident) and 0.009 to 0.023 (double coincidences). Obtained results are baselines for future development of the coincidence method for ^{134}Cs measurement – using multidetector systems with measuring geometry close to 4π. In additon, the 796 keV photopeak in a coincidence mode has been considered as appropriate for ^{134}Cs detection in a sample containing ^{137}Cs and decay products of ^{226}Ra and ^{232}Th.

Key words: Cs-134, NaI(Tl) detector pairs, gamma coincidences

CALCULATION OF ACTIVATION ENERGY USING VHR METHOD FOR LOW TEMPERATURE PEAK OF GYPSUM MINERAL

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Gypsum ($CaSO_4 \cdot 2H_2O$) is a common mineral obtained from surface and underground deposits. This natural mineral occurs in sedimentary deposits consist of limestone, dolomite, shales, marls and clays, massive anhydrite beds and such environments. Using natural minerals as dosimeters, it is important to characterize them with respect to general properties such as dose response, heating rate according to its mineral structure. In this study, activation energy of natural gypsum mineral was calculated using the various heating rate (VHR) method. In the VHR method, natural gypsum sample was irradiated with β-irradiation of 50 Gy and thermoluminescence (TL) glow curves were obtained with four heating rates of 2, 7 and 10 °C s^{-1}. In TL theory, the TL glow peaks are affected by heating rate and shifted to high temperatures. It was seen that the results of the heating rate experiment were consistent with the TL theory.

THE EXAMINATION OF THE CHANGES IN THE SACALIN LAGOON'S (ROMANIA) SEDIMENTATION RATE WITH THE LEAD-210 DATING METHOD

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The modern asymmetric deltaic peninsula *Sacalin (sf. Gheorghe, Romania)* is the latest feature of the southern Danube branch, Sf. Gheorghe, which was built from fluvial and marine sediments at the mouth of the Danube distributary. This deltaic spit is a highly dynamic and vulnerable coastal landform, which continues to develop itself as long as river sediments are sufficiently available and discharge strong enough to dissipate waves and currents that could remove these sediments.

The aim of this work was to analyze the geochronological the evolution of Sacalin lobe by the application of ^{210}Pb dating method. Sedimentation rates were determined in concordance with ages for the last 100 years by using a constant rate of supply model (CRS) to the measured $^{210}Pb_{excess}$ profile.

The sampling was carried out using a gravity corer. After subsampling the sediment cores into 1-2 cm thick slices, the physical parameters such as water content, porosity were determined. The LOI measurements have been carried out in order to assess the total carbon content as the sum of the organic matter and inorganic carbon content. The total content of ^{210}Pb has been measured via its alpha particle emitting progeny, ^{210}Po (5.304 MeV) using a Soloist alpha-spectrometric system. For the calculation of the total efficiency ^{209}Po (5.881 Mev) was used. The supported ^{210}Pb was determined by a high resolution gamma spectrometric system with HPGe detector, measuring the gamma lines of emission of its ^{238}U series precursors,^{214}Pb and ^{214}Bi (295.1keV, 351 keV and 609).

On the Sacalin Lagoon the sedimentation rate increases every two years, where the sedimentation rate alternates between 3.21-1.23g/cm^{2}y on the 2005-2013 period. From the sedimentation`s point of view, the southern part of the Sacalin Lagoon is more exposed, due to the dominance of marine current. Up to the year 1980, the sedimentation rate was 3.2 times higher.

RADIOLOGICAL INVESTIGATION OF RED MUD: TH AND PO LEACHING STUDIES

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The valorization of industrial by-products such as red mud became a tempting opportunity, but the understanding of the risks involved is required for the safe utilization of these products. One of the risks involved are the elevated levels of radionuclide concentrations in red mud that can affect human health. There is no satisfactory answer for the utilization of red mud; the main current solution is still almost exclusively deposition. For the safe utilization and deposition of red mud it is important to be able to assess the leaching behaviour of radionuclides.

The leaching features of red mud were studied by methods compliant with the MSZ-21470-50 Hungarian standard, the British CEN/TS 14429 standard and the Tessier sequential extraction method for Th-232 and Po-210. Both Th-232 and Po-210 are alpha decaying radionuclides with high energy (approx. 4 MeV for Th-232 and 5.3 Mev for Po-210), a possibility to accumulate in the food chain and may cause a human health hazard by increasing the chance of various cancers. Knowledge about the leaching characteristics of NORM material regarding various radioactive isotopes is crucial for assessing their environmental and human health impact, since it gives information on their mobility and availability to the food chain.

After the execution of the tests, the leached solutions were taken to radiochemical separation followed by spontaneous deposition for Po and electrodeposition for Th. Compared to a previous study, where 262±19 Bq/kg ^{238}U was measured by aqua regia digestion from red mud, while the leached amount was HNO_3+H_2O_2 digestion 75%, distilled water 5 %, Lakanen-Erviö solution 25%; for Tessier: I. step ~3%, II. step ~1%, III. step ~30%, step IV. ~7%, the 332±33 Bq/kg, the ^{232}Th content proved less mobile. The leached values were HNO_3+H_2O_2digestion 40%, distilled water 1 %, Lakanen-Erviö solution 6%; for Tessier: I. step ~2%, II. step below detection limit, III. step ~4%, while more than 85% remained in the residue. The pH dependence test revealed availability ~1% below pH 8, until pH 4,2 where it rose up to ~4%. The ^{210}Po had a severe disturbing effect in many cases probably due to the large amount of iron present in the red mud, from the 310±12 Bq/kg by aqua regia digestion, HNO_3+H_2O_2 digestion ~80%, distilled water 23%, Lakanen-Erviö solution ~13% while the Tessier method and the pH dependence test revealed contrary results.

THE VALIDATION OF THE RADIOCARBON SAMPLE PREPARATION METHOD AND LSC MEASUREMENTS ON THE ENVIRONMENTAL SAMPLES

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The improvement of measurement devices and new methods is given great importance to the different sample preparation methods development. This is particularly true in case of environmental samples in which measurement is access near to the detection limit. The aim of this study was to develop a device, for the radiocarbon determination by LSC by capture of CO_2 from the carbonate content of environmental water samples and high alkalinity phase of liquid samples. The developed device is able to release the CO_2 gas trapped in the water in the form of carbonates, then absorb it in a medium (Carbo-Sorb®–Perkin Elmer™) designed for the absorption of this gas. The absorbed gas was analysed with liquid scintillation spectrometry, the instrument used was a Quantulus 1220. The yield of absorption and the all efficiency of the device were determined. Absorption efficiency was determined with two different methods: the first was to gravimetrically determine the absorbed gas content from the known input carbonate. In this measurement the efficiency was determined from the ratio of the known input and measured output of the system. The second method included the use of a known amount of radiocarbon. This way the efficiency can be determined directly from the measured counts by the LSC.

A complete C-14 measurement procedure is adequate for natural level water samples, and high alkalinity phase of liquid samples. The results confirmed the validity of the sample preparation and measurement procedures, providing and increased reproducibility compared to traditional techniques. A validation test using $CaCO_3$ resulted from IAEA standards (shell and marble samples). The routine procedure was applied on different type of liquid phase (natural water and high alkalinity liquid sample).

The natural water samples were taken from surface waters and the variation of the radiocarbon concentration in the function of sampling time is essential due to the huge seasonal variation of precipitation. To determine the variation, the samples were taken from the same places on a fixed period of time, which is set as 3 months. The sampling times are set to be in the middle of meteorological seasons. The measurements are carried out continually; the results presented here include the samples taken at 10/09/2016. Analysing the results obtained from the same region shows that the deviation of the overall low activity concentration is coming only from statistical reasons. This way we proved that the radiocarbon activity is coming only from natural sources.

SYNTHESIS OF SILVER NANOPARTICLES FOR X-RAY DOSIMETRY

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The use of nanoparticles in radiotherapy and radiodiagnostic has been widely studied in the past decade, their interactions with photons at different energies give place to the combined diagnosis and therapy (theranostics) and they could even be modified to carry specific drugs or for a better biotoxicity in human organisms. Dosimetric techniques can also take advantage of the beneficial properties of inorganic nanoparticles and their combination with typical dosimetric techniques could be used as a preliminary step for their later inclusion in radiagnostics or radiotherapy treatments. One of the main limitations in the use of inorganic nanoparticles is their colloidal instability, which is typically minimized by using stabilizing agents, such as biopolymers or surfactants to prevent their aggregation and improving at the same time the biocompatibility.

This work presents a method to synthesize, purify and characterize silver nanoparticles in a gelatin matrix for dosimetry applications. Porcine skin gelatin was used as stabilizing agent and as a reactive in the thermal reduction of silver nitrate, to provide compatibility with typical gel dosimetry systems. The effect of synthesis variables like temperature, reaction time, and relative concentrations was studied to obtain products with different mean sizes and distributions. The obtained nanoparticles were characterized by different analytical techniques such as TEM, SEM, UV-Vis and gravimetric techniques in order to evaluate their distribution characteristics and the reaction yield. These nanoparticles were used as X-ray fluorescent agents within tissue equivalent materials with low energy X-ray beams at different concentrations and depths within a water equivalent phantom with the aim of assessing their performance as X-ray fluorescent agents useful for nanoparticle detection and/or localization. Finally, the nanoparticles were used in gel dosimeters to quantify the dose enhancement factor, paying special attention to the dose recorded by these materials irradiated with beams of energies below and above the excitation edge of silver. Both applications, as X-ray fluorescent agents in aqueous solutions and as dose enhancers in dosimetric systems were compared to MC simulations with similar setups.

The results indicated that nanoparticles with mean sizes ranging from 2 to 20 nm, with a lognormal distribution were obtained by means of the proposed production process. Both the mean size, and standard deviations of the distributions were mainly dependent on the gelatin concentration and temperature. The overall yield of the synthesis was around 61% w/w, and a thorough purification method was applied to obtain a pure product. The X-ray fluorescence of these nanoparticles in aqueous solutions was successfully detected with concentrations as low as 0.005 mol/L and depths within a water-equivalent phantom from 1 mm to 15 mm.

EFFECT OF INORGANIC SALTS ON POLYMER GEL DOSIMETRY BASED ON ACRYLAMIDE

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Polymer gel dosimetry is the only tissue equivalent dosimetry system able to record 3D dose distribution acting both as phantom and dosimeter at the same time ensuring post-irradiation stability. Therefore, a great effort has been made in the past two decades to obtain materials highly sensitive to ionizing radiation and with sufficient stability to preserve the dose information over time. A polymer gel dosimeter is constituted mainly of four components, an aqueous gelatin type material which limits the mobility of the reactive species and of the formed polymers after the irradiation, a monomer and a crosslinking chemical species that reacts with the radicals formed during the radiolysis of water molecules upon irradiation, and an antioxidant molecule, which consumes the oxygen present in the material and helps to avoid the inhibition effect of oxygen over the polymerization reactions. Among the different studies of the past decades aiming to improve the sensitivity of polymer dosimeters, the use of different monomers, crosslinking agents and antioxidants attained some level of success, giving place to commercial and registered materials, such as BANG, BANANA, and systems based on n-isopropyl acrylamide, methacrylic acid, acrylic acid, etc. Recently, several modifiers have been proposed to enhance the sensitivity of these materials like the use of co-solvents to enhance the solubility of the crosslinker or monomer, or the use of dopants like inorganic nanoparticles, organic molecules, or inorganic salts which could alter the disposition of water molecules around the chemical species improving the kinetics of the polymerization reactions. Despite the beneficial effects on the sensitivity of these modifications, most of these studies arrived to the conclusion that the thermal stability and the capacity of the gel dosimetry systems to preserve information over time decrease with the proposed modification. This effect is mainly due to the breakup of the gelatin structure in the dosimeter. Also, many of these studies suggest the use of a chemical modification of the supporting material to avoid this collateral drawback.

In this study, the effect of different inorganic salts, namely $MnCl_2$, $MgCl_2$ and $CaCl_2$, on the sensitivity of a dosimeter based on acrylamide (PAGAT) with a chemical modification of the gelatin support with glutaraldehyde has been investigated. A correlation between the elasticity of the supporting material and the dosimetric sensitivity has been found, suggesting that a great amount of the contribution of the inorganic salts on the sensitivity of the dosimetric material is related to the increase in the mobility of the chemical species. Therefore, a compromise exists between enhancing the sensitivity and preserving the spatial distribution of the dose. An optimal concentration of the gelatin modifier and inorganic salt was obtained for $MgCl_2$, where the sensitivity of the standard PAGAT dosimeter has been enhanced by a factor of 1.8.

OUTDOOR AND INDOOR AMBIENT DOSE EQUIVALENT RATES IN BERANE TOWN, MONTENEGRO

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This paper presents the results of ambient dose rate measurements conducted in the air of Berane town, Republic of Montenegro. Measurements were performed by Geiger Miller counter - Radex RD1503$^+$, in the middle of October 2015. An average daily value of 114.8 nSv/h of ambient dose equivalent rate was obtained, spanning from 50-160 nSv/h in the morning and 70-177 nSv/h in the evening. Analysis of the impact of spatial variations on gamma radiation levels shows a very weak correlation between indoor and outdoor ambient dose rate in the morning ($r = 0.09$) and in the evening ($r = 0.19$). Building materials or stuffs in buildings do not contribute additionally to ambient dose rate. Due to lack of published data of dose rates, these results are the first measurements of radiation levels in Berane town.

NEUTRON DIGITAL SPECTROMETER

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A newly developed fast digital spectrometer for neutron spectroscopy is presented. A pulse shape discrimination (PSD) performance of the spectrometer has been evaluated within two experiments with different neutron energies. A modular design of the spectrometer allows a variety of measurements in mixed radiation fields. The detector signal output is connected to an analog input amplifier and split into two channels with a different gain. Each signal channel is digitized by a fast analog digital converter. The digital channels are merged into one composite channel with a higher digital resolution in a wide dynamic range of energies.

The experimental measurements of secondary neutrons were carried out at the Proton Therapy Center in Prague. Secondary neutrons were generated during the interaction of the primary proton beam of energies in the range of 100 to 200 MeV with a plastic phantom. A detector with liquid scintillator NE-213 was employed in experiments.

COMPLEMENTARY TECHNIQUES BASED ON THE SYNCHROTRON AND NEUTRON RADIATION AND ELECTRON MICROSCOPY FOR CULTURAL ARTIFACT STUDIES

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One of the main world trends in the study of museum artifacts is the use of a variety of synchrotron and neutron techniques as well as electron microscopy, which significantly expands the information about different artifacts, exploring their in-depth. It makes possible to draw conclusions on the peculiarities of their structure, the elemental and phase composition, degree of preservation, which is also crucially important for the determination of the optimal methods for restoration, preservation, storage and demonstration of museum exhibits. It is very effective for supporting of the traditional methods of extracting historical information from written and archaeological sources, which didn't lost relevance, but largely exhausted their limits.

Species of research techniques are determined by the kinds of the studied samples and questions raised – X-ray and neutron tomography, elemental and phase analysis, etc. Complex instrumentation base including both sources of synchrotron and neutron radiation, and a wide range of laboratory equipment as electron microscopies and X-ray diffractometers, provides good opportunities for studies of the archaeological and arts objects. The laboratory NSciTeCH (Natural Sciences Techniques for Cultural Heritage) was established in 2015 at NRC Kurchatov Institute especially to conduct the comprehensive studies of the artifacts.

In this paper we present the results of the research of the metal artifacts from Historical State Museum, Pushkin Museum of fine arts and Institute of Archaeology RAS, which were carried out at the Kurchatov Institute: spear and beads from the Bronze Age, medieval crosses and statues from Italian Renaissance.

ELECTRON MICROSCOPY STUDIES OF CULTURAL HERITAGE OBJECTS

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The usage of traditional material science methods to the study of cultural heritage objects results in new discovery. Within that collaboration material analysis plays an important and unique role in providing a scientific base for the gradual development of art history, archaeology, authentication, conservation, restoration and related topics. The study of archaeology involves the use of a wide range of techniques. One of such methods is the scanning electron microscopy (SEM), generally using energy dispersive x-ray analysis (EDAX). This method provides a relatively quick and nondestructive means of obtaining qualitative information on the constituents of a material without much specimen preparation. In NRC "Kurchatov Institute" conducted a study of cultural heritage objects of different epochs and territorial jurisdiction such as: ceramics, samples of metals and alloys, parchment and etc. The surface of the samples investigated in a scanning electron–ion microscope (SEM) Helios (FEI, USA) equipped (EDAX, USA) and dual beam Versa 3D (FEI, USA) in the environment (ESEM) mode. The structures of the samples were analyzed on a transmission electron microscopy (TEM) Titan 80-300 (FEI, USA) with an accelerating voltage of 300 kV. Electron microscopy methods was used to determine the morphology, microstructure and phase composition of the base alloy and inclusion in some archaeological objects such as: the ancient cross-encolpion found in field studies of the Institute of Archaeology RAS near Chernizh-2 (Russia), the metal products horse ammunition, which dates from the IX-VIII centuries. BC. found on the territory of Belogorsk district of Crimea and Italian terracotta "Madonna Friedrichstein", which dates from the second half of the XV century.

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Radiation Oncology

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A PENCIL BEAM KERNEL MODEL FOR FLATTENING FILTER FREE X-RAY BEAMS

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Fast and accurate dose computation is an essential phenomenon for the algorithms that are used in all stages of an inverse planning system. One way to reduce computational time is to decrease the number of variables in the pencil beam kernels and look-up tables. In this study, a kernel that has a minimum number of variables is derived for the Flattening Filter Free (FFF) x-ray beams. This approach is selected due to its minimal profile deformation in depth as a result of the absence of a filter. For this purpose, the parameters of a kernel are redefined for the whole phantom, which is formed by a number of depth layers instead of modeling each measured depth. The benefit of this approach is that the whole phantom be defined using one kernel.

Finite size pencil beam dose calculation code was developed for the kernel generation. Grid size for the dose calculation was set to 2.5 mm. In the stage of kernel generation, parameters (pre-exponential constants, exponential constants and variables) of the kernel were estimated such that the difference between computed and measured profiles is minimized by utilizing the global gamma analysis technique. Criteria for this technique are 1 % dose difference at 1 mm distance with 10 % threshold. Profiles for each of three fields (5x5 cm^2, 10x10 cm^2, 20x20 cm^2) at five standard depths (d_{max}, 5 cm, 10 cm, 20 cm, 30 cm) 15 profiles, were used to evaluate the kernels. The multi-objective, non-derivative, unconstrained, non-linear optimization method was used to generate kernel parameters. Performance of the system was tested for the static fields. The threshold for gamma analysis was set to 10 % of the maximum dose.

In static fields, more than 95% of data points satisfy the criteria defined in the global gamma analysis with 3% and 3 mm.

It is demonstrated that the pencil beam model developed in this study can be used for the FFF x-ray beams. There is no need to define pencil beam kernel parameters at each depth; it is only necessary to calculate the scattered component to primary component ratio of the kernel as function of depth. Other parameters used in the pencil beam model are defined as constant for each depth.

Radiation Physics

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ADVANCES IN COSMIC MUON IMAGING

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Cosmic-ray muons can be used for imaging of large structures, or high-density objects with high atomic number. The first task can be performed by measurement of muon absorption within very thick material layers, while the second approach is based on muon multiple scattering. However, the muon imaging of small structures with low atomic number and density was not yet solved appropriately.

Our research group has demonstrated recently completely new imaging method by cosmic-ray muons, based on the detection of secondary particles produced by muons in object material (I. Bikit et al, Novel approach to imaging by cosmic-ray muons, EPL 113 (2016) 58001).

Novel imaging technique by cosmic-ray muons is based on the detection of secondary produced particles generated within materials and objects by passage of cosmic-ray muons. This method opens up possibility to obtain 2D and 3D images of small objects made of materials with low atomic number. The advances of “conventional” muon imaging systems based on muon absorption and scattering and detection of incoming and scattered muons will be presented, and compared with the new imaging technique. The possible applications of the new imaging technique will be discussed.

NEURAL NETWORK ESTIMATIONS FOR STOPPING POWER, RADIATION YIELD, CSDA RANGE AND DENSITY EFFECT PARAMETER FOR ELECTRONS

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In this work, stopping power, radiation yield, CSDA range and density effect parameter values in various absorbing materials for the electrons have been estimated by using artificial neural networks. According to the results, the estimations are in consistent with the available theoretical values calculated by using computer program. The root mean square errors are in the order of about 0.005 MeV.

BACKSCATTERING OF TERRESTRIAL-ORIGIN GAMMA RADIATION IN ATMOSPHERE AT SEA LEVEL

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Low-energy continuous gamma radiation with maximum of energy distribution at ~ 80 keV reaches the Earth's surface from the upper hemisphere. Besides component resulting from cosmic-origin low-energy gamma radiation, there is prominent contribution arising as a consequence of gamma photons emitted by environmental radionuclides, which are backscattered by air above ground. Covering the same energy region of gamma radiation (mainly 30keV – 300 keV), it is not simple to determine separate contributions of each radiation component to the total gamma flux. The efficient way to solve this long-standing problem is to study backscattering of gamma radiation on the atmospheric air by Monte-Carlo simulations. In our simulations we obtained air-backscattered spectra, as well as gamma photon fluxes which can be expected for certain activity concentrations of natural radionuclides (K-40,Ra-226, Th-232) distributed in the ground. In addition, we also simulated air-backscattering effects in the situations where initial gamma emission is restricted only to the area which is relatively far from the position where backscattered photons should be detected.

TOWARDS A PORTABLE NANODOSIMETER

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It is accepted today that the damage induced in biological systems by ionising radiation is strongly correlated to the features of particle interactions at nanometric scale. In order to study the physical bases of radiation damage, experimental nanodosimetry analyses the stochastics of ionisation events induced by primary particles of different type and energy in sensitive volumes of nanometric size. At present, three different nanodosimeters are operative, which count the number of ionisations in a target volume filled with organic gas at low density, as a substitute for the biological target. However, these detectors have been developed for fundamental research, and are very complex and bulky, not suited for the everyday use required, for instance, in radiotherapy or radiation protection applications.

In order to explore the feasibility and potential outcomes of a compact, portable nanodosimeter, a Monte Carlo study has been designed and carried out by means of the Geant4-DNA toolkit. The geometry of the simulated setup consists in a set of nanometre-sized target spheres randomly dispersed in a water cylinder, modelling a simplified radiation-sensitive detector based on nanostructured technology (a practical implementation of this model could be, for instance, a set of quantum dots dispersed in a PMMA layer). The detector is irradiated by a homogeneous broad beam of ionising particles, with a trajectory parallel to its main axis.

The response of the system when irradiated by incident light ions of different charge state and velocity has been studied for various geometrical configurations of the setup. Since the counting of the exact number of ionisations inside a physical volume of nanometric size could be hardly feasible, results were analysed not only in terms of the ionisation yield inside each of the detecting spheres, but also in terms of the number of spheres hit by a single primary particle (where a sphere is considered "hit" if at least a given number k of ionisations take place inside it). The viability of such an approach has been assessed. The influence of various system parameters on the detector response has also been investigated, in particular diameter and number density of target spheres and threshold value k.

The comparison with radiobiological data of cell survival suggests that such a detector could be used as a monitor of radiation damage induced by light ions to biological systems, provided that the geometrical parameters are chosen appropriately for each biological end-point under investigation.

MONTE CARLO DETERMINATION OF THE EFFECT OF DEAD-LAYER THICKNESS OF A COAXIAL HPGe DETECTOR ON FULL ENERGY PEAK EFFICIENCY

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It is very well known that dead layer thickness of germanium crystals has to be taken into account when Monte Carlo model of the detectors are built. A coaxial HPGe detectors having relative efficiencies of 34 % was considered. The detector's front, back and lateral dead layer thicknesses are 0.03 mm, 700 µm, 0.3 mm, respectively. Given these reference parameters, the full energy peak (FEP) efficiencies were calculated for the energy values from 40 keV to 2.5 MeV increasing the dead layer thicknesses 20 %, 40 %, 60 %, 80 % and 100 % for each calculation. The results revealed that front dead layer thickness has effect on FEP efficiency for the energy interval from 40-100 keV, while the back dead layer thickness has effect on FEP efficiencies for the energy interval from 600 keV to 2500 keV. It was also observed that the lateral dead layer thickness has effect on FEP efficiencies for the energy interval from 100 keV to 600 keV.

EPR DOSIMETRY OF HUMAN FINGERNAILS: STUDY OF THE VARIABILITY OF THE ENDOGENOUS SIGNAL AND DOSE RESPONSE SUBJECTED TO GAMMA RAYS AND SUNLIGHT EXPOSURE

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Human fingernails and toenails have been studied for years by means of Electron Paramagnetic Resonance (EPR) spectroscopy to develop a new capability of estimating ionizing radiation doses received by individuals in case of radiological accidents.

A stable free radical has been identified as marker of the irradiation. Unfortunately, this marker presents the same spectral characteristics as an endogenous signal observed in human nails. As this endogenous signal is more intense than the radio-induced component, the quantification of these radio-induced free radicals based on their EPR signal is extremely difficult to achieve. Moreover, the endogenous signal is extremely stable with thermal stability up to 240°C, and also shows strong variation in its intensity that are possibly correlated to UV exposure and moisture content of nails. This latter effect is reproducible when repeating cycles of water soaking and drying of the nails. However, such an effect is not observed for the radio-induced components.

An additional challenge is the inter-individual variability of the endogenous signal intensity. In order to be able to propose a method of dosimetry based on EPR analysis of the radio-induced radicals in nail clippings, it was first necessary to investigate the variability of the endogenous signals and to study the parameters influencing its intensity.

We will report on the sources of variability of the endogenous signal due to:

intensity variations over a 3 months of daily sunlight exposure period within different donors;

signal shape and intensity for about 30 different donors;

moisture effect on intensity;

Moreover, we will report on the dose response of the radio-induced signal subjected to gamma and UV rays.

THE INFLUENCE OF IRRADIATION ON THE PHASE EQUILIBRIUM PARAMETERS IN LIQUIDS

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Present work is dedicated to the investigation of radiation emission influence on those thermodynamic properties of liquid systems, which are defined by the shift of chemical potential of the regarded system and its components under the influence of irradiation. It was shown, that irradiation of coexisting phases in stationary state leads to the shift of the parameters of phase transitions of the first order. The work is dedicated to the investigation of irradiation influence on those properties of liquid systems too, which are defined by the change of chemical potential of the liquid and its components under the influence of irradiation. It was shown, that irradiation of the coexistent phases at the stationary state leads to the shift of phase transition point parameters. The main regularities of irradiation influence on the solubility of solid in liquids were obtained. The shift of the temperature and pressure of the phase transition was obtained for the first order phase transitions under the influence of irradiation. Both entropy and energetic factors were included in chemical potential of the regarded system.

ASSESSMENT OF PHYSICO-CHEMICAL PROPERTIES AND RADIOLOGICAL DOSE DUE TO URANIUM IN WATER SAMPLES BELONGING TO SOLAN AND SHIMLA DISTRICTS OF HIMACHAL PRADESH, INDIA

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In the present investigation, an attempt has been made to study the physico-chemical properties like pH, electrical conductivity and total dissolved salts in water samples collected from different sources like tap, handpumps, borewells, tubewells etc. from wide range of locations in Solan and Shimla districts of Himachal Pradesh. LED fluorimetry technique has been employed to determine the radiological and chemical risk due to uranium concentration in water samples. In this region, the uranium concentration in 68 water samples varies from 0.03 to 19.43 $\mu g\ l^{-1}$ which is less than the recommended safe limit of 30 $\mu g\ l^{-1}$ (WHO, 2011). The average value of Excess Cancer Risk (ECR) from the ingestion of uranium is 2.19 x 10^{-6}. The Lifetime Average Daily Dose (LADD) and Hazard Quotient (HQ) have mean 0.04 $\mu g\ kg^{-1}\ day^{-1}$ and 0.07 respectively. The estimated annual effective dose ranges between 0.02 $\mu Sv\ a^{-1}$ and 11.01$\mu Sv\ a^{-1}$ with an average value of 1.18 $\mu Sv\ a^{-1}$.

EVALUATED OSL TRAPPING PARAMETERS OF BeO CERAMIC PELLETS SINTERED AT DIFFERENT TEMPERATURES

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Beryllium Oxide (BeO) ceramics has been widely used for numerous applications in different fields of technology such as nuclear and technological research. In this study, BeO nanophosphors were synthesized using sol-gel method and BeO pellets were prepared from pressed and sintered BeO nanophosphors at 1100 °C and 1600 °C. The effect of sintering temperature on OSL decay curves, defect structures and trap parameters of BeO ceramic pellets were investigated using Optically stimulated luminescence (OSL) signals. We found that the life times for as 0.84 s, 0.06 s and 22.17 for BeO ceramic pellets sintered at 1100 °C and as 7.93 s, 47.61 s and 208.31 s for BeO ceramic pellets sintered at 1600 °C. Furthermore, isothermal annealing and heating rate methods were performed to determine the thermal activation energies of OSL traps.

Key words: Beryllium Oxide (BeO), Optically Stimulated Luminescence (OSL), Various Heating Rate, Thermal Activation Energy, Isothermal Annealing.

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DETERMINATION OF POTENTIAL USE OF $Li_2B_4O_7$:Ag,Tb FOR DOSIMETRIC PURPOSES USING OSL TECHNIQUE

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In this study, Optical Stimulate Luminescence (OSL) characteristics of Ag and Tb doped lithium tetraborate ($Li_2B_4O_7$) (LTB) have been reported. LTB: Ag, Tb powder phosphor was synthesized using solution combustion method. The structural investigation of undoped and doped $Li_2B_4O_7$ was performed by X-ray diffraction (XRD), Fourier transform infrared (FT-IR) analyses, scanning electron microscopy (SEM) and Thermal Gravimetric Analysis (TGA) methods. OSL properties such as decay curve analysis, dose response and energy response of the phosphor were investigated. No significant variation of OSL responses for 10 repeated measurements were observed. 1 month dark storage showed < 10 % fading. LTB: Ag, Tb phosphors show that good OSL dosimetric properties under beta irradiation.

Key words: Lithium tetraborate ($Li_2B_4O_7$), Optical Stimulate Luminescene (OSL), ionizing radiation

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LOW DOSE RADIATION RESPONSE: MODELING OF IRRADIATED CELL TRANSFORMATION

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There exists a vast number of studies of biological effects of ionizing radiation, mostly dedicated to radiation-induced cancers. Whereas the field of early effects is quite well understood, the low doses (below, say, 100 mGy) that may create only late or very late effects are a subject of on-going research. Estimation of a cancer risk for low doses or ionizing radiation requires not only rigorous statistical approach to mathematical analysis of already collected data. One should in parallel develop universal biology-based model, taking into account essential processes that take place in irradiated cells. We present relatively simple approach which can show what could be expected for the dose-effect dependence in the colony of cells. The modeling starts with rather simple consideration of how many cells can transform to cancerous ones, once mutations in them starts. An influence of both, the dose and dose-rate, is considered. The general pattern emerging from the modeling indicates sigmoidal shape of the dose-effect curve as the most likely one. It is well known that the hazard functions calculated for high doses are also of this type.

THE ENERGY DEPOSITION DISTRIBUTION AT THE MICRO AND NANO-SCALE FOR MOLECULAR TARGETED RADIOTHERAPY: COMPARISON BETWEEN ^{125}I, ^{99m}Tc AND ^{64}Cu

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Given the very short range (micrometers to few nanometers) of Auger electrons (AE), Coster-Kronig electrons (CKE), Super Coster-Kronig electrons (SCKE), conversion electrons (CE) emitted by several radionuclides, they are nowadays considered as promising solutions for molecular targeted radiotherapy. The aforementioned electrons can locally deposit their energy near the radionuclide decay site, reducing in this way the radiotoxicity of the surrounding healthy tissues. ^{125}I ($T_{1/2}$=59 days, 23 Auger electrons emitted per decay) and ^{99m}Tc ($T_{1/2}$=6 h, 4.4 Auger electrons emitted per decay) are two radionuclides that are largely studied for their potential use in theranostic, even if the effectiveness of the ^{99m}Tc Auger emissions in inducing DNA double strand break (DSB) is still controversial. However in recent years the use of ^{64}Cu ($T_{1/2}$=12.7 h, 1.80 Auger electrons emitted per decay) emerged and became a burning issue, because, in addition to its imaging capabilities, some studies showed cytotoxicity capabilities when associated to radiolabeled compounds in tumor cells.

Therefore, for ^{64}Cu the accurate assessment of the energy deposition pattern near the radionuclide decay site and how this energy varies with the radionuclide-DNA center distance is of paramount importance in order to better design therapeutic strategies based Auger electrons.

For this reason the aim of this study is twofold: i) calculate the optimal energies that maximize the energy deposition in the DNA for different distances of the radionuclide to the DNA volume and ii) study the energy deposition in the DNA and cell volumes considering the aforementioned three radionuclides above described and for the different spectrum emissions of AE, CKE, SCKE, CE and β.

In order to reach these goals, the state-of-the-art Monte Carlo (MC) radiation transport program MCNP6 was used. For modeling and simulation purposes, a simplified geometry for the DNA segment, the cytoplasm and the cell, composed of liquid water, was considered and an isotropic-like source was modeled. Emission data (photons were neglected) were obtained from the International Commission on radiological Protection (ICRP) publication ICRP-107. This study shows to what extent the deposited energy pattern distribution is affected when several spectra qualities are considered (Auger, Conversion and β emissions); discussion and comparison of results (also in terms of S values calculated in this work and reported by MIRD) obtained for ^{64}Cu, ^{125}I and ^{99m}Tc are reported.

EFFECTS OF TRANSITION-METAL-DOPING ON THE RADIO-LUMINESCENCE PROPERTIES OF MAGNESIUM ALUMINATE SPINEL CRYSTALS

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Magnesium aluminates spinel (MAS-MgAl2O4) is consider as prospective material for application in many technologies based on the luminescence properties. Particularly, transition-metal-doped spinel is potential candidate for white light source, tunable solid-state laser, optically stimulated luminescence for dosimeters. The main feature of MAS structure is the presence of cationic disorder and as a consequence the locally charged anti-site defects which influence on the optical and luminescent properties of spinel crystals. In this paper we present the results of investigation of radio-luminescence (RL) in the wide range of wavelength in spinel single crystals grown by Verneuil method as nominally pure and doped to different concentration with Cr, Mn, and Fe as well.

The RL spectra from nominally pure spinel crystals demonstrates very intense band of electron-hole recombination luminescence in the UV range which is identified with anti-site defects. In crystals doped with transition metal ions at the lowest concentration of 0.01 mass% the intensity of this band sharply drops. It means that transition-metal-doping spinel crystals lead to partially decrease of cationic disorder.

Besides, spectra of nominally pure crystals show some bands which appear due to uncontrolled impurity ions. Intentionally doping with transition metals allows us to identify luminescence centers and determine modification of crystal properties. In the RL spectra of MAS-Cr the band of characteristic for Cr^{3+} ions structure (zero-phonon lines at wavelength of 686.6 nm which is accompanied with phonon assisted satellites) sharply increases. Mn-doped MAS crystals demonstrate very strong green emission band at wavelength of 520 nm. At the doping MAS with iron in RL spectra we observed two low intensity bands: one of them 517 nm almost coincide in wavelength with emission from manganese-doped MAS, another wide band has maximum at approximately 710 nm. It was revealed that intensity of Cr^{3+} luminescence in Mn-doped spinel also increases and photon-assisted structure becomes more developed that allow us to make conclusion on the substantial ordering of spinel structure.

Also in nominally pure and in every doped crystals we observed low intensity RL band at wavelength of 360 nm the intensity of which is slightly dependent on the type of doping metal. Another wide band at 470 nm can be registered only in nominally pure MAS crystals due to overlapping with intense, but narrow, Mn emission band. These bands were tentatively identified with transitions in F-type centers (thermodynamic anion vacancies captured one or two electrons).

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ELECTRON SPIN RESONANCE STUDY OF PARAMAGNETIC DEFECTS AND RELATED CHARGE CARRIER TRAPS IN COMPLEX OXIDE SCINTILLATORS

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Scintillating material is a convertor transforming the energy of photons of ionizing radiation or high-energy particles into UV/visible light easily detectable with a conventional photomultiplier or semiconductor diode. Wide band-gap oxide materials of high degree of structural perfection are most suitable for such a purpose. They must accomplish the fast and efficient transformation of energy of incoming photons/particles in a number of electron-hole pairs collected in the conduction and valence bands, respectively, and their radiative recombination at suitable luminescence centers. However, the migrating electrons and holes (eventually created excitons) before the radiative recombination can be trapped at lattice defect or even autolocalized. The intermediate transport stage of the scintillation mechanism is a substantially critical, since any kind of defects in a lattice can potentially decrease the scintillation performance. Monitoring of electron/hole trapping states in a scintillator material and revealing the nature of corresponding lattice defects is of crucial importance to optimize the materials performance close to the intrinsic limits.

It is the aim of this report to present selected results of Electron Spin Resonance (ESR) study of various point defects which participate in the processes of charge carriers transfer and capture in the family of practically important complex oxide single crystal scintillators based on molybdates, aluminum perovskites and garnets, and orthosilicates. ESR allows not only the detection of impurity ion or lattice defect with unpaired spins but also determination of their local structure and characteristics at atomistic level. Particular attention is paid to the most natural defects inevitably present in oxide materials such as anion and cation vacancies, antisite defects induced by structural disorder or natural nonstoichiometry of the material, autolocalized electron and hole states. Current understanding of the nature of such charge trapping states and mechanisms of their creation in the selected oxide scintillation materials will be discussed.

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THERMOLUMINESCENCE AND DOSIMETRIC CHARACTERISTICS OF ZnO:In NANOPOWDERS AND CERAMICS

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The ZnO single crystals, nanopowders, coatings and ceramics were intensively studied due to their various applications as light emitters, transparent electrodes in solar cells, scintillators, varistors etc. Recently it was found that undoped ZnO nanostructures are promising material for thermoluminescence dosimetry. In present study the thermoluminescence of ZnO: In nanopowders and ZnO:In ceramics was studied.

ZnO:In nanopowders were prepared by vapor condensation using focused solar energy. The ceramics were sintered at 1200 ^{O}C in air. Nanopowders and ceramics were studied by XRD, SEM(TEM), EDX and FTIR methods.

The defect states play a major role in *thermo*- luminescence processes. These defects were studied by various luminescence methods using unique experimental setup containing of multi-layer detection system: CCD camera *Andor IDus* coupled with *Andor Shamrock* monochromator for analysis of spectral distribution of radiation as well as *Hamamatsu* PMT tube for low-light detection. Radioluminescence intensity, its spectral distribution and dependence on irradiation dose was analyzed in this research.

Thermoluminescence was studied after x-ray irradiation at room temperature. Heating rate: 2K/s. Special attention was devoted to studies of spectral distribution of thermoluminescence allowing analysis of the defect types created under irradiation as well as those responsible for recombination processes. Two thermoluminescence peaks were detected: first one at 325-400K and second at 475-550K. The dosimetric characteristics were measured in 1-60 kGy irradiation dose region.

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MEASUREMENT OF NEUTRON FLUX IN (γ,n)- REACTION ON ZIRCONIUM NUCLEI

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A target of modified titanium dioxide ($ZrO_{2\,(40\%)}TiO_{2(57\%)}AsO_{4(3\%)}$) was used for the first time for neutron production via the thin-target Zr (γ,n) reaction and quantitative determination of neutron flux. Neutron in Zr (γ, n)-reactions was measured using Aluminium activation detectors in which neutrons with energy 4-12 MeV initiate reaction ^{27}Al (n, p) ^{27}Mg. The Geyger-Muller detector and scintillate spectrometer with NaI(Tl) used for measuring the number of pulses from irradiated materials and identified peak of ^{27}Mg. The compound of crystal titanium dioxide ($ZrO_{2\,(40\%)}TiO_{2(57\%)}AsO_{4(3\%)}$) used as a zirconium-contained target. In the second experiment the compound ($TiO_{2(97\%)}AsO_{4(3\%)}$) was as a target. The both compounds were synthesised by original methods and had a crystal structure, same mass and differ only zirconium in the structure. Targets were irradiated in the same conditions, during 30 min, with uncollimated bremsstrahlung beams of 24 MeV, generated from an electron accelerator at Uzhgorod National University. The time interval between the end of irradiation and the start of measurements was 30 minutes. In such conditions, with good accuracy can be calculated neutron flux from the nuclei of zirconium. Cross section of (γ, n)-reaction on nuclei of zirconium greater than nuclei of Oxygen, Titan and Arsenic.

The density of neutron flux in reaction Zr (γ, n), is φ=1.263 10^8 n/sm ^{2}c. Using of such substances as target, with their strict crystalline structure, much simplifies calculations in the study of photonuclear reactions.

THE EFFECTS OF ANNEALING ON THE THERMOLUMINESCENCE GLOW PEAKS OF THE NATURAL MUSCOVITE MINERAL

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The annealing effect on thermoluminescence (TL) glow peaks of natural white muscovite mineral has been investigated. Muscovite is a rock-forming silicate mineral within the mica group and there is a growing interest in the study of the TL characteristics of it due to its dosimetric potential. In this study, the muscovite mineral was annealed at the temperatures ranging from 100 ˚C to 600 ˚C with an increment of 100 ˚C for 30 min., 1 h and 2 h for TL measurements. All annealing treatments were performed with a specially designed microprocessor-controlled electrical oven, which is able to control the temperature within ±1 ˚C. The irradiations at room temperature (RT) were carried out with the β-rays from a calibrated ^{90}Sr–^{90}Y source (≈0.115 Gy/s) after each annealing process. The muscovite samples exposed to a beta dose of 207 Gy were readout with a linear heating rate of 2 ˚C/s from RT to 400 ˚C in N_2 atmosphere by using the Lexsyg smart luminescence measuring system. With the comparison of the TL glow peaks of both un-annealed and annealed samples irradiated with the same beta dose, the effects of annealing temperature and time on TL response were observed.

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A PRELIMINARY STUDY OF TL AND OSL TRAPS FOR THE ARAGONITE MINERAL

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Luminescence (thermoluminescence (TL) and optically stimulated luminescence (OSL)) methods are important for dosimetric studies. Understanding the TL and OSL traps of dosimetric materials is critical to explain their different and similar properties. In this study, TL and OSL signals of natural aragonite mineral were recorded using lexsyg smart TL/OSL reader after different beta irradiations. TL and OSL trap properties were compared with each other using the obtained TL glow curves and OSL signals. In sequential measurements, while the TL signals were observed after the OSL measurements, the OSL signals were not observed after the TL measurements. In conclusion, TL and OSL traps are located close to each other within the band gap of aragonite mineral and the OSL traps affect the TL signals if the TL measurements are done firstly.

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ANALYSIS OF THERMOLUMINESCENCE KINETIC PARAMETERS OF APATITE WITH CGCD METHOD

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In this study, thermoluminescence (TL) kinetic parameters of apatite mineral were determined using computerized glow curve deconvolution method (CGCD). The apatite samples were irradiated with beta doses of 1 and 30 Gy and then the TL glow curves of the samples were recorded from room temperature (RT) to 450°C with a linear heating rate of 2°Cs^{-1} by using lexsyg smart TL/OSL reader system. Nitrogen gas was allowed to flow into the reader during all readout process to avoid any spurious signals and background readouts were subtracted from the TL glow curves. In conclusion, TL kinetic parameters of these glow peaks were compared for both dose values and TL measurements show that the irradiated samples have four TL glow peaks at around 85, 125, 175 and 220°C, respectively.

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CALCULATION OF THALLIUM HYPERFINE ANOMALY

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In recent years, the precision reached in laser spectroscopy experiments coupled with advances in atomic theory has enabled new atomic physics based tests of nuclear models. Understanding the occurrence of shape coexistence in atomic nuclei is one of the greatest challenges faced by theories of nuclear structure. For neutron-deficient isotopes near Z = 82 closed shell reveal along with the near-spherical ground states the presence of oblate structures. The measurements of hyperfine constants are highly sensitive to nuclear charge and magnetic radii changes because they depend on the behavior of the electron wave function near the nucleus. These hyperfine splitting measurements can serve as very useful tool for understanding of shape coexistence phenomena in atomic nuclei.

Magnetic hyperfine constants are usually assumed to be proportional to the nuclear magnetic moments. However, this is true only for the point-like nucleus. For the finite nucleus we need to take into account (i) the distribution of the magnetization inside the nucleus which does not reduce to the magnetic moment of the nucleus and (ii) the dependence of the electron wave function on the nuclear charge radius. Former correction is called magnetic and the latter is called charge correction. Together these corrections are known as hyperfine anomaly.

In this report the method of computation of hyperfine anomaly is described and applied to different short-lived isotopes of thallium and its hydrogen-like ion. Due to these calculations the influence of nuclear charge and magnetic radii on the hyperfine splitting shifts between thallium isotopes was investigated. We consider thallium as atom with one valence electron and other electrons are included into atomic core. We use Dirac-Coulomb Hamiltonian in the no-pair approximation. Usually the dominant correction to the one-electron amplitudes comes from random phase approximation. This correction is also calculated. Due to comparison theoretical and experimental values for thallium isotopes hyperfine anomaly estimations of their nuclear magnetic radii are obtained.

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PHASE COMPOSITION EFFECT ON THERMOLUMINESCENCE BEHAVIOR OF Dy^{3+} AND Tb^{3+} DOPED PHOSPHATE GLASSY CRYSTALLINE MATERIALS

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Radiation dosimetry is a key element in safe application of radiation sources and nuclear technologies. Medical, scientific and technological application of radiation sources requires precise control of radiation doses in a wide range of doses and dose rates. During last decades many dosimetric systems were elaborated and are successfully used up to now, allowing for dose measurements in a wide range from uGy up to hundreds of kGy. One of the most commonly used dosimetric methods is thermoluminescence dosimetry (TLD), based on the generation of dosimetric signal in solid materials as a result of high energy particles interactions with the absorbing medium. Good dosimetric material should exhibit linear dose response and good signal stability. Till now many solid state dosimetric materials have been characterized and are successfully used, especially in low dose ranges, however, for high dose range (technological) applications availability of good TLD dosimeters is limited.

In this work, we will present results concerning various contribution of amorphous and crystalline phases and influence of different phase composition on the thermoluminescence signal structure and glowing efficiency of Dy^{3+} and Tb^{3+} doped phosphate matrices.

Phosphate glass samples (PPG) doped with Dy^{3+} and Tb^{3+} ions were synthesized by the melt-quench technique. The materials used for synthesis were of highest available purity: ammonium dihydrogen phosphate ($NH_4H_2PO_4$), sodium carbonate (Na_2CO_3), aluminum oxide (Al_2O_3) and respective rare earth element oxide (Dy_2O_3 or Tb_4O_7). The batch components were accurately mixed in an agate mortar, placed in Al_2O_3/ZrO_2 95/5 composite crucible and subsequently heated at 800°C for 3 hours. After this time, bubble free melt was further heated to 1200°C. The melt was quickly poured on a stainless steel plate. After cooling and crushing, samples were grinded in ZrO_2 planetary ball mill. Two steps synthesis process was applied to ensure homogeneity of the glasses. Powdered glass samples were partially or completely crystallized by annealing slightly above glass transition temperature, resulting in formation of materials with desired contribution of glassy and crystalline phases. For evaluation of the thermoluminescence signal pellet type dosimeters were prepared using PTFE powders as agglutinator. Polymer-glass composite pellets were irradiated with ELU-6E (6 MeV electron beam) and/or Co-60 gamma sources in Institute of Applied Radiation Chemistry. TLD measurements were performed with TL RA-94 thermoluminescence reader within the temperature range 40-400°C. Results indicate for the improving TL signals resolution upon increasing degree of crystallinity with simultaneous increasing of TL signal intensity. The observed effect may be used for preparation of tailored TLD materials with precisely defined properties.

EFFECT OF LOW-DOSE BETA- AND GAMMA-RADIATION ON PHOTOLUMINESCENCE OF COELENTERAMIDE-CONTAINING FLUORESCENT PROTEIN OBELIN FROM OBELIA LONGISSIMA

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Coelenteramide-containing fluorescent proteins are convenient bioassay for studying the effects of low-dose radiation in terms of physical and chemical processes. The destructive effects change structure of the protein by modifying amino acid microenvironment of the fluorophore (coelenteramide) and the effectiveness of proton transfer in its excited state, which leads to a change in the ratio of the neutral (purple) and ion (blue-green) form coelenteramide. To study effects of low-dose radiation was chosen discharged photoprotein obelin, a representative of a group of coelenteramide-containing fluorescent proteins. Obelin is a perspective bioluminescent and fluorescent biomarker for biomedical investigations. Discharged obelin has several advantages, such as stability, non-toxicity and high fluorescence quantum yield.

Tritium and ^{137}Cs-containing particle were used as model sources of beta- and gamma-radiation. Tritium, a beta-emitting isotope of hydrogen, is one of the most widespread products of radioactive decay of industrial radioisotopes, was used as a source of internal exposure. Due to low energy of its radiation, tritium produces a specific action on living organisms. ^{137}Cs-containing radioactive hot particles were used as the point sources of external gamma radiation. The particles were extracted from the floodplain soils and sediments of the Yenisei River in the area affected by the operation of the Mining-and-Chemical Combine of Rosatom (Bolsunovsky and Tcherkezian, 2001; Chuguyevskiy et al., 2010).

Patterns of change in the intensity and color of luminescence of discharged photoprotein obelin by exogenous non-radioactive compounds currently studied in detail, which creates prerequisites for understanding the effects of ionizing radiation on the luminescence of discharged obelin.

In this work we studied effects of tritium (200 MBq/L) and ^{137}Cs (2070 μGy/h) on spectral characteristics of photoluminescence of obelin.

It was found that the exposure of obelin to tritium during 18 days and ^{137}Cs during 7 days change color of photoluminescence of discharged obelin: the contribution of purple spectral component with maximum at 415 nm increased, while the contribution of blue-green component with maximum at 500 nm decreased. The decrease of “blue-green” 500-nm maximum was concerned with reducing efficiency of charge transfer process in obelin chromophore in the radioactive solution.

The study forms a basis for development of fluorescent biomarker to monitor biological toxicity of radioactive media.

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INVESTIGATION OF PROPERTIES OF SHIELDING ABILITY OF CONCRETE MATRIX COMPOSITE MATERIAL REINFORCED WITH COLEMANITE AGAINST NEUTRON RADIATION

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Neutron radiation has been used with many materials for use in shielding. Boron compounds are the preferred compounds in this area because of their high thermal neutron flux cross section. Turkey is rich in boron compounds as a country with about 73% of the world boron reserves.

Studies on boron compounds have shown that the thermal neutron shielding values of colemanite are extremely high. In this study, it is aimed to investigate neutron shielding values which will be the result of mixture with concrete. Colemanite reinforced concrete composite specimens were prepared for use in neutron radiation shielding and the neutron shielding capabilities of the obtained specimens were investigated. 241Am-Be neutron source with 74 GBq activity were used in our experiments. Average neutron energy of this source is approximately 4.5 MeV. BF3 detector with diameter 2.54 cm and length of 28 cm was used for counting neutrons.

Key words: Neutron radiation, shielding, colemanite, concrete, composite material

IMPACT OF DEFECT CONCENTRATION ON PERCOLATION IN DISCRETE IRREVERSIBLE DEPOSITION

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Irreversible deposition on a triangular lattice with quenched impurities is studied by Monte Carlo simulations. Irreversible deposition is often modeled by random sequential adsorption (RSA). In RSA processes particles are randomly, sequentially and irreversibly deposited onto a substrate. The particles are not allowed to overlap and they are permanently fixed at their spatial positions. Thus, the dominant effect in RSA is the blocking of the available substrate area and the limiting (jamming) coverage is less than in close packing. During the process of irreversible deposition number of deposited objects increases, causing the growth of clusters of occupied sites. Percolation assumes existence of a large cluster spanning two opposite sides of the substrate. Formation of long-range connectivity in disordered systems is of a great importance in many physical, chemical and even sociological systems. In our simulations the lattice is initially randomly covered by point-like impurities at certain concentration p. The depositing objects are formed by self-avoiding random walks on the lattice. Jamming coverages and the percolation thresholds are determined for a wide range of impurity concentrations. It was found that the jamming densities decrease with the impurity concentration p. Results of the simulations show that the percolation can be reached at highest impurity concentrations with angled object, and the critical defect concentration p_c is lowest for the most compact objects. Defects on a lattice are more successfully avoided by angled objects, which makes the percolation more robust in the presence of impurities.

Radiation Protection

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THE FORWARD GENETIC APPROACH COMBINED WITH GAMMA RAY MUTAGENESIS TO ENHANCE DROUGHT TOLERANCE IN AGRICULTURAL PLANTS

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Now new challenges such as climate change, human population growth, etc., are posing a big threat and challenge to sustain food production worldwide. Thus, increasing crop yields to ensure food security is a major challenge. Mutagenesis is an important tool in crop improvement and is free of the regulatory restrictions imposed on genetically modified organisms. The mutagen treatment, either physical or chemical, breaks the nuclear DNA and during the process of DNA repair mechanism, new mutations are induced randomly and heritable. So, it has induced to broaden the genetic diversity for enhancing crop productivity in both seed and vegetatively propagated crops. The goal of recent project is to enhance drought tolerance in wheat using gamma ray mutagenesis. To achieve this goal, *in vitro* and *in vivo* selecting techniques were used to obtain drought tolerant mutant line(s), after obtaining gamma ray induced mutant wheat population. Candidate four mutant lines were selected in fifth generation and their agronomic performances were evaluated using both agronomic (plant height, flag leaf area, tiller number, grain yield per plant, days to heading, days to maturing, drought susceptibility index, etc.) and biochemical (the content of total chlorophyll and proline, and the activities of SOD, CAT and POX) parameters under normal and stress conditions in green house environment.

IMPACT OF MICROBIOLOGICAL PREPARATIONS ON RADIOACTIVE CESIUM EXCRETION RATE UNDER CONDITION OF ITS CHRONIC INGESTION

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Prospects for the development of nuclear technologies determine the necessity of solving the problems of radiation safety for man and his environment. Among the most dangerous radioactive pollutants in the ecological aspect are isotopes of ^{134}Cs and ^{137}Cs. In this regard, searching practical ways and means to reduce the accumulation of radioactive cesium isotopes in the body and their rapid excretion is an urgent issue. Food supplements that reduce cesium accumulation in the organism could be used by population for reducing the collective dose of radiation exposure under the conditions of chronic ingestion contaminated food.

The experiment was carried out on four groups of laboratory white rats, males six months of age herd breeding in vivarium conditions. All groups of animals get feed contaminated with ^{137}Cs over 135 days with the established pauses (7 and eight days) to evaluate the half-life of ^{137}Cs in the animal bodies. The activity of ^{137}Cs in the daily diet was 34,95 ± 5,62 Bq/day. Lifetime measurement of the specific activity (Bq/kg) were carried out four times in two series -- every two months after receiving contaminated feed and after 7-8 days of receiving relatively clean diet.

Estimation of ^{137}Cs in the bodies of animals produced using Ortec gamma spectrometer with germanium detector GEM-40200-P. The immobilized animal was placed in a plastic case, and the put in the lead detector chamber on 10-15 minutes to get the number of pulses sufficient to determine the activity of a radionuclide with an error of not more than 7.5%. The method was calibrated by comparing the readings of the detector on a live animal and its average sample of tissues and organs, placed in a standard geometry “denta” to determine the true activity of 137Cs in the body. The correction factor calculated on the basis of the calibration was 2,31±0,12.

Microbiological preparations EM-1 and EMX-Gold (EMRO, Japan) were used for correction of ^{137}Cs biokinetic. Assessment of the half-life of ^{137}Cs performed separately for each animal in all groups by the difference in the activity of the radionuclide in the first and second measurements in each of the two series.

Main results:

1. In conditions of chronic ingestion of ^{137}Cs effective half-life of the radioisotope in the body 8-month-old male rats kept on a standard diet is 352±69 hours, 10-month rats -- 394±148 hours.

2. The including into the diet of male rats microbiological preparations EM-1 and EMX-Gold on the period of 2 months reduces cesium half-life time at 16-19%, but the differences with control are valid only at significance level 0.15.

3. Under the 4-month maintenance of male rats on a diet contaminated with radioactive cesium permanent addition to the drinking water microbial additives EM-1 or EMX-Gold does not alter the rate of excretion of the radionuclide from the body.

TEST OF BIOLOGICAL SHIELDING OF HOT CELLS WITH HIGH ACTIVE SOURCE ^{60}Co (300 TBq)

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The purpose of the paper is to present a test of biological shielding of hot cells facility constructed as a part of the project SUSEN.

In our facility we have 10 hot cells and 1 semi-hot cell. The hot cells are used for preparatory and auxiliary operations with irradiated materials, (receiving of irradiated materials, unloading of containers), but also for mechanical testing and determination of structure characteristics. Semi hot cell is used for microstructure analyse of samples (scanning electron microscope, nanoindenter).

Biological shielding of the hot cells is made by steel plates having a thickness between 300 mm - 500 mm. This biological shielding allows us to work with activity of up to 300 TBq for ^{60}Co. Semi hot cell is suitable for 250 GBq for ^{60}Co.

The purpose of this test was to demonstrate that the biological shielding of the hot cells has the desired efficiency and the measured values at selected points correspond to the contractual values, which were mandatory for supplier of biological shielding. The results are also used as a proof of the optimization of radiation protection for the State Office for Nuclear Safety, which shows that radiation protection is optimized and allowed to work safely work in the facility of hot cell.

During this test of biological shielding was revealed that radiation protection in the hot cells facility is optimized for nominal activities of samples.

NATURAL RADIONUCLIDES IN BOTTLED MINERAL WATER AT THE SERBIAN MARKET

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Natural radionuclides are present in mineral water as a result of geochemical processes that influence its final composition. The quality of mineral water varies and, apart from the natural disasters such as droughts and floods, it is also affected by industrial activities. The aim of our investigation is to determine the activity concentrations of ^{40}K, ^{238}U, ^{226}Ra and ^{232}Th in mineral waters available at the Serbian market. Nine samples of carbonated mineral water and five samples of non-carbonated natural spring water, collected during 2016, are analyses by standard gamma spectrometry. The maximum ^{40}K specific activity measured in the samples is 3.6 Bq/l, while the ^{238}U, ^{226}Ra and ^{232}Th specific activities are below minimal detectable activity. These results show that according to the national regulations, all samples are radiologically safe for human consumption.

THE CREATION OF THE NATIONAL COMMITTEE OF MEDICAL PHYSICS IN GUATEMALA, CENTRAL AMERICA

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The IAEA human health reports, No. 1, The Medical Physicist: Criteria and Recommendations for Academic Training, Clinical Training and Certification in Latin America, suggests that the Medical Physicists of the region be accredited. "The accreditation is issued by a duly authorized professional entity (for example, a college or a professional society) serves as a public recognition that gives quality to the service provided"

In Guatemala, the Ministry of Energy and Mines, which regulates the use of ionizing radiation through the Directorate General of Energy, took as reference for the accreditation and exercise of the profession of Medical Physics in Guatemala the report No. 1 of the IAEA. For this reason, the Guatemala Engineers association (CIG), where the physicists are members, created the CIG Medical Physics Commission and this commission convened to Universidad de San Carlos de Guatemala USAC (national university), Directorate General of Energy DGE and Guatemalan Association of Physics AGF (civil association) to appoint their representatives for the creation of the National Committee of Medical Physics, whose functions will be to endorse the registration of medical physicists, and deliberate regarding medical physics when required.

RISK OF CANCER ASSOCIATED WITH CARDIAC CATHETERIZATION PROCEDURES: THE FRENCH "COCCINELLE" STUDY

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Introduction. Cardiac catheterization procedures (CCP) are examinations in which the heart is catheterized under x-ray guidance, allowing visualization of the heart and surrounding vessels and treatment of a wide range of structural and electrophysiological disorders. There has been a rapid increase in CCPs over recent decades. The radiation doses from these procedures are often quite large, leading to concerns over the later risk of developing radiation-related cancer. Such concerns are especially important in the context of CCPs conducted on children, because they are thought to be especially sensitive to the carcinogenic effects of ionizing radiation. Moreover, the survival of children with even complex congenital heart defects has greatly improved, meaning many now live long enough for radiation-induced cancers to manifest.

Objective. The main objective of the cohort study "Coccinelle" (French acronym for "Ladybird") is to investigate the relationship between early-life exposure to ionizing radiation from CCPs and subsequent cancer risk. This will strengthen the epidemiological basis for understanding the radiation-related risk of cancer in people exposed early in life (a demographic group for which such data are very sparse) and will directly assess the cancer risks associated with an increasingly-common radiological procedure performed on children.

Methods. The study population consists of patients who underwent at least one CCP(either for diagnostic or therapeutic purposes) before the age of 10 years and from 2000 to 2013. Individual CCP-related doses are being assessed for each child included in the cohort. For each CCP performed, dosimetric parameters (dose area product, fluoroscopy time) are retrieved retrospectively. The cohort will be followed up through linkage with French paediatric cancer registries and through the French medical insurance system.

Results. Data collection is ongoing but actually the study includes about 14,000 children and 18 000 CCP. A description of the main characteristics of the children included will be presented. Radiation doses will be presented for each CCP category, according to patients' age and weight. The main CCP categories investigated are: Diagnostic, Patent Ductus Arteriosus (PDA) closure, Atrial Septal Defects (ASD) closure, Valvuloplasty and Angioplasty.

Conclusion. The cohort study "Coccinelle" is specifically designed to provide further knowledge on the potential cancer risk associated with paediatric CCP. It will also provide comprehensive information on typical levels of doses for paediatric interventional CCP in France.

RH CONTROL OF Cs^{137} IN ANIMAL FOOD AND ANIMAL PRODUCTS

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As accredited, Labrah-Laboratory for Radiation Hygiene conducts more than 25 years of full-time radiation-hygienic monitoring of animal products and animal feeds. The objective of this work is to point to current radiation situation in the field of radiation hygiene feed control in the food chain and manner of implementing of procedures and measures to prevent feed contamination from radioactive nuclides produced in normal conditions, as a basis for the protection of animal health. This paper presents the results of the RH control Cs^{137} in the last 5 years. From these results we conclude that the activity of Cs^{137} in food and animal feed in the period from 2010 to 2015, far below the prescribed limits and that value is reached before the accident in Chernobyl. This means that during this period there was no additional radioactive contamination of the environment, we mean and the nuclear accident in Fukushima, but also to the activities of the radionuclides in our nutrition is very low.

PRELIMINARY SHIELDING ANALYSIS FOR THE BNCT FACILITY

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A proton accelerator based Boron Neutron Capture Therapy (BNCT) facility is under development in Korea. BNCT is a noninvasive therapy for treating malignant tumors especially for brain tumor and recurrent head and neck cancers. Proton beam is produced in ion-source and transported to Radio Frequency Quadrupole (RFQ) by injector with 45 keV. Then the proton beam is accelerated up to 3 MeV in RFQ and 10 MeV in Drift Tube Linac (DTL). The 10 MeV proton beam is irradiated on the beryllium (Be) target through beam transport line and produce neutrons. Purpose of the research is performing a radiation shielding analysis for the BNCT facility design satisfying radiation safety requirements and obtaining an operating license for the radiation facility through the domestic nuclear commissioning procedure. Radiation shielding analysis was achieved based on the computational particle transport code. MCNPX 2.7.0 transport code and ENDF/B-VII.1, JENDL-HE nuclear data library were used for particle transport and nuclear reaction for proton, neutron, and gamma-ray up to 10 MeV. Induced activities due to neutrons were calculated with FISPACT-2010 inventory code and EAF-2010 nuclear data library. The dose rate was estimated with flux-to-dose conversion factor of ICRP publication 116. The dose rate limit was set to 5 μSv/hr for worker's area, 0.25 μSv/hr for public area by applying 1/2 safety factor. The first step of radiation shielding analysis was neutron source term evaluation. The neutron source terms were evaluated in 19 angle groups respect to the beam direction and 100 energy groups in log scale at 4 positions; RFQ, DTL, beam transport line, and Be target. The effectiveness of computational calculations in following steps was improved about 500 times by utilizing source terms. Secondly, bulk shield thickness analysis was carried out to evaluate required thickness satisfying designated dose limit. The required thickness was evaluated as 120 cm for accelerator room and 200 cm for treatment room. The final facility design was determined by applying the bulk shield thickness. Next, dose rate at the points of interest and dose rate distribution (dose map) during an operation were verified. After satisfy the designated dose limit for each area, neutron activation analysis for the air was carried out. The irradiation condition was set to 1 hour of operation and activities were calculated for 1 second, 1hour, 1day, and 1 week after shutdown. As a result, H-3, C-14, Ar-41 were proved as representative radioisotopes in the BNCT facility. The activities of each isotope satisfied the domestic regulation values.

CONSEQUENCES OF THE RADIATION ACCIDENT IN 2012 IN POLYMERS AD DENYA, VARNA REGION

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Ignorance and inability to use radioactive sources are basics reasons for radiation incidents. Such incidents are particularly dangerous to the person who was in direct contact with the radioactive source and this danger should not be ignored. The article describes the doses received by people who were in direct contact with the stolen radioactive sources in industrial enterprise Polymers AD, town of Devnya, Varna region, Bulgaria on September the 5th, 2012.

Key words: Ionizing radiation, radiation accident, activity, received dose

ON SITE DOSE ON DEMAND® CYCLOTRON DOSE RATE MEASUREMENTS AND RADIATION EXPOSURE OF PERSONNEL

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Background. F-18 FDG is the most common PET/CT radiotracer used in oncology. In Bulgaria PET/CT was first installed in 2009 to the Nuclear Medicine Department in St. Marina University Hospital, Varna. It is used for diagnostic purposes (oncology, neurology and cardiology) and for treatment planning in radiotherapy. In 2013 the on site dose on demand® F-18 FDG production cyclotron was installed at the above mentioned hospital.

Aim. As we have more than three years opportunity working on dose on demand® cyclotron and we have injected more than 10 000 patients using on site production of F-18 FDG, we can make the evaluation of the radiation environment around the facility. The aim of this study is to analyze data from radiation dose rate measurements of gamma rays and neutrons in cyclotron and radiochemical laboratory and to calculate the radiation exposure of personnel.

Methods. Radiation measurements are performed at all stages of FDG single dose productions. Gamma rays dose rate measurements are taken using gamma dosimeter Micro –Gamma LB112 and neutron dose rate measurements are taken using neutron probe LB6411. They are mounted on the walls inside the cyclotron and radiochemical rooms. The radiation exposure of personnel is measured using TLD dosimeters and individual portable Dose Rate Meters-Gamma Twin, Graetz.

Results. Heightened levels of radiation exposure of personnel are observed during F-18 transfer from cyclotron to radiochemistry module, FDG syringe extraction and dose synthesis card exchange.

Conclusion. Analyzed data from the radiation monitoring inside the controlled area (cyclotron facility) during the FDG production process show levels within the permitted. Annual effective dose measurements of the personnel are between 0.5 mSv and 2 mSv, as for the last year they are below 1 mSv, that is way below the dose limits established in government regulations.

RADIATION HAZARDS AND RADIATION PROTECTION PRACTICES OBSERVED FROM DIFFERENT PERSPECTIVES

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The term of radiation hazards is connected to the hazardous levels of ionizing radiation that could be harmful to the living tissue. Reflecting the contemporary lifestyle the World Health Organization (WHO), stated that as the use of ionizing *radiation* increases, so does the potential for health *hazards* if not properly used or contained. The increased rate of ionizing radiation can be attributed to the variety of anthropogenic activities, ranging from ore extraction, medical services, and energy production to military installations. At the other hand, radiation protection practices term indicates the measures directed to the protection of humans, at the first place, and other living organism from the harmful effects of *exposure* to *ionizing radiation*. In that sense, efficient and effective radiation protection from the perspective of society usually involves minimizing costs and capital commitment in any way. On the other hand, effective and efficient radiation protection management activities from the perspective of the army involve broader radiation protection measures during peacetime, emergencies and even wartime. The aim of this paper is to help development of an integrative model for radiation protection, addressing the contemporary needs within the different but prominent stakeholders: civil structures, energy sector and military. The paper offers an in-depth analysis of related core terms: radiation protection principles and modalities of protection. The applied methodology consists of comparative analysis and statistical evaluation of available data. Obtained results are intended to be used in further implementation processes regarding the developed model.

HEALTH CONSEQUENCES IN THE DESCENDANT POPULATION OF THE PARTICIPANTS IN THE DIMINUTION OF THE CHERNOBYL DISASTER

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Introduction. The effects of the Chernobyl accident are felt, and now many children are born, with very serious birth defects through genetic transmission. Health monitoring in relation to the identification of chromosomal abnormalities that affect the integrity of the genetic material, represent a topic of great current at the level of scientific research in this area.

Materials and methods. The evaluation analysis of the blood count indicators and biochemical analysis, and the dynamic morbidity study in children of participants in liquidation of consequences of Chernobyl disaster, aged between 1-18 years, in 2010-2015 periods.

Results and discussion. The analysis in our study shows an increase in gastro-intestinal pathologies in 2010-2013 years, and less frequently in the number of cases in the years 2014 to 2015.

In the descendents population of participants in liquidation of consequences of Chernobyl disaster population decreased thyroid gland diseases and anemia incidence “target” of ionizing radiation.

Conclusions. In the descendents population of participants in liquidation of consequences of Chernobyl disaster population decreased thyroid gland diseases and anemia incidence “target” of ionizing radiation.

These results demonstrate the need for clinical-genetic study to determine the particularities of chromosome aberrations in people exposed to ionizing radiation, inclusive children of participants in liquidation of consequences of Chernobyl increasing intensity to reduce morbidity rates.

THE MANAGEMENT OF MATERIALS THAT ARISE FROM DECOMMISSIONING THE VESSELS OF THE VVR-S REACTOR

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The VVR-S nuclear reactor from Magurele had a maximum thermal power of 2 MW that used distilled water as moderator, coolant and reflector. After 40 years as successful operation, the reactor was stopped in 1997. In 2010 was started the decommissioning project. The VVR-S reactor is the first nuclear installation in decommissioning from Romania. Important quantities of materials are being generated during the decommissioning program. All these materials can leave the nuclear site by recycling (free release) or final/intermediate storage (radioactive wastes management).

The VVR-S reactor contains three aluminium vessels: (i) the central vessel which is designed to contain the nuclear fuel from the active area; (ii) the median vessel which separates the primary cooling circuit from the secondary cooling circuit; (iii) external vessel that contain the other vessels. The reactor vessels are the most activate part of the reactor block.

The working methodology for the reactor components decommissioning contain the dismantling, sorting, radiological characterization, free release and radioactive waste management. For each component dismantling a working procedure is established to give the details of the work to be done, and analysis of safety aspects are being considered (conventional and radiological). The materials sorting step is based on primary radiological characterization. The materials that meet the threshold primary radiological characterization are transferred to the Radiological Characterization Laboratory for final radiological characterization. The aluminium alloy reactor vessel parts with high activity are segmented and inserted in 220 l drums. The drums with radioactive waste are being radiologically characterized prior to intermediate storage.

The aim of this paper is to present the management of waste (radioactive or nonradioactive) that arises from the decommissioning of the VVR-S reactor vessels.

EVALUATING THE HEALTH OF CATEGORY A SPECIALISTS INVOLVED IN RADIOLOGICAL PRACTICES

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Introduction. Professionals involved more directly in the use of ionizing radiation should receive education and training in RP at the start of their career and the education process should continue throughout their professional life as the collective knowledge of the subject develops. Underestimating the health risks from exposure to ionizing radiation could lead to unjustifiable patient and physician exposure and to a concomitant increase in the overall population dose.

Material and methods. The evaluation analysis of the hemogram with total indicators of the specialists category A, involved in radiological practices (ionizing radiation therapy and diagnostic radiology) in 2013-2015 periods.

Results and discussions. The results of the analysis of hemogram at the women, shows a diminution of hemoglobin which causes by development of anemia in 2013 year.

In subsequent years of study (in the coming year study), it was found the slow normalization dynamics of the indicators with the exception of the content of lymphocytes to the men increased, in 2014 and 2015 years.

Conclusions. Comparing the research results in dynamics of the laboratory investigations results of the personnel involved in radiological practices with previous years have not established the essential changes. This is explained by compliance with the requirements of radiation protection structures mentioned the equipment, used during the hours of work (working hours) witch contributing by carrying out radiological activities safely. Exposure to ionizing radiation should be minimized as much as possible whilst achieving the required diagnostic or therapeutic outcome (optimization).

THE DEVELOPMENT OF NEW APPROACHES TO THE PREVENTION OF COMPLICATIONS OF RADIATION THERAPY IN ONCOLOGY

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Currently, radiotherapy, as one of the principal methods in treating of malignant tumors, allows to achieve complete or partial (70-75%) tumor regression. Life expectancy after the end of treatment measures is higher, however the risk of post- radiation complications is also increased. These complications – post-radial ulcers, adhesions - are very torpid and difficult to treat, moreover, they are able to fully determine the negative outlook for cancer patients, significantly reduce their quality of life, often leading to early disability and even death. A new approach to prevent or mitigate these side effects of radiotherapy is to use low-toxic and well-tolerated radioprotectors capable to selectively protect normal tissues surrounding the tumor. We have synthesized and studied a range of compounds – selective inhibitors of inducible and endothelial nitric oxide synthase (NOS), N,S-substituted isothioureas, able to create transient tissue hypoxia and therefore may be effective radioprotectors in non-toxic doses. This paper presents the ability of two of them (compounds named INOS1 and INOS2) to selectively protect the non-malignant tissues during radiation treatment of tumors. Studies were carried out on the model of radiation therapy of transplantable sarcoma M-1 in Wistar rats (KYO). INOS1 and INOS2 were administered in the optimum radioprotective dose (1/4 LD16) once before single (32 or 36 Gy) or fractionated (two doses of 20 Gy) local g-irradiation of the tumor. The dynamics of tumor growth were evaluated with an interval of 2 days. The degree of radiation damages of the skin was evaluated by classification RTOG/EORTC-95. Although INOS1 and INOS2 are quite effective radioprotectors (DRF – 1.4-1.8), these compounds did not alter the growth and radiosensitivity of sarcoma, and didn't modified antitumor effects of g-radiation. At the same time, the INOS1 and INOS2 statistically significantly limited the severity of skin damages in all modes of irradiation. These compounds did not affect the development of inflammatory and regenerative processes, but significantly reduced the post-radiational alterations of the deep layers of the skin and underlying tissues – thereby, manifested itself as preventive radioprotectors, causing short-term reduction in radiosensitivity of non-malignant tissues. The results present that NOS-inhibitors can become the basis for new effective means of prevention of complications after radiotherapy of tumors.

DETERMINATION OF LAYER-THICKNESS USING X-RAY FLUORESCENCE ANALYSIS

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Materials are coated in many technical applications with the purpose of improving their desired physical, electrical and / or chemical properties. One parameter to assess the quality of the coating is it's thickness. In this project, an experiment is carried out to determine the thickness of materials by means of X-rays fluorescence analysis. The experiment is intended to teach the students of the "THM" (University of applied sciences in Hesse, Germany) the theory of X-ray fluorescence.

Several samples with layers of different thicknesses were examined. In order to create a calibration function, the layer-thicknesses were determined mechanically. For this purpose, the surface profile of a sample is measured once without a layer and once with a layer. The two data series are subtracted from each other and averaged. The mean value of the difference gives the average layer-thickness. Subsequently, the sample is irradiated with X-rays and the fluorescence intensity is detected with a semiconductor. This process is repeated several times and the mean value is calculated from the individual measurements.

The resulting calibration function is an exponential curve asymptotically approaching a limit, whose course will be described in detail based on a physical model. Further characteristics, such as the measuring range are also taken into consideration.

On the basis of this experiment, the students will learn how to make use of physical principles in the practice of radiometry. Moreover, the relevance of this work also lies in the mechanical determination of the thickness of the coating. This approach allows a layer-thickness-analysis with respect to its surface roughness along a measured distance, which also provides students with an insight into the material knowledge. The general procedure for creating a calibration function is also to be repeated and deepened.

A PRELIMINARY STUDY ON PHOTONEUTRON SHIELDING CALCULATION IN A MEDICAL ACCELERATOR ROOM USING AN EMPIRICAL FORMULA FOR DOSE ESTIMATION

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In this study, we constructed a muti-step simulation structure to increase accuracy of Monte Carlo simulation for photon and photoneutron in a medical accelerator room, operating a high energy electron mode. A dose estimating formulae was derived considering the various combinations of Lead-BPE laminating.

A case study was performed to examine sensitivity of calculation accuracy to decartelization of particle energy and direction. It was found that there in not any difference in reduction of statistical error between a photon and a neutron, where a magnitude of statistical error increases as the grid size of energy increase in case of a photon. The optimal grid size was considered as 100, the median value of energy range. The sensitivity study to angle differencing showed that the statistical error could be reduced considerably by employing angle differencing.

Shielding characteristics are analyzed considering the capture-to-production reaction of a photon and a neutron in a laminating structure of lead-BPE. In the case of a neutron source, the photon fluence is rapidly decreased within the depth of 20 mm in BPE material. However, it increases continuously by increasing the thickness of BPE. Considering a lead, the production rate of secondary photon has the magnitude of 1/100 of the BPE. The sensitivity to the source particle energy was performed considering 10 MV, 15 MV, and 18 MV. It was noted that a dose gradient is deeply decreased as the energy of source electron decreases, which are consistent with all the energy.

A dose estimating formulas was modeled by employing the Toolbox of curve fitting of MATLAB, based on the fluence of a photon and neutron along the depth of Lead-BPE shield. Photon fluence was modeled in the form of exponential function, $y = A_1 * \exp(-x/t_1) + A_2 * \exp(-x/t_2) + y0$. A neutron dose was extremely depressed penetrating through a lead, and therefore modeled by two function of exponential decay term.

It is expected that a empirical formulae might be useful to dose estimation for photoneutron shielding calculation in the field of radiation treatment without any expert for Monte Carlo simulation.

CONSTRUCTION OF HOT CELLS

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Paper presents the construction of hot cell facility within the project SUSEN (Sustainable Energy) at Research centre Rez. The project uses existing building converted for the purpose of placement of new hot cells. Within this project a new complex of 10 hot cells (divided to 8 gamma hot cells and 2 alpha hot cells). Our facility allows work with radioactive samples with activity up to 300 TBq 60Co. The cells will be used for preparation and testing of irradiated materials.

Paper is focused on constructional difficulties that come out from new layout of hot cells. Constructional solution of these difficulties will be discussed, namely airtight steel box, material transfer device, temporary sample storage and pre-chamber. All solution must be safe, functional and stable for long time, with low maintenance and all automatic manipulation replaceable with manual force.

The project SUSEN is fully funded by the European Union. Most components must be purchased on the basis of competitive tendering or competitive dialogue.

EVALUATION OF THE GAMMA EXPOSURE DOSE RATE OF THE PUBLIC IN XIANGSHAN URANIUM DEPOSIT OF CHINA

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Uranium mining often leads to higher terrestrial gamma-radiation levels in the surrounding area of the mine. Xiangshan Uranium Ore Field is a typical representative of volcanic hydrothermal uranium ore field in China, and more than 20 uranium deposits are found in Xiangshan Basin.

In order to investigate the environmental ionizing radiation level in uranium mining area, 51 soil samples were collected in Xiangshan Uranium Deposit, and the specific activity of uranium, radium, thorium and potassium were determined by a high purity germanium gamma spectrometer in the laboratory. The dose rate and annual effective dose were estimated. The results showed that the average terrestrial gamma radiation dose rate and annual effective dose were 162.60 ± 50.68 nGy / h and 0.20 mSv, respectively, based on the data of uranium, thorium and potassium specific activity of soil samples. The maximum absorbed dose rate and annual effective dose were 1415.65 nGy / h and 1.74 mSv, respectively. There are high gamma radiation doses in the vicinities of near-surface uranium mineralization areas and the zones near uranium ore dressing plant or the waste ore, which will cause large external exposure to near residents. The results of this study are significant for Xiangshan Uranium Deposit. It is suggested to further investigate the dose rate and concentration levels of indoor and outdoor radon and its daughters, estimate the total absorbed dose of local residents, and further improve the public's radiation protection work.

EASY METHOD FOR THE MONITORING OF RADIOACTIVE CONTAMINATION NEAR RADIATION FACILITIES

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Humans do not possess any radiation sensory organs. They must rely solely on instruments to detect and measure existing radiation, and therefore must always have an appropriate, functioning instrument whenever a radiation source is present or is thought to be present. As a national RI R&D institution, the Advanced Radiation Technology Institute (ARTI) has made a significant contribution to the development of technologies for RI utilization in Korea. ARTI has many workspaces using unsealed RI materials, and each space is routinely examined using a survey meter to check the degree of contamination before and after RI operation for worker safety. A Geiger-Muler (GM) counter for m ensuring usually displays the measured counters, and thus the degree of contamination is not shown directly. If the degree of contamination is needed, conversions can be made from the counter rates (CPM) to the contamination level (Bq/cm^2) using the efficiency rate of the survey meter. If an instrument with multiple setting functions can be used, the measured results can be automatically calculated and easily shown. However, it is not easy to effectively calculate and obtain the results. Furthermore, information on whether a place is contaminated unavailable. In addition, statistical techniques must be used to distinguish low-level measurement from the omnipresent background, and to distinguish between two measurements that are relatively close to each other. This study shows how to control the contamination in an effective manner, and provides a method to easily obtain the contamination level. In conclusion, anyone can use this method easily and find the degree of radioactive contamination using a calculated chart for checking the radioactive contamination in the workspace.

RADIATION EXPOSURE FROM PATIENTS AFTER RADIOIODINE THERAPY FOR THYROID CANCER

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Radionuclide therapies lead to radiation exposure for the staff members and after discharge of the patient for members of the public, too. After discharge the radiation exposure can not easily be examined as direct measurements of e.g. relatives are very demanding. In this situation an easy but well-rooted estimation is very helpful.

In this work we measured whole-body activities of 170 patients during their in-patient stay. The dose rate at the time of discharge was calculated from the repeated measurements on the basis of the last measurement and taking the specific dose rates - in this work both dose rates Hx and H*(10) - into account. Annual doses were calculated using the effective half-life and for different scenarios with a conservative assumption of a long stay compared to the effective half-life in the vicinty of the patient in three distances (0.5m, 1m, 2m).

In nearly all cases the annual doses for members of the public are found significantly below 1 mSv. Even for the close distance 1 mSv can hardly be reached. Typical arithmetic means of the annual effective doses were 56 μSv (2m), 181 μSv (1m), and 620 μSv (0.5m). Taking the high activity into account that is typically administered for thyroid carcinoma (up to 10 GBq) this low values for the radiation exposure might be surprising but it is easily explained by the fact that after (near-)total thyroidectomy the radioiodine is rapidly eliminated. After an in-patient stay of 3 - 4 days, the whole-body activity is comparatively low. Nevertheless, an in-patient stay of such a period is highly recommendable as, additionally, the risk of contamination and incorporation of exhaled radioodine is also drastically reduced for members of the public.

THE ASSESSMENT OF THE RADIOACTIVE INVENTORY FOR THE RADIOACTIVE SOLID WASTES RESULTING FROM REACTOR DECOMMISSIONING

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The present paper analysing the activity inventory of the radioactive solid wastes resulted from decommissioning of reactor block from VVR-S research reactor, from Bucharest, Romania which is in the last phase of the decommissioning process. After the dismantling of the activated and contaminated structures the radioactive wastes are placed in 220 l drums and analysed by gamma ray spectrometry method and are proper managed according to the activation/contamination degree, the radionuclides components and its dimensions. The total activity inventory is about 2.00E+11 Bq and is concentrated in the 6.6 tons of radioactive waste representing 33.15% of estimated inventory. The estimation was done by calculation and is about 6.00 E + 11 Bq for 703.1 tons of radioactive solid wastes. The most important weight in inventory is owned by the activation product - ^{60}Co (38.6%) which was identified in the cast iron, steel and aluminium in significant quantities. The hardly detectable radionuclides such as: ^{59}Ni (0.30 %), ^{55}Fe (31.65%) and ^{63}Ni (13.81%), were detected in the aluminium, graphite and cast iron components and structures. Their activity is calculated based on the key radionuclide activity - ^{60}Co - using the scaling factors method. The fission product ^{137}Cs (7.81%) is found in significant amount (1.54 E + 10Bq) in the automatic controller bar (steel), in the aluminium and stainless steel components and 125Sb (8%) it was detected in the aluminium channels and sheaths from the active core. The europium radionuclides such as: ^{152}Eu (0.003%), ^{154}Eu (0.005%) and ^{155}Eu (0.003%) were identified in the activated aluminium components. Also have been identified the actinides: ^{238}U (0.002) and ^{235}U (0.0003%) in the aluminium channels and sheaths from the active core and ^{241}Am, in the plastics from the horizontal channels 3, 4 and 5.

DETERMINATION OF POLONIUM (^{210}Po) IN URINE SAMPLES

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^{210}Po occurs widely in nature and is an important component of man's natural radiation background. ^{210}Po accumulates in some animal and plant species e.g. tobacco, fish, shellfish. Polonium is present in the human body at very low concentrations. The most of the human intake of ^{210}Po comes from food. The remaining fraction is inhaled and the intake of polonium-210 can be increased by smoking. ^{210}Po is an alpha emitter. The alpha particles travel only a few centimeters in air and do not penetrate the skin. Therefore, ^{210}Po is not a hazard unless it is taken into the body. Internal contamination leads to irradiation of tissues and cell damage, giving rise to a risk of cancer. ^{210}Po cannot be measured directly in the human body. Its content can only be assessed indirectly, using values of the excretion rate in urine, therefore urine analysis is an important tool for the estimation of internal dose.

The aim of this work was to compare two selected methods of ^{210}Po determination in urine samples and to optimize the deposition parameters. First of the methods was based on sample evaporation and mineralization while in the second method co-precipitation of polonium was carried out.

The determination of ^{210}Po was based on the spontaneous deposition of ^{210}Po on a silver disc. Autodeposition is a technique used for the preparation of the polonium source for measurement. The yield of the deposition procedure was determined by using ^{209}Po as tracer. The chemical yield depended on time of deposition, temperature and acidity of the sample. Moreover, sample type and the addition ascorbic acid used to reduce iron were very important. During the tests effects of the duration of deposition and the fluid volume on the chemical yield were checked. Two independent systems for heat and constant stirring of the solution were also tested.

In the next step two separate methods of ^{210}Po determination were examined. In the first method urine samples were mineralized by nitric acid (HNO_3), hydrogen peroxide (H_2O_2) and hydrochloric acid (HCl). The second method was based on co-precipitation of calcium phosphate with 25% ammonia. The precipitate was mineralized to dry residue. The activity of the radionuclides deposited on the silver disk was determined by alpha-spectrometry.

The average chemical yield of deposition of ^{210}Po on a silver disc was in accordance with literature data. High chemical recovery values obtained by the use of both selected methods prove their applicability in determinations of polonium in urine samples.

EVALUATION OF EMF FIELD LEVELS IN URBAN AREAS

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In the last years, there has been a significant increase in the use of mobile communication services and this growth is expected to continue with the introduction of new generation technology standards. This leads to the increasing number of base stations especially in the urban areas.

The results of studies related to the measurement of electromagnetic field from base stations show that despite of the increasing number of base stations and deployment of additional mobile technology, the levels of electromagnetic exposure remain almost the same in public areas.

The report presents the results of measurement and exposure assessment of electromagnetic fields in the areas with greater density of communication sources.

For the purpose of this study the available information concerning sources in the area, including location and technical characteristics was processed. The points of measurements are selected to meet the criterion of the “worst case” of exposure. Wide frequency range measurements were performed at all selected points of evaluation. A detailed assessment of the contribution of different emitters in the respective frequency ranges is made by spectrum analysis.

The measured values of the electromagnetic field are in compliance with national legislation for public protection. The measured values do not exceed the exposure limit values according to the international regulations as well.

Key words: EMF sources, measurement, exposure

STUDY ON THE PERSONAL PASSIVE DOSIMETERS REGARDING THE MEASUREMENT ACCURACY OF THE LIMIT DOSES RECORDED IN DIFFERENT RADIATION EXPOSURE CONDITIONS

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The personal monitoring is performed with different dosimeters characterized by performance and limits regarding the dose assessment and measurement accuracy. Generally, the personal dosimeter is elected in function of the features of the work place, radiation sources and practices of the occupational exposures. The norms of radioprotection and standards of quality recommend to follow some rules and technical testing in order to obtain accuracy in measurements of doses. Some detectors allow recording of data for low and high doses but reproducibility of the data for extreme doses is hardly. Of the passive dosimeter used for personal monitoring which work in nuclear field, this paper refers to thermoluminescent (TL) and halide film detectors. For TL detector GR-200A type with LiF: Mg, Cu, P the manufacturer communicates a dose range of (0.001-1000) mSv. The Agfa personal monitoring film with a combination of two types of photographic emulsions records doses from 0.1 mSv to 1 Sv not only soft but also hard radiation with mention that depending of the dosimeter badge filters. Other solution for obtain accurate result in dose measurement is procedure of data processing. The chemical and physical treatment applied on detectors conduct to the increase or falling of the measurement accuracy. Also, the mathematic equation which fits the recorded data influenced the dose assessment. This work presents the results recorded by TLD and film dosimeter to the limit dose of detection such as minimum and maximum detectable dose, doses to whom have to change the procedure of data processing recorded by dosimeter for more accurate results. In this way, more data recorded by TL and film dosimeters to different times of exposure but keeping the irradiation conditions were processed in order to establish the extreme dose reproducibility, refer to the lower and higher doses which to reproduce with good accuracy. Taking into consideration the experimental data obtained in custom conditions for halide film the following doses were considered: 0.1 mSv, 30 ÷ 50 mSv, 800 mSv for high energy, using a ^{137}Cs standard source; 0.01 mSv, 1 mSv and 10 mSv for ^{241}Am standard source. Regarding TL dosimeter the doses of 0.01 mSv, 10 mSv and 100 mSv obtained to a ^{137}Cs standard source were considered. For higher doses, 500 mSv, 700 mSv and 800 mSv other technical procedure have to apply. The halide film dosimeter response has a high dependence of low energy that was the reason for which doses obtained to ^{241}Am standard source were studied.

MEASUREMENTS OF AMBIENTAL DOSE EQUIVALENT RATES IN MUNICIPALITY OF KURSUMLIJA, SERBIA

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In order to get any information of radioactivity in an area, it is advisable to measure background radiation, i.e. the gamma dose rate everywhere where it is possible. For this reason, investigations should begin with the measurements of dose rate, commonly with Geiger-Miller counter. A series of measurements of ambient dose equivalent rates were conducted at 31 locations in Kursumlija municipality at the end of summer 2016. The ambient dose equivalent rates ranged from 73-170 nSv/h with a mean value of 119 nSv/h. A similar median value (120 nSv/h) indicated normal distribution of results. According to data from Serbian Radiation Protection and Nuclear Safety Agency, this mean value of ambient dose equivalent rate is comparable with a mean annual value of dose rate in Novi Sad, in 2015. The highest values (>150 nSv/h) were measured in Merdare, Selova and Prolom Banja. The possible reason could be different geological structure, although values of “normal” background radiation range from 30-200 nSv/h. This will be confirmed by some further investigations.

RAD2017

THE ASSESSMENT OF THE POTENTIAL RISK TO HUMAN HEALTH DUE TO NATURAL RADIONUCLIDES IN SURFACE SOIL AROUND "NIKOLA TESLA A" COAL-FIRED POWER PLANT, SERBIA

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Increasing trend in overall cancer incidence was identified for Serbia in last decades. Therefore, the assessment of cancer risk (*CR*) is of vital importance, especially for the population in the areas endangered by environmental pollution.

The excess lifetime *CR* for residents in the surroundings of the coal-fired power plant (CFPP) "Nikola Tesla A" (Obrenovac, Serbia) due to natural radionuclides in soil was evaluated. The methodology of US EPA was applied based on specific activities of ^{40}K, ^{226}Ra and ^{232}Th in the surface soil. Risk from incidental ingestion of soil, inhalation of soil dust, external exposure to ionizing radiation and consumption of produce (fruits and vegetables) were taken into account. Soil samples were collected from thirty locations up to 10 km distance from the CFPP following radial sampling grid. The total cancer risk (CR_{tot}) was calculated as a sum of *CR* from all radionuclides investigated across multiple exposure routes. The specific activities of radionuclides were determined by gamma-ray spectrometry.

The calculated minimal, mean and maximal values of CR_{tot} were 7.02×10^{-4}, 1.16×10^{-3} and 1.65×10^{-3}, respectively. *CR* due to inhalation of soil was negligible and fell in the range from 6.83×10^{-19} to 2.33×10^{-18}. Direct ingestion of soils generates no significant *CR* and varies from 1.98×10^{-6} to 6.08×10^{-6}. Overall *CR* caused by external irradiation was 1.06×10^{-4} to 2.66×10^{-4} with mean of 1.81×10^{-4}. The greatest fraction (approximately 84%) of the CR_{tot} came from ingestion of produce, and ranged from 5.95×10^{-4} to 1.37×10^{-3} with mean value of 9.75×10^{-4}. The rural part of the study area is an agricultural region and this pathway had to be considered. Nevertheless, considerable number of people live in Obrenovac and its suburbs, and their dietary is mostly based on groceries from super-markets supplied by different food retailers, so it is likely they are not exposed to this kind of risk. If this risk was not included, the CR_{tot} would be in the range 1.08×10^{-4} to $2.72 \times 10^{-4}$with average of 1.08×10^{-4}. ^{232}Th should be mostly concerned regarding to direct ingestion of soil and inhalation, while the greatest fraction of *CR* from consumption of agricultural products and external irradiation originating from ^{40}K. The Public Health Institute of Belgrade recorded the cancer occurrence rate for adults in Belgrade of 3.3×10^{-3} in 2013. In comparison to this value, the calculated mean CR_{tot} for all exposure routes is extremely high and makes 35 % of real cancer occurrence. Nonetheless, CR_{tot} excluding the ingestion of farm produce is noticeably smaller and contributes to up to 8% of published values for Belgrade.

The results reflected that exposure to natural radionuclides in soil through direct ingestion and inhalation of soil and external irradiation would not cause serious lifetime *CR*. The *CR* due to ingestion of produce grown on study area was identified as an issue of most concern to the residents.

ASSESSING THE REAL THREAT AND RISK OF A TERRORIST USE OF RADIOLOGICAL WEAPONS

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In principle, CBRN (Chemical, Biological, Radiological and Nuclear) materials could potentially be used by terrorists to construct a weapon of mass destruction in the future. This is why the European Union (EU), IAEA, NATO and other international groupings or organizations have taken relevant measures in fighting this threat. At present, it seems that especially the high-activity radioactive sources used in industry and medicine present a more probable danger than the use of other CBRN components. There have been introduced at the international and national levels various measures aimed at the reduction of the risk due to the radiological terrorism, including prevention - ensuring that unauthorised access to such sources is as difficult as possible, detection - having the capability to detect radioactive materials if control over them is lost , and preparedness and response - being able to efficiently respond to incidents involving high-activity radioactive materials and recover from them as quickly as possible. Nevertheless, we have to be prepared for the use of radiological weapons and be able to realistically assess the danger they present and to mitigate their impact on the population and the environment. The paper discusses the real consequences of the attack based on a typical powerful radioactive source. It has been found that the impact would be much lower than usually predicted. However, one cannot estimate the chaos and psychological effects which may be more dangerous than the exposure of persons affected and the radioactive contamination of the surrounding areas of the attack.

RADIATION RISK COMMUNICATION TO THE PATIENTS

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Ionizing radiation and radionuclides are widely used in diagnostic radiology, nuclear medicine and radiotherapy. The radiation related methods and procedures are especially useful in diagnostic applications where they provide valuable information about the patient conditions and problems. In this case the effort is concentrated in obtaining the required diagnostic data while keeping the exposure to the patients to a very minimum level. On the other hand, the therapeutic use of radiation, in the form of external or internal exposure, is aimed at delivering the relevant (rather high) doses to a particular volume of the organ or tissue in order to cure the tumour. In both of these modalities the patients also receive a certain undesirable dose to healthy or normal tissues. Obviously, any exposure may result in stochastic effects characterized by a very small increase in probability of developing additional cancer in years to come after the exposure. The risk of these effects is so low that it is more than compensated by the patient benefit from the use of radiation. The occurrence of stochastic effects is proportional to the effective dose received by a person. Just for the comparison, the effective dose of 1 mSv is associated with the risk of about $5x10^{-5}$ mSv^{-1}, i.e. five in 100,000 persons exposed. The annual exposure to natural background radiation amounts to approximately 3 mSv. One chest X-ray examination (about 0.02 mSv) corresponds just to the exposure received by passengers during a five hour flight (due to higher contribution from the cosmic radiation). These, and other similar examples, should be used to inform the patients about the risk of the exposure associated with the use of radiation in fully justified medical applications. The paper will discuss various methods in explaining the radiation risk to patients undergoing specific examinations or treatments involving radiation exposure.

QUANTIFICATION OF THE RISK-REFLECTING STOCHASTIC AND DETERMINISTIC RADIATION EFFECTS

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The purpose of radiation protection is to protect workers, patients and members of the general public against any excessive impact of exposure to ionizing radiation, and to control radioactive contamination of the environment in accordance with the strict regulatory requirements. In order to introduce any measures to control the exposure from various sources, it is necessary to introduce a reliable and consistent system of the quantification of radiation exposure due to external and internal sources. Under normal circumstances only very low doses (comparable with the natural radiation background) are encountered. Such exposure may result in stochastic (delayed) effects where the probability of their occurrence is proportional to the effective dose expressed in Sv (sievert). The main quantities for the assessment of the stochastic risks are the equivalent dose (related to an organ or a tissue exposed) and the effective dose (expressing the total impact of the exposure to the whole body). While for the stochastic effects only the unit of Sv can be used, the quantification of deterministic effects which occur at rather higher doses, other quantities and units are more appropriate. In this case one relies on a new quantity RBE-weighted dose with a unit of Eq-Gy (equivalent gray). Whereas the quantification system for the assessment of stochastic effects is well developed and includes also so-called operational quantities, the assessment of deterministic effects is still being refined and it is not as comprehensive as the system for low exposures. The paper deals with an analysis of the current state in quantifying radiation risk based on the recent approach.

MONITORING OF LONG TERM RF RADIATION FROM CELLULAR BASE STATIONS

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In parallel with technological developments, cellular systems and therefore base stations have begun to take up more space in our daily lives. Since each base station behaves like an electromagnetic radiation (EMR) source, this increase in base stations leads to an increase in the value of EMR. Therefore, it is very important to measure and evaluate the EMR emitted from the base stations for human/living health. In this study EMR measurements were taken in ten different locations (schools, hospitals, homes, shopping malls, etc.) during 24hours to investigate the time/location dependent changes in EMR. For the measurement, the PMM8053 EMR meter measuring the total EMR in the frequency range of 100kHz-3GHz was used, the highest electric field strengths (E_{max}) in the environment and the average electric field strengths (E_{avg}) were recorded. The measurement results show that the electric field strength (E) originating from the base stations change significantly depending on the measurement location and time (usage intensity). The changes in E measured during the daytime in the home environment are softer, while for workplaces it is sharper due to open/close. It is seen from the measurements the highest E_{max} is 7.88V/m and the highest E_{avg} is 2.952V/m. In order to analyze the 24hour measurements more precisely, four specific time interval such as morning (6am-12am), afternoon (12am-6pm), evening (6pm-12pm) and night (12pm-6am) were selected. The mean E value for morning is 1.45V/m, while 1.85V/m, 1.35V/m and 1.08V/m for afternoon, evening and night respectively. E level in the morning increases by 71% compared to in afternoon. At the end of the study daily variations of E values were examined and empirical models were proposed using curve fitting methods. With the use of these models the E in the environment, especially for home, can be predicted with an accuracy of up to 90%.

ELECTRONIC REGISTER OF SOURCES OF ELECTROMAGNETIC RADIATION IN RESIDENTIAL AREAS

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The paper presents a web-based register of sources of electromagnetic fields (EMFs) developed in the framework of Programme *"Public Health Initiatives"* with the financial contribution of the Norwegian Financial Mechanism 2009-2014 and EEA Financial Mechanism 2009-2014, Project: *Improving control and information systems in risk prevention and healthcare.*

Aim: Providing accurate, on-line, in real time, reliable, dynamic and independent information about the sources of EMF radiation and the exposure levels in residential areas for the competent governmental/administrative bodies, and to inform the population.

Scope and methods: The web-based register is built on the base of the experience and best practice of different countries. Most of the information used for developing the register is the available data in NCPHA about base stations for mobile communication, digital TV stations, also information collected by point measurements, 24-hours monitoring, measurement in "sensitive" areas and in urban regions with high density of sources of radiation.

Results: Web-based register has been developed for the EMF sources in Bulgaria. The main functions of the register are presented here.

Conclusion: The web-based register gives to both general population and government/administration to receive real idea for the electromagnetic exposure in the residential areas in real time. In addition, it guides the control bodies to use new information in their practice, as technical characteristics of the EMF sources, a possibility for developing control reports, implementation of results from the EMF monitoring in their reports.

QUALITY CONTROL IN DENTAL RADIOLOGY IN SERBIA: PRELIMINARY RESULTS

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The quality control was carried out on 40 intraoral and 20 panoramic dental x-ray units in use in the public and private sector in Serbia. Quality control was performed using: visual inspection of the dental x-ray units and related equipment, performance testing of the dental x-ray units and inspection of the radiation protection facilities for patient, personnel and population. The results showed that most of the examined devices (88% intraoral and 95% panoramic x-ray units) operate within regulatory standards. The worst results showed intraoral devices that operate on 50 kV within the repeatability of exposure time and the lack of adequate filtration. The main reason for this is irregular and insufficient servicing of X-ray equipment and related equipment.

RESULTS OF CENTRALIZED PERSONAL DOSE MONITORING OF MEDICAL STAFF IN UKRAINE

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The individual monitoring of occupational exposure of medical staff in Ukraine is carried out from 1979 by Central Laboratory of Radiation Hygiene of Medical Staff. Now about 6100 persons from 670 hospitals of almost all Regions of Ukraine are covered by centralized dose monitoring by Central Laboratory. There are all groups of staff from Radiation Therapy and Nuclear Medicine departments and about 35 % of personnel of Diagnostic and Interventional Radiology Departments. For personal monitoring the TLD-method is used (TL-detectors LiF (Mg, Ti) and dosimeters type DTU-1) which give the possibility to measure the equivalent dose Hp(10).

Annually the results of personal monitoring for different groups of medical staff are analyzed using the special software and dosimetry information collected in Database IDAIS. There are doses of the radiologists; nurses; radiation technicians, medical physicists; engineers; radiation protection specialists from Brachytherapy manual gamma-radiotherapy with sealed sources; radiotherapy (gamma-therapy units and linacs), nuclear medicine; diagnostic radiology; interventional radiology and other radiological departments.

The software of IDAIS-system allows to collect, accumulate and save the individual doses of each person during period of monitoring. This system also provides the opportunity to create annual reports with data of annual and cumulated doses for every worker which work with radiation sources and reports with data about the collective doses and average annual doses of medical staff of all radiological departments. This information is sent to all monitored Ukrainian hospitals. The annual reports with data about collective doses and the average annual doses in hospitals of all regions of Ukraine and for 35 separate occupational groups of medical staff are sent to Regulatory Authorities of Ukraine: Ministry of Health, State Nuclear Regulatory Inspectorate. All cases of exceeding the dose limits for category A and annual reference level (20 mSv and 10 mSv per year respectively) are analyzed.

The results of personal monitoring of medical staff during 1991-2015 are analyzed and presented. For most part of medical staff (up to 92-98 %) the annual doses are less than 5 mSv. The most exposed groups of medical staff are nurses who are responsible for keeping of radioactive substances (RS-keepers), radio-manipulation paramedical nurses (RPP) in Brachytherapy Departments with manual work with Co-60 applicators and personnel which involved to the interventional radiology procedures.

The average annual doses of medical staff of Brachytherapy Department: RS-keepers and RPP nurses were 3.0-8.5 mSv/year and 1.5-5.0 mSv/year respectively. For personnel of interventional radiology departments the average annual doses were at the level 1.5-3.0 mSv/year.

Further optimization of radiation protection personnel in medical radiology should be aimed at the decrease of doses of personnel in these professional groups.

STUDY OF PATIENT DOSES IN CONVENTIONAL DIAGNOSTIC RADIOLOGY

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Now in Ukraine there are above 10500 X-ray units. In 2016 there were carried out about 40 million X-ray diagnostic procedures, so 0.9 procedures per capita. The values of patient effective doses from X-ray Diagnostic examinations are presented in protocols annexed to the Ministry of Health № 295 from 7/18/2001. However, such estimations do not correspond to real doses of patients because do not consider the techniques and parameters of diagnostic procedures in each X-ray room.

In our study the patient dose estimations were carried out for:

– 12 types of radiographic studies and fluorography – the estimation of entrance surface dose (ESD) in different X-ray departments by direct TLD measurements for 1950 patients and calculations of ESDs for 5800 patients from values of radiation output of X-Ray units which corresponding to the exposure conditions;

– 4 types of fluoroscopy – the 580 measurements and calculations of dose area product (DAP);

– mamography – 470 calculations of average glandular dose on breast (AGD).

It was established that for some types of X-ray examinations on separate X-Ray units the ESD's values differ up to 10-50 times. The main reasons of considerable difference of results are the technical state of X-ray Units and the use of various diagnostic techniques.

The analysis of ESD's distribution for different types of radiographic procedures has shown that practically for all types of examinations the value of the third quartile exceed in 1.3 – 2.0 times the recommended levels of IAEA BSS.

The highest doses for patients have been observed during X-ray exams of the spine and gastrointestinal fluoroscopy. For fluoroscopy units with analog image system - phosphor screens (direct fluoroscopy) and with image intensifier the maximum dose rate was exceeded in 1.5–7.5 times the IAEA recommended level (25 mGy/min) at low image quality. The patient doses on different fluoroscopy units differed up to 10 times or more. The results of this analysis demonstrated the inexpediency of the use of the fluoroscopy units without image intensifier in the practice.

For mammography screening the X-ray units type MADIS (Ukraine) are wide used in Ukraine. It was shown that patient's average gland doses (AGDs) on this type of mammography unit were about 1.5–2.5 mGy for single project that less than acceptable level in according EU recommendations but the quality of the diagnostic images on the criteria of the EU Guidance and the IAEA is not satisfactory.

Introduction of an indirect method of patients' doses estimation using the results of radiation output checking allows to study the patients' doses for the most common X-ray examinations practically in each X-ray diagnostic units and to compare them with values established as national Diagnostic Reference Levels. It will give the chance to carry out the target actions directed on optimization of medical exposure and decrease of collective population doses in Ukraine.

DETERMINING THE EFFECT OF ESTABLISHMENT OF 4G SYSTEMS ON ELECTROMAGNETIC RADIATION LEVELS IN A PILOT DISTRICT

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The level of electromagnetic radiation (EMR) exposure increases day by day as natural consequences of technological developments. In recent years, the increasing use of cellular systems due to technological developments in wireless communication systems has made it necessary to measure and evaluate EMR originating from base stations which are the basic structure of these systems. In Turkey, as in April 2016, fourth generation of wireless mobile communication technology (4G) has been introduced and additional base stations are continuing to be added to the system. In this study, EMR measurements were taken at four different times in order to examine and evaluate the change of EMR before and after 4G in Atakum district which is one of the most crowded districts of Samsun, Turkey. Two of the measurements were taken before 4G and the remaining measurements were taken after 4G. Each measurement was taken at different times of the day (morning, noon and evening). The measurements were collected from 46 different location using PMM 8053 EMR meter which measures EMR in the broad band from 100 kHz to 3 GHz. In the measurements, the maximum electric field strength (E_{max}) and the average electric field strength (E_{avg}) were recorded. The highest values have been noticed in these measurements 3.20 V/m and 4.77 V/m for E_{avg} and E_{max} respectively. According to the measurement results, a decrease of 68.7% was observed in the measurement values of the morning hours compared to the measurement values of the evening and noon hours. The average EMR value after 4G introduced has increased by 28.76% compared to before 4G. Apart from these measurements, 24 hour measurements were taken at two different locations where higher values were observed and were analyzed to observe the change of EMRs during a day.

ASSESSMENT OF DERIVED EMISSION LIMITS FOR RADIOACTIVE EFFLUENTS FROM HORIA-HULUBEI NATIONAL INSTITUTE FOR R&D IN PHYSICS AND NUCLEAR ENGINEERING

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The paper presents studies in order to assess the derived emission limits (LDE) for potential radionuclides emitted in the form of liquid and gaseous effluents due to nuclear activities in Horia-Hulubei National Institute for R&D in physics and nuclear engineering, IFIN-HH. In the institute operates several departments that represent potential sources of atmospheric or liquid radioactivity such as radioactive waste treatment plant; ii) radioisotopes and radiation metrology department; iii) research center radioisotopes. There is also ongoing work of decommissioning, the final stage of the research reactor VVR-S type, thermal neutron reactor moderated and cooled distilled water.

In studies to assess derived emission limits the concentrations of radioactivity for each radionuclide potential were considered. They were made by qualitative and quantitative determinations of competent laboratories recognized by CNCAN, in accordance with rules and legislation through certification.

Specific methods and equipment used in the determination of radionuclides in liquid effluents and gaseous components are gamma spectrometry systems and tritium monitoring system for monitoring iodine.

The nuclear regulatory body, CNCAN approved for IFIN-HH the collected dose constraint recorded by a person from the critical group Econstr = 100 μSv /year

The radionuclides contained in gaseous effluents identified by qualitative and quantitative specific measurements are ^{60}Co, ^{134}Cs, ^{137}Cs, ^{108m}Ag, ^{152}I, ^{154}I, ^{155}I, ^{3}H total. The maximum concentration was identified in the case of Co-60 radionuclide and is 109 Bq/a.

In the liquid effluents were identified a number of radionuclides such as ^{14}C and ^{123}I in a concentration of 109 Bq/a and 108 Bq/a respectively. The concentration of the ^{99m}Tc, ^{99}Mo very short life radionuclides were below 1010 Bq/a.

From experimental data obtained by measuring gamma spectrometric of the aerosol filters mounted at the mouth of chimney results that those two types of effluents could contain the following potential radionuclides:

Gaseous effluents: ^{60}Co, ^{134}Cs, ^{137}Cs, ^{108m}Ag, ^{152}Eu, ^{154}Eu, ^{155}Eu, ^{3}H total;

Liquid waste**:** ^{123}I, ^{125}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{241}Am, ^{60}Co, ^{192} Ir, ^{152}Eu, ^{3} H total, ^{177} Lu, $^{-99m}$ Tc, ^{188}Re, ^{14}C, ^{68}Ga, ^{235}U, ^{238}U, ^{99}Mo, ^{65}Zn, ^{24}Na, ^{58}Co.

ROLE PLAYED BY THE OPERATIONAL RADIOPROTECTION FOR THE CUTTING ACTIVITIES OF THE ALUMINUM VESSELS FOR THE VVR-S NUCLEAR RESEARCH REACTOR FROM BUCHAREST - MAGURELE, ROMANIA

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The VVR-S Nuclear Research Reactor owned by Horia Hulubei – National Institute for Physics and Nuclear Engineering (IFIN-HH), was built in Romania between: 1955 - 1957. The research reactor operated until 1997 and was permanently shut-down in 2002. It was the first research reactor using the VVR-S type soviet design. The main role of the reactor was for research and radioisotope production. VVR-S means that is a thermal neutrons reactor model S moderately cooled and reflected with distilled water, It was fueled with enriched uranium 10% in the beginning and 36% subsequently. Protection of biological of the block reactor consists from the wall of the aluminum inner vessel, the water layer between the inner cup and the middle wall of the aluminum vessel, the wall of the aluminum middle vessel, the water layer between middle vessel and the outer wall aluminum vessel, outer lining (shield) cast iron and a wall of heavy concrete with added iron ore and Limon with density 3.2 kg / dm3 and 226 cm thick. Our principal scope was to ensure the radioprotection safety for the professional worker that made the dismantling works. Implementation of the decommissioning strategy for the VVR-S nuclear research reactor, IFIN-HH, requires knowledge of the activation and contamination levels of were occurring during operation and are maintained after stopping the installation. Neutron activated materials is by far the major contributor to the total inventory of radioactive reactor. The principal radionuclides implicated are the 60Co (60%), 137Cs (30%), (152Eu and 154 Eu) (10%) with theirs correlation factors respectively. Maximum values of dose rate at external aluminum vessel wall were between 3.5 mSv/h. and 9 mSv/h. Maximum values of the inner aluminum vessel near the active core were between 7.85 mSv/h. and 16.62 mSv/h in conformity with the location the experimental channels. The cutting on the aluminum vessels it was executed remote. It was reported maximum dose rates up to 20 mSv/h, at contact point of the cutting device, dose rate increasing around reactor core position. The activity of the aluminum vessels cutting at the VVR-S Nuclear Research Reactor was performed without incidents until today. The dosimetry monitoring and calculation help to keep the professionals who work to decommissioning the vessels safe. The cut aluminum vessels are in interim storage until a final storage solutions at the old spent fuel storage facility now used for this destination. All activities were monitored from point of health and safety, radioprotection, environmental protection and so on. We have in place a comprehensive Integrated Management System, all the activities have approved procedures and are under regulatory body control CNCAN - National Commission for Nuclear Activities Control in Romania.

RADIATION PROTECTION OF FIREFIGHTERS IN RADIOLOGICAL EMERGENCIES

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Radiological emergencies (RE) are those emergencies which involve radioactive material that is not nuclear but emits ionizing radiation. Although such sources are usually kept and transported shielded and closed, their shielding or packing can be damaged in case of accident or fire. If the source becomes unshielded or opened environmental exposure can increase or even a potential radioactive contamination can occur. As we know, depending on their type and dose ionizing radiations can cause morbidity or even mortality, meanwhile they only can be detected with special instruments but not our senses. That is why first responders are the most endangered in a RE and their radiation protection is imperative during the live- and wealth-saving. In terms of this the operations may be limited spatially, temporally, in manpower or in other way.

However, a fire incident does not differ significantly in that regard whether a radioactive source is present or not. At least in that sense, that it does not have any influence on the spreading and other features of the burning. The only difference will appear in the methodology in order to prevent the unnecessary and extreme exposure of the interveners. The point is to avoid the deterministic effects and to decrease the possibility of stochastic effects so in a RE application of the radiation protection regulations, namely justification, optimization and limitation, is highly needed.

Thus, even at the initial stage of the intervention, the incident commander (IC) has to tackle with several urgent tasks and a huge responsibility. Alarm level classification and on-spot reconnaissance take on a crucial role here. It is the task of the IC to weigh risks and benefits. It must be taken into consideration among others whether live-saving is needed, escalation of the emergency is expected or what financial loss and environmental damage can be caused with cancellation or delay of the intervention.

Optimally, the IC has appropriate information to make decisions on occupational safety of the interveners, but not in all cases. Moreover in Hungary, personal dosimeters are not involved in personal protective equipment which makes the determination of the firefighters' exposure more difficult. Thus, in some cases intervention in presence of a radioactive source even raises occupational-ethical and moral questions.

The paper introduces this special field, presents hazards and shows possibilities of occupational radiation protection of firefighters.

A CASE STUDY ON THE USE OF AN X-RAY INSPECTION SYSTEM FOR THE SAFE SCREENING OF PASSENGER VEHICLES AND VANS WITH A MINIMAL EFFECT ON THE TRAFFIC FLOW

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According to the current ICRP Recommendations, the principles of justification, optimization, and dose limitation for planned exposure situations are directly applicable to the use of ionizing radiation in security screening. The use of different X-ray inspection systems is carried out in some States and prohibited in others and there are no published regulatory decisions on formal justification of this type of practice.

The decision for the use of X-rays involving human imaging for security screening shall be justified by the government.

The aim of this paper is to present the quantitative assessment of the radiation detriments and the expected benefits of a designed screening system and the analysis of the measurements performed to demonstrate the respect of the dose constraints for members of the public and the conformity with the IAEA recommendations and the applicable standards.

MEASUREMENTS OF PUBLIC EXPOSURE TO RADIOFREQUENCY ELECTROMAGNETIC FIELDS IN HUNGARY

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By the spreading of the wireless technology, the radiation levels and the exposure on radiofrequency electromagnetic fields (RF-EMF) of the general public are getting higher and higher. Typical radiation sources in this 300 kHz-300 GHz range are TV and radio broadcast antennae, cellular phones and their base stations, microwave ovens, wireless and cordless telephones, internet, Bluetooth, navigation systems and radars. These applications and devices are essential parts of our modern life and their radiation affects everybody.

Meanwhile we do not have precise knowledge about the health effects of these irradiations since we do not use these applications so long time en masse. Notwithstanding that according to WHO even a small health risk of the radiation can be a huge public health problem because of the widespread usage. Therefore it was not a surprise that in 2011 RF-EMF had been classified to the possible human carcinogenic class (2B) by IARC.

Hence it is clear that thorough epidemiological studies are needed and the public personal exposure must be assessed. For the assessment of the exposure level of a person we should use personal exposure meter since it is the most reliable method for this exercise. The point of the exposimetry is to assist epidemiological surveys with measurements. Personal exposimetry in the RF range is one of the most topical problems of public health, however, instrumentation and methods of this research are still under development.

In Hungary, since 2007 National Institute of Radiobiology and Radiohygiene in cooperation with Eötvös Loránd University were engaged in these examinations.

Since the basic problem of exposimetry is that there is still not an accepted international protocol nor for measurement and data processing neither for statistical analysis, the main aim was to develop an appropriate procedure for tasks like data gathering, processing and evaluating. Nevertheless, these improvements can be done only in practice, so we started the improvements in connection with a personal exposimetry survey and later, these developments were also used in other examinations.

The target of the first study was a group of undergraduates, and the second survey regarded to inhabitants live near mobile phone base stations. In the third one we aimed at assessing children's exposure with different methods, and the fourth study focused the determination of occupational exposure from EDR of ambulance men. Later, microenvironmental measurements got into focus in which not individuals but rather special whereabouts, like home, office, public transport vehicles, outdoor/indoor areas, were examined.

The aim of the paper is to introduce the features of the RF-EMF exposure and to present the Hungarian exposimetry surveys from the last decade.

THE REMOTE CONTROL ROBOT FOR THE HORIZONTAL FUEL CHANNELS DECOMMISSIONING FROM THE NUCLEAR REACTOR

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The authors contribution to this paper is present a possible designing solution concept of the remote control robot for decommissioning of the nuclear reactor horizontal fuel channels. In this paper the authors present a few properties of geometry, kinematics and dynamics of the robot movement into the reactor fuel channel and a few considerations required due to material thickness, according to the radiation protection procedures. The main stages of dismantling operation in terms of operational safety are: positioning, coupling and locking, operating accordingly with approved decommissioning procedures, sorting and storage extracted items in the robot container. All operating steps are designed to be automated and performed by one robot which shall provide radiation protection during the dismantling stages, ensuring radiation protection of the workers. The operations are monitored by the internal sensors and transducers, by pyrometer for temperature during the cutting process and cameras for the dismantling components video surveillance, in order to ensure assembly operating facilities and a permanent control. The remote control robot radiation protection has a safety system able to extract the robot from the channel in case of blocking or decommissioning activities disruption due to any error registered in order to ensure the environmental and workers protection.

Key words: Fuel channel, decommissioning, dismantling operation, radiation protection, remote control robot

PRACTICAL ISSUES IN IMPLEMENTATION OF RADIATION PROTECTION IN HEALTHCARE INSTITUTES

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In this presentation, several types of obstacles to the implementation of radiation protection as well as MRI safety in clinical setting are identified and discussed. These obstacles range from asynchronous development of imaging departments and the accompanying legislation, to organizational and technical issues. Some possible solutions are proposed (such as embedding radiation and MRI safety information into existing RIS/HIS or dedicated databases, closer cooperation with healthcare funds in identifying patients to be screened for MRI, radiation protection management through the activities of clinical physics departments) and examples of the existing good practice (radiation protection measures and MRI safety procedures already in place) are quoted.

ASSESSMENT OF RADIATION EXPOSURE IN MANNED MISSIONS TO MARS FOR THREE MISSION PROFILES

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The human exploration of Mars is likely to be the biggest scientific and technological challenge in the coming decades. Getting astronauts to the Martian surface and returning them safely to Earth, however, it is an extremely difficult engineering and safety challenge [1]. One of the biggest risks, if not the biggest risk to the health of astronauts will be radiation exposure during the Earth's exit, cruise to Mars and stay on the planet's surface [2,3]. The main radiation sources of concern are the trapped particles in the Van Allen (VA) belts, the galactic cosmic radiation (GCR), and the solar energetic particles (SEP) events.

In this work we will present an estimate of the radiation dose exposure of an astronaut for each of three preliminary mission scenarios proposed by the NASA. The Geant4 [4,5] toolkit is used to simulate the energy deposited in the ICRU sphere [6], representing the astronaut, due to each of the radiation sources mentioned above. Doses from trapped particles are calculated using particle fluxes retrieved from SPENVIS [7] using a highly elliptical injection trajectory. The same tool is used to obtain the GCR for solar minimum (2009) and solar maximum (2014) conditions used as primary fluxes in the calculation of the dose received during the cruise to Mars. The Martian radiation environment is simulated with the dMEREM [8,9] model, providing the particle spectra resulting from the interaction of GCR in the Martian atmosphere and soil at the coordinates of the Gale crater. These particle spectra are than used as the primary fluxes in the simulations of the energy deposited in the sphere.

To understand the contribution to the dose due to secondary particles produced in the spacecraft structure, simulations are done with and without shielding. For the latter we consider a 10 cm Al slab that is comparable to the shielding of the RAD/MSL [10] during its 235 day cruise to Mars. Comparisons between measured and simulated shielded fluxes and doses in the relevant energy range and solar conditions during transit are used to benchmark our simulations. Simulated doses at the Gale crater radiation environment are also compared with results from the RAD/MSL mission.

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BIOMARKERS FOR ASSESSING RADIATION INJURY AND EFFICACY OF RADIATION COUNTERMEASURES

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Exposures to ionizing radiation, whether they are intended or unintended, are currently an undeniable reality and carry potentially catastrophic health consequences. Therefore, medical preparedness and countermeasures are critical security issues, not only for the individual, but for the nation as a whole. Acute radiation exposure induces apoptosis of hematopoietic, digestive, cutaneous, cardiovascular, and nervous system tissues; extensive apoptosis ultimately leads to acute radiation syndrome (ARS). Significant scientific advances have been made over the last six decades toward the development of a safe, non-toxic and effective radiation countermeasure for ARS.

Several candidate drugs for ARS have been identified which have low toxicity and significant radioprotective and radiomitigative efficacy. Inasmuch as exposing healthy human volunteers to injurious levels of radiation is unethical, development and approval of new radiation countermeasures for ARS are therefore presently based on animal studies and Phase I safety study in healthy volunteers. The Animal Rule that underlies the U.S. Food and Drug Administration (FDA) approval pathway requires a sound understanding of the mechanisms of injury, drug efficacy, and efficacy biomarkers. What is necessary for this strategy to be successful are biomarkers in animals which faithfully reflect mitigation effects as they might be found in humans. Presumably, specifically-purposed biomarkers will (i) assess the dose of radiation to which a victim is exposed and (ii) be reporters of therapeutic success when such countermeasures are applied.

In this context, it is important to identify biomarkers for radiation injury and drug efficacy that can extrapolate animal efficacy results, and can be used to convert drug doses deduced from animal studies to those that can be efficacious when used in humans. We have identified several promising biomarkers for radiation injury and countermeasure efficacy using hematology, cytokine/chemokine/growth factor analysis, microRNA identification/validation, proteomics, transcriptomics, metabolomics, and lipidomics. These biomarkers will definitely help promising countermeasures under development for US FDA approval.

Disclaimer: The views expressed do not necessarily represent the Armed Forces Radiobiology Research Institute, the Uniformed Services University of the Health Sciences, the Department of Defense, or the United states.

ESTIMATION OF EFFECTIVE DOSES IN COMPUTED TOMOGRAPHY BY THERMOLUMINESCENT DOSIMETRY

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For two last decades the computer tomography (CT) is considerably extended for diagnostic application. This method brings great diagnostic benefit, however, associated with high radiation exposure. According to sources international organizations, the contribution of CT to the collective effective dose is 40-60 % of all sources of ionizing radiation used in medicine. Therefore, in the field of radiation protection the questions of dose evaluation for CT studies are most relevant. Evaluation of the effective doses for CT requires the use of the complex mathematical model and may not take into account all peculiarities of examinations. The goal of this study is a definition of effective doses at a computer tomography by method of thermoluminescent dosimetry (TLD) and the analysis of distribution of equivalent doses.

The investigation was carried out by irradiation of the “standard” anthropomorphic phantom type Alderson-Rando on spiral CT “Toshiba Aquilion 16”. For measurements TL-detectors Lif: Mg, Ti (type MTS-N, Poland, Krakow) are used. The phantom has 39 layers with holes for location of 255 TL-detectors that allows to determine the absorbed doses for 17 organs and tissues according to the scheme. The detectors were placed in a phantom in the hole that corresponding to the individual organs and tissues according to the scheme, as well as on the surface of the phantom at given points. Physical and technical conditions of phantom irradiation were the same for the real patients during CT-research.

Radiation doses at CT of the head, thorax, an abdominal cavity, a basin taking into account the fabric weighed coefficients were defined, and also distribution of equivalent doses on separate bodies and fabrics is received. Effective and equivalent doses from CT of the head, thorax and abdominal cavity, pelvis were defined using the weighed coefficients of all organs and tissues. The distribution of equivalent doses in organs and on the surface of body was studied.

It was found that the average effective doses from CT examinations were the next: CT head – 2.0 ± 0.5 mSv, chest – 5.5 ± 0.8 mSv, the abdominal – 6.0 ± 0.9 mSv pelvis – 6.3 ± 0.7 mSv.

The assessment of equivalent doses has shown that the highest doses during different CT-investigations were following:

- Head-on skull and eye lens - 86.2 and 81.97 mSv, respectively;

- Chest - on the thyroid and breast (14.4 and 10.3 mSv), and lung - 8.4 mSv;

- Abdomen - on the gall bladder and stomach - 17.3 and 17.9 mSv;

- Pelvis - gonads and the colon - 20.7 and 10.0 mSv

DRY STORAGE OF SPENT NUCLEAR FUEL / ANALYSIS OF FUEL PROPERTIES DURING LONG TIME STORAGE

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Spent fuel storage is a common issue in all states with nuclear reactors. The nuclear industry worldwide has accumulated significant fuel storage operating experience over the past 50 years. This experience, however, is largely based on safe and effective wet storage and the effect of time on structures and materials during this limited period of time. Dry storage is a safe and economic intermediate solution while awaiting the development of a back-end fuel strategy: direct disposal or reprocessing and recycling. Generally the dry storage is considered as a highly resistant and passive system and records accumulated over the past 30 years confirmed this statement. One of the prerequisites for confirming the safety of dry spent fuel storage technologies is the ability to predict the condition of the spent fuel during period of storage more than 50 years.

The main criterion from the point of view of preventing radioactive material release is the fuel rod integrity during dry storage. The following factors can cause fuel rod failure: thermal creep of cladding alloy under internal pressure; corrosive damage of the inner and outer cladding surface; hydrogen induced cladding defects and so on.

The simulation started with TRANSURANUS code prediction of fuel rod status after 4 years operation in the Russian type reactor WWER-440. The power history and boundary conditions in the reactor vessel were supplied by the team of NPP Kozloduy. For this purpose they performed neutron and thermo-hydraulic calculations taking into account the neutron flux, mass flow rate and water pressure. The fuel performance code TRANSURANUS is capable to predict the thermo-mechanical behavior of the fuel rods during different steps of the fuel rod life, irradiation in 4 cycles, cooling in the pool (5 years at 60^{o}C) and dry storage in He atmosphere (50 years) although the linear heat rate, fast neutron flux and the cooling conditions are considerably different. TRANSURANUS code allows accounting for the change of the coolant nature by the restart mode which is an important advantage of the code. The linear heat rate out of reactor conditions has to be assessed from the residual decay heat in the fuel rod.

Knowing the isotopic composition of the fuel at the time of discharge is a prerequisite for residual decay heat and fast neutron flux calculations. The last version of the modular code system SCALE 6 was applied to evaluate the isotopic concentrations at the nodal level using spectrum history and power density.

The results obtained in these first analyses, show the present code version is applicable to the problem of analyzing behavior of the spent fuel under long term storage - both wet and dry one. These results are reasonable from physical point of view, with no contradictions with the preliminary expectation.

PRESERVATION AND TRANSFER OF SPECIFIC VVER KNOWLEDGE FOR NON-NUCLEAR PROFESSIONALS VIA CORONA ACADEMY

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Preserving and further developing of nuclear competencies, skills and knowledge related to VVER technology, as a technology used by many EU countries, is among the main objectives of the H2020 CORONAII Project. This objective will be achieved by the establishment of state-of-the-art regional training center for VVER competence – the CORONA Academy. The Academy will act as VVER related knowledge management system and on-demand training provider. Training schemes for four target groups - VVER nuclear professionals, non-nuclear specialists and subcontractors, university students, and trainers/Instructors have been developed. The training scheme for non-nuclear professionals contains training programs oriented to four target subgroups, divided by their job description. Two subgroups of the non-nuclear professionals are defined. They address government officials, non-nuclear engineering and management staff, who will work either onsite or outside the VVER NPP. They will receive detailed knowledge on nuclear facility access regulations, VVER technology and equipment, radiation protection, emergency planning, VVER NPP life-cycle and RAW management. The subgroup of the non-nuclear technical staff will receive specific knowledge on the above matters that will allow them to perform their duties in safe and efficient manner. The subgroup of the public communicators includes journalists, teachers, public relation officers, etc. The specific training program, developed for them, gives a general view on VVER related issues to allow them to communicate with their audiences in a proper and educated manner. The materials needed to cover the training scheme for non-nuclear professionals are prepared in order to ensure easy understanding by the trainees. E-learning option will be also available, to overcome the mobility obstacles. The CORONA Academy will serve as comprehensive source of knowledge for the VVER technology that will allow the new-coming specialists to easily step into the area. In this way the gap between the generations will be efficiently overcome and the safe operation of the VVER based power plants will be ensured for the decades ahead.

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MUTAGENIC EFFECTS INDUCED BY ACCELERATED ^{11}B IONS WITH ENERGY OF 30 MeV/N AND LET 45 AND 60 KeV/mkm ON YEAST SACCHAROMYCES CEREVISIAE

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In connection with the active space exploration the studies of the effects of heavy ions are currently of particular interest. It is possible to modulate the effect of cosmic radiation by using heavy-ion beams at the Heavy-Ion Accelerator in Dubna (JINR).

The purpose of this study was to investigate the biological effects induced by accelerated boron ions with the energy of 30 MeV/n and LET 45 and 60 keV/mkm to the Bragg peak in yeast: dose dependence of lethal damage, the induction of gene and chromosome mutations, calculate the value of relative biological effectiveness (RBE) and compare the biological effects of ions on yeast and mammalian. Unicellular yeast cells were used as a model eukaryote. Most of the genes associated with the repair of ionizing radiation-induced damage in mammalian cells initially characterized in this model organism. They are useful for studying the dose dependence functions of mutagenic effects. The relationship between LET and lethal and mutagenic effects was investigated by using a different assays to detect forward mutation, frameshift mutation, base pair substitution, deletion and recombination. The yeast was irradiated with boron ions in a dose range from 25 to 100 Gy to the Bragg peak.

The study of the biological effect of accelerated boron ion irradiation showed that the dose dependence of the lethality was linear. The average value of RBE for the accelerated boron ions with the energy of 30 MeV/n in the investigated dose range was 1.8 and 2.4 for different strains for LET 45 and 60 keV/mkm correspondently. Dose dependences for mutagenesis were not linear for forward, frameshift, base pair substitution and ectopic recombination but were linear for large deletion in plasmid. RBE for different mutations was from 1 to 5.45 for LET 45 keV/mkm and from 1 to 6.57 for LET 60 keV/mkm. In ones cases RBE was increased but in the others – without changes. Our data had good agreements with proposal that the function of RBE of lethal effect from LET is the curve with maximum ~100 keV/mkm. However the maximum of RBE depends from the nature of mutations.

A DOSE-DEPENDENT PERTURBATION IN CARDIAC ENERGY METABOLISM IS LINKED TO RADIATION-INDUCED ISCHEMIC HEART DISEASE IN MAYAK NUCLEAR WORKERS

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Epidemiological studies show a significant increase in ischemic heart disease (IHD) incidence associated with total external gamma-ray dose among Mayak plutonium enrichment plant workers. Our previous studies using mouse models suggest that persistent alteration of heart metabolism due to the inhibition of peroxisome proliferator-activated receptor (PPAR) alpha accompanies cardiac damage after high doses of ionising radiation. The aim of the present study was to elucidate the mechanism of radiation-induced IHD in humans. The cardiac proteome response to irradiation was analysed in Mayak workers who were exposed only to external doses of gamma rays. All participants were diagnosed during their lifetime with IHD that also was the cause of death. Label-free quantitative proteomics analysis was performed on tissue samples from the cardiac left ventricles of individuals stratified into four radiation dose groups (0 Gy, < 100 mGy, 100–500 mGy, and > 500 mGy). The groups could be separated using principal component analysis based on all proteomics features. Proteome profiling showed a dose-dependent increase in the number of downregulated mitochondrial and structural proteins. Both proteomics and immunoblotting showed decreased expression of several oxidative stress responsive proteins in the irradiated hearts. The phosphorylation of transcription factor PPAR alpha was increased in a dose-dependent manner, which is indicative of a reduction in transcriptional activity with increased radiation dose. These data suggest that chronic external radiation enhances the risk for IHD by inhibiting PPAR alpha and altering the expression of mitochondrial, structural, and antioxidant components of the heart.

RESPIRATION OF RATS' THYMUS TISSUES UNDER THE EXPOSURE TO IONIZING RADIATION

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Immune system participates in the development of the initial reactions to radiation damage, and it is highly sensitive to the effects of various damaging factors. It is essential to disclosure of the mechanisms of disorders of the immune and other systems when exposed to ionizing radiation, and evaluation of the state of energy metabolism at the tissue, cellular and subcellular levels.

In our experiments, the white rats were subjected to acute total gamma-irradiation on the "IGUR-1", ^{137}Cs source at a dose of 0.5 Gy, the dose rate of 0.92 Gy/min. Polarographic analysis of oxygen consumption by the tissues of the thymus was performed at 3, 10, 30, 60 and 90 days after exposure.

The level of respiration in thymus tissue of male rats in mature age is relatively high and amounts to 6.7±0,8 nmol O2 / min • mg of protein. Within three days after acute exposure to ionizing radiation at a dose of 0.5 Gy endogenous respiration in thymus tissues falls sharply. It corresponds to the stage of acute stress reaction. On the 10th day after irradiation increasing of endogenous respiration level was observed. Endogenous respiration reaches the level of control on the 60th day, and continuing to grow until the 90th day when it reaches 40% more in comparison with control. The overall dynamics of the recovery of tissue respiration corresponds to the regeneration steps, advancing in the thymus at 3-30 days and mild stages of the secondary devastation of thymus on 30-60 days.

The rate of oxygen consumption after addition of uncoupler is the maximum under the given state of the respiratory chain and ensure its recovery products. 2,4-dinitrophenol has a relatively weak stimulatory effect on endogenous respiration in the thymus tissues of intact animals. Thus, the maximum fall in tissue respiration in the 2,4-dinitrophenol background action takes place on the 3rd day after irradiation, indicating that the full exhaustion of reserve capacity of the respiratory chain.

The inhibitory analysis shows a high activity of succinate dehydrogenase and predominant contribution of the second complex in the mitochondrial oxidation of the thymus tissue of rats. After studying this pattern manifests itself most clearly in the 3rd and the 10th day. Then, the differences in the participation of both complexes are reduced and become a minimum of 90 hours.

Thus acute gamma-irradiation of rats at a dose of 0.5 Gy caused a sharp drop in the level of endogenous respiration in the thymus as soon as possible after exposure, accompanied by a marked disturbance of the functioning of the electron transport chain. In the remote terms after irradiation occurs undulating recovery of endogenous respiration.

COUNTERMEASURE TESTING IN A PEDIATRIC MODEL OF HEMATOPOIETIC ACUTE RADIATION SYNDROME (H-ARS) USING THE GOTTINGEN MINIPIG (SUS SCROFA DOMESTICA)

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There is a pressing need to develop animal models as well as treatment appropriate for age-specific radiation injuries. Data from adult animal models cannot be directly translated to the pediatric population because of major differences in the organ anatomy, physiology, metabolism, pharmacokinetics and pharmacodynamics between adults and children. For the same reason, countermeasures shown to provide benefits to adults must be tested in animal models of age range appropriate to mimic the same developmental characteristics as the target population.

The minipig represents a promising animal model for testing the effects of radiation on the pediatric population. We subjected piglets, age 6 weeks old (corresponding to humans 1 month to 2 years old), to either sham irradiation or to total body irradiation (^{60}Cobalt 0.6 Gy/min) with doses spanning from 1.6 Gy to 2.0 Gy, and determined the dose-survival relationship in the presence of minimal supportive care, as well as natural history of disease. The LD50/45 was 1.83 Gy [CI 1.70 – 1.91]. The course of H-ARS in the piglet model resembled that of humans; similarly, kinetics of blood cell loss and partial recovery mimicked the expected radiation-induced changes. Due to lower baseline erythrocyte counts in piglets with respect to adult animals, anemia may play a bigger role in the development of ARS in the Gottingen minipig pediatric model. Piglets were administered with granulocyte-colony stimulating factor (G-CSF) as a countermeasure for H-ARS. Administration of G-CSF enhanced survival by 37.5% and reduced duration and nadir of neutropenia. In conclusion, the minipig provides a practical and feasible animal model for the development of radiation countermeasures for the pediatric population. Further studies are required to validate the findings of this study in other large animal models and its relevance to human pediatric population.

GENOTOXIC EFFECTS OF INTERMEDIATE FREQUENCY MAGNETIC FIELD ON DOG AND HUMAN BLOOD LEUKOCYTES IN VITRO

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The electromagnetic exposures to intermediate frequency magnetic fields are continuously increasing in public and working environment due to the new emerging technologies such as wireless (inductive) power chargers, energy saving compact fluorescent lamps (CFL), radio frequency identification (RFID) systems, electronic surveillance and security systems, induction heaters (cooking), electric and hybrid vehicles. The widespread presence of electromagnetic sources in our daily life has incited several studies on the effects of radiofrequency and power frequency fields. Nevertheless very few research on biological effects of exposure to IF EMF has been presented so far [Shigemitsu et al. 2007]. As reported by the World Health Organization there is a need for high quality research to determine biological interactions in the IF range [WHO, 2005]. According to the opinion of Scientific Committee on Emerging and Newly Identified Health Risks there are too few studies about the effect of the IF exposure accessible and no epidemiological studies have been conducted. The expected increase of the occupational exposure to IF would require studies on biomarkers and health outcomes in workers [SCENIHR, 2015].

The aim of this experiment was to evaluate possible genotoxic effects of exposure to 123.9 kHz and 250.8 kHz intermediate frequency magnetic field and the induced electric field on dog and human blood leukocytes. We used special, cylindrically divided Petri dishes in our experiments to investigate the effects of magnetic fields with different induced electric fields. In the first set of experiments we evaluated the effects of exposure to 123.9 kHz magnetic fields at 0.79 mT with exposure durations of 1, 2, 3, 4, 5, 20 and 24h. For the assessment of genotoxicity we used alkaline Comet assay and we found significant effects on DNA damage following 20 h exposure to IF magnetic fields. The evaluation of the experiments is still in progress, so the overall results will be reported at the RAD 2017 Conference.

GENOTOXIC EFFECTS OF ULTRAVIOLET (UV) RADIATION ON HUMAN 3D SKIN MODEL IN VITRO

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UVB (280-315 nm) and UVA (315-400 nm) exposure from the sun and artificial sources (sun beds) are the most important etiological factors for development of skin cancer. UVB and UVA radiation has been classified as Class I carcinogen by the International Agency for the Research on Cancer (Fatiha et al., 2009). Ultraviolet (UV) radiation is responsible for a wide variety of different acute and chronic effects on the skin. Acute responses of human skin to UV radiation include photodamage, erythema, mutation, immunosuppression, synthesis of vitamin D and tanning. Chronic UV radiation effects include photoaging and photocarcinogenesis which are considered to be induced by mutation and immunosuppression (Ullrich, 2002). UVB radiation is more cytotoxic and mutagenic than UVA and, according to wavelength dependent studies, is 3-4 orders of magnitude more effective per unit physical dose (J/cm2) than UVA for DNA photodamage (Young et al., 1998). UVA, which in contrast to UVB is not filtered by window glass, is able to penetrate deeper into the skin and reach the dermis. While UVB is absorbed directly by DNA, and induces base structural DNA damage, UVA is mainly responsible for indirect DNA damage by the generation of reactive oxygen species (ROS) that include superoxide anion, hydrogen peroxide, and singlet oxygen and result in single-strand breaks in DNA and in DNA-protein crosslinks (Sander et al., 2004).

The aim of this experiment was to evaluate the possible genotoxic effects of exposure to UVA and UVB radiation on reconstructed 3D human skin models.

This experiment was done as a preliminary study for the project named „Cellular responce to co-exposure of radiofrequency (RF) and solar ultraviolet (UV) radiation in human in vitro skin model (SKIN-RF)" funded by ANSES.

In this experiment MatTek EPI-201 reconstructed epidermal skin models were used. After the shipment skin models were equilibrated and maintained in culture for 4 days prior to experiments with UV radiation. For the UVA exposure the Chocolate Brown High 300-500 with ULTRAVIT 2.3 filter was used and for UVB Sylvania Reptistar UV-B compact lamp. The UV doses (UVA: 6 J/cm2 and 18 J/cm2, UVB: 1 Standard Erythemal Dose (SED), 1.5 SED) were checked by International Light ILT-900 NIST calibrated spectroradiometer.

The tissues were harvested 24 hours after exposure to UVA radiation but with UVB exposure the skin models were trypsinized immediately after exposure to collect the basal keratinocytes. For evaluation of DNA damage a slightly modified alkaline Comet assay method of Singh et al. (1988) was used.

In case of UVA exposure at both doses (6 J/cm2 and 18 J/cm2) our measurements showed no significant effects on Tail DNA%, whereas the UVB exposure at both doses (1 SED, 1.5 SED) showed statistically significant increasing of Tail DNA%.

MACACA MULATTA MONKEYS' RESPONSE TO HEAD IRRADIATION WITH PROTONS AND ACCELERATED CARBON IONS

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The study has been performed as part of research on the cognitive functions of the central nervous system of *Macaca mulatta* monkeys after radiation exposure. This work is topical in view of planning manned interplanetary flights. The monkeys had their head irradiated twice with an interval of 41 days: first, with 170 MeV protons at a dose of 3 Gy; 41 days later, with 466.2 MeV/nucleon ^{12}C ions at a dose of 1 Gy. The particle ranges allowed providing the uniform exposure of the animal head tissues. On the 1st, 49th, 99th, and 454th days after proton irradiation, venous blood samples were taken for chromosome aberration analysis. A study of blood lymphocytes of non-irradiated monkeys showed a relatively low level of chromosome aberrations by both the chromosome aberration frequency and the frequency of dicentrics, which are a radiation exposure marker. A cytogenetic analysis of peripheral blood lymphocytes showed a dicentric level being several times as high as in the control group. A significant increase of dicentric yield was observed one day after a proton exposure and seven days after carbon ion exposure. The study has revealed an exponential character of the decrease of chromosome aberration yield during 454 days after head irradiation with protons at a dose of 3 Gy and ^{12}C ions at a dose of 1 Gy with an interval of 41 days. The results show that even when only the head is irradiated, quite a significant increase of chromosome aberration yield is observed in *Macaca mulatta* monkey blood lymphocytes throughout the whole study.

NOVEL METHOD OF PRELIMINARY CRYOPRESERVATION OF HUMAN CADAVERIC VASCULAR ALLOGRAFTS FOR SAFE RADIATION STERILIZATION

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Aim: to develop and verify novel method for human cadaveric vascular allograft cryopreservation for further radiation sterilization in freezing state to promote biocompatibility of potential vascular implants. We use low – viscous polydimethylsiloxane (PDMS) as a well-known, promising coolant and potential extracellular cryoprotectant (based on its hydrophobic properties). This allowed us to completely omit usage of any cytotoxic cryoprotective or vitrifying solutions. Using of PDMS potentially may provide an opportunity to develop secure protocols of tissue — engineered vascular conduits cryopreservation.

Materials and methods. After mathematical modeling of cooling process and its validation, we have conducted the experiment for isolated freezing at low temperature conditions of 30 femoral arterial segments. Native segments were used as controls. The segments were at least 10 cm in length and taken from 15 cadaveric donors in the age of 65–85 years. The freezing process was carried out by immersion of segments in PDMS (-80 C, 500 ml, viscosity 1 CS) for one minute. Segments were stored dried in special vacuumized plastic container with vertical fixation set and sterilized (vacuuming was used in purpose of reducing reactive oxygen species generation and cross-linking of PDMS). Sterilization by gamma irradiation (30 kGr, one side, 15 minutes) was performed on linear electron accelerator (e-beam). Then after thawing in container with other sterilized PDMS solution (+25 C, 1500 ml, viscosity 25 CS) biomechanical properties of these segments were evaluated with the Instron machine.

Results. There was no significant difference between cryopreserved/sterilized/thawed segments and controls what was confirmed by validation of their biomechanical properties and restricted histological analysis. We've demonstrated a prominent extracellular protective effect of PDMS confirmed by a SEM (with lanthanoid counterstaining) and histological results, and its mediated radioprotective effect, in particular because of safe cryopreservation procedure.

Conclusion. A use of PDMS in preliminary cryopreservation process for gamma sterilization showed its rationality, however it requires additional researches.

Key words: Cryopreservation, radiation sterilization, tissue-engineering

LOW LEVEL PHOTODIODE THERAPY OF THE HEART MUSCLE AFFECTED BY GAMMA-RADIATION

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Purpose. The aim of this research was to investigate electrical activity of myocardium, levels of protein oxidative modification (POM) and lipid peroxidation (POL) processes in the heart muscle consequently exposed to high intensity gamma-rays and to low-intensity red light emitting diode (LED) radiation

Materials and methods. Forty four white mongrel rats were exposed to Cobalt-60 (two peaks: 1.17 and 1.33 MeV, the exposition dose, 5 Sv). The animals were divided into four groups: two control groups (the control (C) and the chronic control (CC) groups) and two experimental groups (the experimental (E) and the chronic experiment (CE) groups). The E group animals were treated by LED radiation at twentieth minute after exposition to gamma-rays and the CE group entities received the same LED light exposition daily (640 nm, the spectral band half-width, 20 nm, fluence rate, 5 mW/cm^2), during 4 days. The C and E group specimens were biochemically examined in two hours after gamma-rays irradiation, and the animals from the CC and CE groups on fourth day after the event of the gamma-rays exposition. 10 rats of the shame group were free of irradiation by both gamma-rays and LED light irradiation

Results. Ionizing radiation modified electrical activity of the heart and low level red light therapy in the experimental groups provided rehabilitation of the myocardium activity. The statistically confident increase of levels of both POM and POL products in the control groups samples with respect to the shame group data and decrease of them in the experimental groups treated with LED low level light was statistically confidently demonstrated in this investigation ($p \leq 0.05$).

Conclusions. Red low-intensity LED radiation can provide rehabilitation of the heart muscle electrical activities, decrease of proteins and lipids oxidation products in internal organs tissues treated with gamma-rays. Analysis of POM can help to evaluate consequences of myocardium exposure to ionizing radiation.

Key words: Light emitting diodes, ionizing radiation, proteins oxidative modification.

INFLUENCE OF LOW IODINE-131 DOSES ON SUSCEPTIBILITY TO IONIZING RADIATION AND BIOMARKERS OF HEALTH RISK

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Despite the fact that precautions are clearly established, nuclear power plants accident or any radioactive threat might happen. An emerge of the ^{131}I in the ambient air might be a one of the first sign of misfortune. Iodine in human body is preferentially concentrating in the thyroid, thus ^{131}I is frequently used in nuclear medicine to diagnose or cure it. We have reported earlier strong variability in biomarkers of health risk [1] detected in lymphocytes of patients after diagnostic and therapeutic I-131 applications. Now we report molecular and cellular responses to high X-rays challenging dose applied *in vitro*, as well as DNA repair capacity examined in lymphocytes isolated from whole blood samples collected from subjects exposed to the diagnostic ^{131}I dose, and 30 persons unexposed. Aim of study was to find out if molecular and cellular repair capacities of persons diagnosed with very low I-131 doses diverge from unexposed control group, and how confounding factors like age, gender, family vulnerability to cancer and polymorphism in genes associated to repair mechanisms, can affect it. The DNA repair competence assay, with the use of Comet method and $RD_{T\text{-}DNA}$ (unrepaired during post irradiation incubation - residual DNA damage) were investigated as biomarker of the fast DNA repair, and on cellular level; SCE (sister chromatid exchanges) were measured as biomarker associated to cellular repair *via* homologous recombination and chromosome aberrations as biomarker of health risk. On average, lymphocytes of ^{131}I diagnosed subgroup expressed statistically significant increase in repair efficiency of DNA damage induced by challenging dose, when compared to average from respective unexposed control group. That increase was followed by strong and significant decrease in percentage of cells with significantly higher frequency of SCE (HFC). Observed increase of DNA repair efficiency has also corresponded to significant decrease to CA levels, and to reported earlier MN frequencies [1]. Nevertheless, all biomarkers were characterized by very high variability between individual responses. Obtained results show slight dependence on gender and family predisposition to cancer, and significant dependence on polymorphism in XRCC1(399), XRCC1(399), XRCC13(241) genes. While enlarging polymorphism study is necessary, though, model of short-term reliable biomarker battery is proposed, applicable for triage and prediction of health risk from any IR exposure.

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THE PHOTON CAPTURE THERAPY MODEL FOR IN VIVO AND IN VITRO STUDIES USING Au NANOCOMPOSITES WITH THE HYALURONIC ACID BASED COMPOUNDS

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The aim of the study is to assess the radiobiological efficiency of the X-rays modified with photon capture events by Au, which is a part of hyaluronic acid and melanin based nanocomposite. The compound synthesized by “MARTINEX” company (Moscow, Russia). The *in vitro* study performed on murine melanoma B-16 as the clonogenic assay in order to assess the influence of photon capture events in 2-8 Gy dose range. The RBE values were assessed on 10% survival level with Au concentration of 100 µg per 1 ml of the culture medium. The *in vivo* study done with the model tumor sarcoma M-1 on rats, which has been irradiated locally with 28, 32, and 36 Gy together with Au nanocomposite injected into tumor site (for 28 Gy – 4 mg per animal, 15 min before irradiation). The antitumor efficiency estimated later using the tumor growth suppression factor and skin reaction yield. The both studies has been done on the facility with two X-ray tubes RAP 220-5, anode voltage is 180 kV, average current 5 mA.

The photon capture events contribution assessed with the clonogenic assay for the cells incubated with the 100 µg per 1 ml of the medium and irradiated with the 4 Gy with the X-rays. The multiplication factor of efficiency is 5 (25% cells survived after 4 Gy irradiation in normal conditions while only 5 % in photon capture therapy model). The overall estimation in the 2-8 Gy dose range resulted in the RBE value of 1.5.

The similar effects for tumor growth dynamic curves, measured for 27 days on rats with sarcoma M-1, has been observed after 32 Gy irradiation of X-rays in normal conditions in comparison to experimental photon capture therapy with 28 Gy plus 4 mg of Au. The therapeutic efficiency factor is 4 Gy which is 14%. The tumor growth suppression factor for the rats group receiving the experimental photon capture therapy comparing to the 28 Gy of conventional X-rays irradiation, is 26 %. There was no significant difference observed in the skin reaction yield for the group receiving 28 Gy conventionally in comparison to the group with Au administered into the tumor.

As the results of the study, we estimated the nanocomposite concentration which is not followed by cytotoxic effects. Also we estimated the contribution of the photon capture events to the total absorbed dose with X-rays irradiation both for *in vitro* and *in vivo* cases. Overall we underline the prosperous potential of the Au nanocomposites in the compounds based on the hyaluronic acid and melanin for the photon capture therapy.

STUDIES ON VULNERABILITY OF LYMPHOCYTES TO IONIZING RADIATION IN PROSTATE CANCER AND BPH PATIENTS

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Genetic constitution and lifestyle of an individual can affect his response to various exogenous factors including therapy with ionizing radiation (IR). The DNA repair capacity may be an important factor in determining both; an individual susceptibility to cancer and the response to cancer therapy. The aim of our studies was to verify that the molecular and cellular radiosensitivity can be associated with inclination to cancer induction, and if we are able to predict efficiency of radiotherapy. Responses, to the challenging dose of X-rays, of peripheral blood lymphocytes from prostate cancer (PC) patients we compared to those from benign prostatic hyperplasia (BPH) diseases. To evaluate an individual susceptibility to ionizing radiation and DNA repair competence, the extent of DNA damage was evaluated in defrosted lymphocytes before and immediately after irradiation with challenging 4Gy dose, and additionally after post irradiation incubation, allowing cells to complete fast DNA repair process. The alkaline version of a single cell gel electrophoresis (SCGE) assay was used to estimate the DNA damage on a molecular level and cytogenetic studies performed on whole blood samples on the cellular. The average susceptibility to the challenging dose of X-rays for the group of PC patients was significantly higher than for the BPH subjects, and PC patients' cells repaired the radiation damage less efficiently than BPH patients. These findings correlated well with the results from cytogenetic studies. Significantly higher amounts of chromosome and chromatid aberrations were detected in irradiated lymphocytes of PC patients. What is more, molecular and cellular responses, correlated with factors dependent on life style or family inclinations to cancer. Our results clearly suggest a possible value of the DNA repair competence assay in both epidemiology as in pre-clinical studies as a predictor of patient response to radiotherapy.

TOXIC AND ACTIVATION EFFECTS OF LOW-LEVEL RADIATION VIA BACTERIAL LUMINESCENT ASSAY: DESCRIPTION IN TERMS OF HORMESIS AND THRESHOLD MODELS

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

EFFECT OF IRRADIATION OF CHO-K1 CELLS BY DUAL ION BEAM

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Hadrontherapy is a method used for elimination of cancer cells using heavy ions. Mainly, in this area carbon ions are applied showing good results in inactivation of cells in a Bragg peak area. In this study carbon ions were enriched with oxygen ions to estimate the effect of irradiation of living cells by two different ion beams at the same time. The both types of ions were simultaneously accelerated by the U200P cyclotron situated at the Heavy Ion Laboratory in Warsaw, Poland. Such dual ion beam was used for irradiation of CHO-K1 cells and survival test was adopted. The character of action of the dual ion beam on examined cells was estimated using isobologram method utilizing additional results of survival tests derived for irradiation of carbon and oxygen ions separately.

THE PROBLEM OF THE RELATIONSHIP OF CYTOGENETIC INDICES IN PERIPHERAL BLOOD LYMPHOCYTE CULTURES WITH THE RISK OF DISEASES, IN PARTICULAR, AFTER THE EXPOSURE

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This report presents an analysis of the data published in the scientific literature in connection with the problem of forecast of the development risk of malignant and non-malignant diseases by chromosome aberration frequencies in human peripheral blood lymphocyte cultures. This question is closely linked with the concept of a common chromosomal instability. Paired fragments and chromatid aberrations which may be sources of malignant transformation are indicators of this instability. At the end of the XX century evidence of the possibility of such forecast for malignant diseases was appeared. The conducted scale researches of number of European laboratories from 11 countries allow the following conclusions:

1. In general all observed frequencies of chromosome aberrations were in limits of earlier set background values.

2. Correlation of malignant neoplasm development risk and/or mortality from them with number of aberrations in lymphocyte cultures found several years prior to development of a disease was observed.

3. Communication with risk of development of carcinogenesis existed as well for micronuclei but not for sister chromatid exchanges.

4. Aberrations of chromosomal type were more important than chromatid aberrations.

5. The fact of prior professional harmful effects did not significantly affect the growth of morbidity.

6. With rare exceptions, the lack of information is not allowed to set for each individual nosology regularities inherent in the whole sum of malignancies.

7. Influence of a sex, age and smoking on all these relations was not revealed. At the same time there are significant uncertainties due to interindividual and intraindividual variability.

However, generally speaking, the increased levels of chromosome aberrations at the persons which have undergone or exposed to radiation can not demonstrate the increased risk of development of malignant neoplasms. They are just a consequence of the happened exposure and do not reflect the processes of neoplastic transformation going in an organism and connected with chromosome instability. On the other hand they are caused by the general level of the inflicted genetic damage. In scientific literature there are messages on positive correlation of the increased levels of radiation-induced chromosome aberrations in peripheral blood lymphocyte cultures with risk of development of some both malignant and other somatic pathologies (cardiovascular, endocrine, in particular, thyroid diseases). However it is essential that in contrast to the above European studies cytogenetical analysis in these papers was not preceded by a diagnosis. Thus in these cases one can not speak about the disease development risk assessments. In addition treatment of any disease involves the use of adequate medicinal preparations. Influence of the last on the chromosomal apparatus in most cases was not investigated.

LINE-1 METHYLATION AND FREQUENCIES OF CHROMOSOME ABERRATIONS AND ANEUPLOIDY IN LYMPHOCYTES OF PLUTONIUM WORKERS

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Structural and numerical chromosome aberrations are the most deleterious mutations which lead to copy number variation of numerous genes and epigenetic dysregulation. Epigenetic errors may also result in chromosome instability due to changes in expression of DNA repair and cell cycle genes. The aim of this work was to analyze the relationship between methylation of LINE-1 retrotransposon and structural and numerical chromosome aberrations in human lymphocytes after chronic low dose exposure. Index of LINE-1 methylation, frequencies of aneuploidy of chromosomes 2, 7, 8, 12, X, Y, centromere-negative and centromere positive micronuclei, chromosome aberrations and sister chromatid exchanges were assessed in lymphocytes of 40 plutonium workers (plutonium-239 activity 0.37-6.95 kBq) and 49 controls. LINE-1 methylation was assessed by pyrosequencing. Analysis of aneuploidy was done by fluorescent in situ hybridization (FISH) with centromere-specific probes. Micronucleus test was performed in combination with FISH using pancentromeric DNA probe.

In the group of workers, frequencies of centromere-negative micronuclei (4.74 ± 2.26 ‰ vs. 3.02 ± 1.69 ‰), chromosome-type aberrations (0.81 ± 0.79 % vs. 0.44 ± 0.69 %) and mean chromosome non-disjunction (0.12 ± 0.05 % vs. 0.05 ± 0.02 %) were significantly higher than in controls ($p<0.05$). Index of LINE-1 methylation did not differ significantly between groups of workers and controls (74,93 ± 3,63 % vs. 73,92 ± 4,62 %). Correlations between LINE-1 methylation and frequency of micronuclei ($R=-0.35$, $p=0.048$) was seen in control group, whereas correlations between LINE-1 methylation and chromatid type aberrations ($R=-0.42$, $p=0.012$) and sister chromatid exchanges ($R=-0.34$, $p=0.041$) were observed only in the group of plutonium workers. Thus, LINE-1 hypomethylation after plutonium exposure is associated mainly with chromatid breaks, either repaired or misrepaired.

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EFFECT OF N-METHYL-D-ASPARTATE RECEPTOR ANTAGONIST ON RADIATION-INDUCED GUT INJURIES IN MICE

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Heavy-ion therapy is effective treatment for cancer because it is possible to focus the peak of charged particle beam on the cancer-affected area, whereas the beam can cause damage to the surrounding normal tissues and its damage limits the radiation dose or area for cancer therapy. The intestinal crypt stem cells in gut have a high radiosensitivity, it is dose-dependently reduced by heavy-ion irradiation. Radiation-induced gut injuries are most potent threat to radiotherapy for abdominal cancer. Therefore, radioprotective agents for gut may contribute to more effective and less harmful heavy ion therapy. N-methyl-D-aspartate receptor (NMDAR) is one of excitatory amino acid receptors and NMDAR antagonist has been reported to prevent the radiation-induced injuries in the central nervous system.

We determined that radiotracer of 2-^{14}C-thymidine is useful for predicting radiation- induced gut injuries, in term of crypt repopulation and early diagnosis of cell death. We assume that the peripheral NMDAR activation is a possible cause of injury to normal tissues after irradiation.

We examined the 2-^{14}C-thymidine accumulation in gut after irradiated with carbon-ion until 84 hrs. Mice were given whole body irradiation with carbon-ion (290 MeV/u, 6cm-SOBP, 20keV/μm). 2-^{14}C-thymidine accumulation in gut significantly decreased 4 hrs after irradiated with 9 Gy. At 12 hrs after irradiation, accumulation of 2-^{14}C- thymidine decreased with an increase of carbon-ion doses. On the other hand, 2-^{14}C-thymidine accumulation not showed dose dependence at 84 hrs after irradiation. However, the dose dependence was obtained when 2-^{14}C-thymidine accumulation was corrected by blood flow. The regional blood flow marker ^{14}C- labeled N-isopropyl-p-iodoamphetamine (IMP) in gut markedly increased after 9-18 Gy irradiation. The results of the present study are first demonstration that the 2-^{14}C- thymidine uptake in vivo could be an appropriate marker for early gut response to irradiation and correction by blood flow is essential for the evaluation by 2-^{14}C-thymidine.

The radioprotective effects of MK-801, a noncompetitive NMDAR antagonist, on gut were confirmed by the crypt survival assay. The tritium-labeled [^{3}H]MK-801 was used as a marker for NMDAR activation and injected into C3H female mice intravenously. Gut accumulation of [^{3}H]MK-801 after whole body irradiation of carbon ion. The significant increase of [^{3}H]MK-801 accumulation in gut show that intestinal NMDAR are most activated at 24 hrs after 3-9 Gy carbon ion irradiation.

This study may evaluate the effect of carbon-ion radiotherapy against cancer by PET (Positron emission tomography) diagnosis and it would be possible to inhibit radiation-induced gut injuries by NMDAR antagonists until 24 hrs after carbon ion exposure.

THE EFFECTS OF 1800 MHz RADIOFREQUENCY RADIATION ON GENE EXPRESSION LEVELS IN RAT BRAIN TISSUE

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Aim: Radiofrequency electromagnetic fields **(**RF-EMF) exposure can stimulate the cellular stress response pathways. Hsp20, Hsp25 and Hsp70 are the heat shock proteins. These are one of the most inducible proteins by RF-EMF. Crystallin-alpha A (Cryaa) and Crystallin-beta B1 (Crybb1) are the small heat-shock proteins induced by heat shock proteins and they act as molecular chaperones. We determined these genes expression levels to evaluate the possible carcinogenic effects of 1800 Mhz cell phone radiofrequency radiation (RF) emitted by cell phones on Wistar albino rat's brain tissue.

Materials and Methods: Twenty-seven ten-week old Wistar albino rats included in the experiment, divided into three groups. Rats in exposed group were exposed by 1800 MHz RF two hours per day along eight weeks. Sham group was same conditions with exposed group without RF exposure. Rats in control group were kept in their own conditions in the animal laboratory. All of them were sacrificed at the end of the eight weeks and removed their brains. Total RNA was extracted from whole brain homogenate. cDNA was synthesized from RNA and then Hsp20, Hsp25, Hsp70, Cryaa and Crybb1 genes expression levels were detected with Real-Time PCR system. Study was supported by Mersin University (2015- AP4-1216).

Results: The results demonstrated that long-term exposure of 1800 MHz radiofrequency radiation can alter the Hsp20 ($p=0.0006$), Hsp70 ($p=0.0289$), Cryaa ($p=0.0003$) and Crybb1 ($p=0{,}001$) genes expression levels in the rat brain. However Hsp25 ($p=0.2483$) gene expression level was not altered.

Conclusion: Our conditions of RF may lead to brain diseases as brain tumours due to alteration some genes expression levels. Therefore further studies should be performed.

HPRT MUTANT ANALYSIS IN V79 CELLS INDUCED BY IONIZING RADIATION OF VARIOUS LET

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The modern technological developments have resulted in the use of radiation for military, industrial and medical purposes. The problem of mutagenic action of ionising radiation and, in particular, dense ionising radiation attracts scientists' attention because of increasing a cohort of workers in enhanced radiation background. Some situations arise also during long-term space missions. It is known that high energy protons (up to 85 %), helium ions and other heavy ions are components of the galactic space rays. The fundamental research of the radiation effects on the living organisms is becoming more and more important nowadays. Moreover, the importance of prediction of the genetic effects after irradiation with high-LET radiation increases with the increasing use of high-LET radiation.

This research was conducted with three different heavy ions (^{18}O, ^{20}Ne, and ^{11}B) with the LET in the range of 50 and 153 keV/μm and the ^{60}Co gamma radiation (убрала ЛПЭ). The induction of HPRT mutants was measured for the doses 0.5 – 2 Gy for the heavy ions and 0.5 – 7 Gy for the gamma radiation. After exposure, the number of mutants (mutant fraction) was detected in regular intervals during every cell culture recultivation (approximately every 3 days) - up to 40 days after irradiation (expression time). Non-monotonous progression of the mutant fraction dependence on the expression time was found for every irradiation condition. Particularly at the HZE ions irradiation, mutant fraction was increasing with expression time; reaching maximum, and falling back to the initial levels characteristic for non-irradiated samples. The mutant fraction maximum was reached in different expression times under various irradiation conditions. The position of the maximum was moving with the LET value of the used radiation - to longer expression times with increasing LET. The dependence of mutant fraction maximum on LET can be well described by an exponential function.

THE MONTE-CARLO BASED SURVIVAL PREDICTION FOR IN VITRO STUDIES WITH VARIOUS CELL TYPES IN CARBON ION FIELDS

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The radiobiological modelling plays now a huge part in the experimental studies, which are the first stage before implementing a radiation treatment with the carbon ions. There are numerous models currently existing and used both for radiobiological experiments interpretation (PARTRACK, BIANCA, etc.) and for patient radiation therapy (LEM, MKM, etc.). The Russian carbon ion therapy project now under development by SRC IHEP of NRC "Kurchatov institute", Protvino, Russia in cooperation with A. Tsyb MRRC, Obninsk, Russia also implies the development of such a model to use as a part of a treatment planning software. However, on the preclinical stage this model should be verified.

The Geant4 self-written cell model and Geant4-DNA package have been used to simulate the SSB, DSB and cluster SB yields. Both stationary and exponential cell growth phase together with genomic length data (number of base pairs) have been taken into account. The effective particle spectra for the same geometry as in experimental setup have been simulated with Geant4 and NPLibrary, previously developed at A. Tsyb MRRC. The resulting survival was assessed with the G.M. Obaturov differential model using the predicted SB yield and LET characteristics for different parts of Bragg curves.

The results of the simulations verified against LEMIV and Katz models. The good agreement in the RBE value has been shown for the LET range of 80-160 keV/um for the 455 MeV/nucleon carbon ion beam (which corresponds to the 27-30 cm depth of the Bragg curve) both for pristine and 1cm SOBP. The experimental data obtained by A. Tsyb MRRC with B-16 and V-79 cells also shown the correspondence to all the models. The LET range of 10-20 keV/um which corresponds to the plateau region also well covered by developed and tested models as well with the experimental data. On the other side, there is a notable difference between the developed model and LEMIV/Katz in the distal dose fall-off region and in the tail region of Bragg curve. The future experimental studies will be aimed also on these regions.

The future development of the model will consist of two major improvements. First, we expect to simulate some other measurable cell characteristics such as H2AX yield and introduce chromosome aberrations probability function. In the second, we want to obtain the experimental data on another beam extracted energy and check how survival model will be fitted with another effective spectrum data. Overall, such models show a good opportunity to verify modern simulation tools and could be implemented as a part of treatment planning software, which result in the patient treatment improvements.

RADIATION PROTECTION WITH HEPARIN AND INTERLEUKIN-1

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The aim of our research was the experimental estimation of efficiency of isolated and consecutive application of heparin and interleukin-1β at acute whole body irradiation.

Experiments were conducted on male of inbred mice, BALB/c mice and (CBA x C57Bl) F_1 mice up to 90 days old, which weighted between 18 and 20 g. Heparin was injected to mice intraperitoneal in a dose of 250 Units/kg, interleukin-1β in a dose of 50 mkg/kg in different time before or after irradiation. The animals were exposed to a total whole body irradiation with γ-rays of Co^{60} or X-rays. The estimation of radioprotective effects of heparin and interleukin-1β was carried out by studying 30-days survival rate and average life expectancy of the dead animals, number of hematopoietic cells in endogenous and exogenous colony formation techniques, total number of leukocytes in peripheral blood, and level of myeloperoxidase, alkaline phosphatase and glycogen in neutrophils.

As a result it is established, that after unitary introductions of heparin the radioprotective effect developed through 1 day and was kept on an extent up to 30 days. The maximum radioprotective effect was registered when heparin was administered two days before irradiation. DRF of heparin in conditions of acute whole body irradiation was 1.16.

Interleukin-1β possessed radioprotective effect at its introduction for 20-24 hours before or during 1 hour after irradiation. The maximum radioprotective effect was registered when interleukin-1β was administered 15 minutes after irradiation. DRF of interleukin-1β at acute irradiation was 1.15.

Consecutive introduction of heparin and interleukin-1β allowed to increase survival rate of irradiated in dozes $LD_{70\text{-}100/30}$ mice in 1.5-2.5 times in comparison with isolated radioprotective introduction of heparin and in 1.6-3.1 times in comparison with isolated therapeutic application of interleukin-1β. DRF of combinations of drugs in conditions of acute irradiation was 1.26. The combined use of heparin and interleukin-1β increased number of CFU-S9 at the irradiated mice, reduced expressiveness of leukopenia in early terms after an irradiation, accelerated restoration of number of leukocytes in peripheral blood more effectively, than separate using of drugs. Furthermore, the combined use of heparin and interleukin-1β has a positive impact on the glycogen level, activity of myeloperoxydase and alkaline phosphatase in neutrophils.

The received results show perspectivity of use of the scheme of combined use of heparin and interleukin-1β for radiation protection in conditions of acute whole body irradiation.

THE STUDY OF BIOLOGICAL EFFECTIVENESS OF U-70 ACCELERATOR CARBON IONS USING MELANOMA B-16 CLONOGENIC ASSAY

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Therapy with carbon ions is one of the most promising methods of cancer treatment. Unlike most types of ionizing radiations in case of carbon ions energy transfer is non-uniform and has a maximum in the Bragg peak. However, the available data on the biological effects of carbon ions is limited. This applies both to fundamental dependence RBE-LET, and to issues related to the accuracy of RBE estimation in the Bragg peak and in the area immediately after the peak. The aim of this study was to evaluate the biological effectiveness of carbon ion beam of U-70 accelerator (IHEP, Protvino, Russia) in the three main areas along particles track within biological tissue: area before peak, Bragg peak, and the "tail" (area after the peak).

In the present study murine melanoma B-16 cell culture was used as main test-object. Relative biological effectiveness was evaluated using cell clonogenic assay. Carbon ions were produced using U-70 synchrotron. The experiments were conducted with monoenergetic (450 MeV/nucleon) beam with no spread out effect. The dose rate was in the range of 0.05-2.0 Gy/min, depending on the area: before, after or in the Bragg peak. LET values were: 16±1, 180 ± 26, 20±1 keV/μm before, in the peak and after the peak, respectively. Gamma-rays of 60-Co at the dose rate of ~ 1.0 Gy/min was used as a standard exposure. The data obtained on cell survival were processed using the statistical software R and graphics applications Veusz. Dose-survival fitting was carried out using linear-quadratic model.

Dose dependences for carbon ions in the Bragg peak and in the area before the peak were nearly linear. In case of the area after the peak (the "tail") dose-survival curve has a certain quadratic component and this is similar to the dose dependency for low-LET radiations (such as gamma-rays in the present study). This could be explained by secondary radiation spectrum. In case of the "tail" comparing the area before the peak there was no carbon ions but the amount of secondary particles: He, H, B, Li and Be was on the same level.

Based on the data received RBE values were calculated (on the level of 10 % survival): 1.7±0.2, 4.5±0.5 and 2.4±0.2 for the area before the peak, in the Bragg peak and after the peak, respectively. The maximal RBE values (according to the alpha coefficients ratio) were: 3.3±0.3, 8.7±0.9 and 1.8±0.2 for the area before, in the peak and after the peak, respectively.

The present study allowed to expand the data related to biological efficacy of carbon ions. Linear-quadratic dose dependence observed for the area after the Bragg peak demands the further studies. Conducted experiments were the important step to the future clinical trials using U-70 synchrotron.

THE FOCAL BRAIN PROTON BEAM IRRADIATION INSULT IN RATS – INDUCED MEMORY DISTURBANCE RELATED CHANGE IN ACETYLCHOLINE RECEPTOR BINDING

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Cerebral dysfunction is one of the major concerns associated with radiotherapy of brain tumours. However, little is known about the neurochemical basis of brain dysfunction induced by proton irradiation. We here investigated the early consequences of brain damages caused by proton beam. Brain of male wistar rats was locally irradiated with 70 MeV proton beam. The eight-arm radial maze task was tested on irradiated rats. In order to assess preservation (recall) of memory, the rats that memorized the spatial cognition were irradiated. The impairment of the preservation memory was not observed in the irradiated rats compared to control at 24 hr after irradiation. Repeated measures of two-way ANOVA of correct choices and number of errors showed no differences between the control group and 30 Gy irradiated group. In order to assess the acquisition process of memory and working memory for the platform location in water maze, the task was started on the 24hr after irradiation. Learning task (The acquisition process of the memory), latency to platform showed no difference between the control-group and irradiated-group. The rats that memorized the location of the standard position were irradiated, the impairment of the long-term memory was not observed in the irradiated rats compared to control at 24 hr after irradiation. However, irradiated rats required substantially longer time finding out a platform than control rats when the platform had been placed in non-standard position. This follows that a proton dose of 30 Gy impaired the working memory of rats.

Function of muscarinic acetylcholine receptors was analyzed by in vivo binding assay using radioligand quinuclidinyl benzilate (^{3}H-QNB). Irradiated rats were intravenously injected 5.5 MBq of ^{3}H-QNB at 24hr after the irradiation. The autoradiographic studies showed a transitional increase of ^{3}H-QNB in vivo binding in the early phase after proton irradiation. On the other hand, no change in in-vitro ^{3}H-QNB binding was seen in autoradiogram of brain slices from irradiated rats. The cerebral blood flow and the histological features of brain were also changed at 5 or 6 months post-irradiation. These results indicated that relation between behavioral impairment caused by radiation is closely related to early change in receptor function which could be detected in in-vivo condition.

THE MORBIDITY STUDY OF THE LIQUIDATORS OF CHERNOBYL POWER PLANT DISASTER CONSEQUENCES LIVING AT HIGH ALTITUDES

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In spite of the long period that has passed after the Chernobyl disaster the interest in the medical aspects of its consequences does not weaken. It is largely due to the complex and long-term nature of the adverse impacts of this disaster. The interest of the Armenian researchers towards this problem is conditioned not only by the disaster factors common for all the countries affected, but by those specific for the liquidator- residents of Armenia, like ethnicity, geographic location, socio-economic reorganization etc. Here there is a multi-factor influence on the state of health not only of radiation factors but other non-radiation factors as well. In this respect we find it interesting to examine the liquidators living at high altitudes in Armenia (Aragats, Tsakhadzor, Sevan and other towns).

It is common knowledge that in the mountains a complex of adaptation reorganization develops which first of all is due to the oxygen insufficiency, functional capabilities are expanded which leads to the increase in tolerance. As a result of the research it was discovered that the pulmonary morbidity level of the liquidators living at high altitudes is significantly low this being evidence of defense mechanisms of people who have lived in hypoxia for a long time.

As for the cardio-vascular system, in the early period the differences between the 2 groups are insignificant and only in the distant period the morbidity percentage is clearly identified in the “highland” liquidators compared to the “lowland” liquidators. This can be accounted for by the fact that the atherosclerotic lesions of the main and peripheral vessels develop later and progress slowly among the mountain living population which is an expedient physiological adaptation emerging in the process of vital activity of the “highlanders”.

Regarding the morbidity of the gastrointestinal tract, it can be noted that significant differences in the percentage of morbidity were recorded only in the distant period. Starting from 2000 the morbidity of the “highland” liquidators is almost three times as low as that of the “lowland” liquidators which can also be accounted for by adaptation mechanisms.

An increase in the morbidity level of NS is recorded in the liquidators living at high altitudes through almost the whole research period.

Thus, the liquidators constantly living in hypoxia turned out to be more tolerant to the exposure of ionizing radiation. They fall behind the lowland liquidators only by the morbidity rate of the nervous system. This can be accounted for by physiological adaptations which appeared in the process of vital activity in the highlands.

THE ASSESSMENT OF CYTOGENETIC INDICES OF CHERNOBYL POWER PLANT DISASTER LIQUIDATORS

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It is common knowledge that one of the first indicators of the exposure of ionizing radiation on the cell is the destabilization of chromosomes. There is a radiation-induced genome instability and all the main distant consequences of ionizing radiation– mutagenesis, carcinogenesis, ageing are connected to it.

The data of many years of observation on the condition of the chromosome apparatus of the somatic cells (peripheral blood lymphocytes) of the liquidators and the results of comparative analysis of chromosome destabilization in case of various nosologies (diseases of the gastrointestinal tract and malignant neoplasms) are analyzed in the current work.

The conducted research has shown that the chromosome apparatus of the liquidators has been affected considerably. These changes also depend on the period that has passed after radiation. The dynamics of the changes of chromosome aberration levels, single and double DNA breaks, metabolic aberrations were described with the help of regressive formulae that allow us to forecast changes in these indices.

Dicentrics and rings considered as biomarkers of ionizing radiation were not found in the liquidators. An important factor in the study was the detection of polyploid cells (mainly tetraploid). In the research until 1990 polyploid form of lymphocytes was recorded sporadically. Later on a significant increase of polyploid cells was recorded. From the point of genome instability the rearrangements of chromatin are assessed as an adaptation process with the aim of elimination of genetic disorders in the cell and the change in the ploidy as one of the possible mechanisms.

The results of the discriminant analysis show that distinctive indicators have been found by 5 cytogenetic indices (proliferation activity, 4n, 1 break, 2 breaks and 0) forming the groups of liquidators with benign and malignant neoplasms. This comes to show that the use of modern methods of system analysis for chromosome disorders can have a prognostic value in case of oncological diseases.

Summing up the results of cytogenetic research of the Armenian liquidators it can be stated directly that the instability of the lymphocyte genome of the peripheral blood is quite marked and in spite of the fact that in the distant period there is a tendency of index normalization- chromosome aberration and proliferation activity, these indices significantly differ from the control group. It should be noted that we did not manage to find out the dependence of the changes in the chromosome apparatus of lymphocytes on the dose received by the liquidators in the distant period using standard statistical methods. At the same time, the significance of the rise in the polyploid cells discovered by us, as a possible cytogenetic marker in the radiated organism should be noted.

CYTOTOXIC AND INTRACELLULAR BIOMARKERS OF RESPONSE TO NON-IONIZING RADIATION EVALUATED IN NEURONAL CELLS

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The aim of this study was to evaluate whether low-level, modulated nonizonizing radiation (NIR) irradiation frequentation of 915 MHz influences the cell viability, proliferation and intracellular microtubular structures of SH-SY5Y neuroblastoma cells. Modulated NIR field was generated inside a Gigahertz Transversal Electromagnetic Mode cell (GTEM-cell) with Anritsu spectrum analyzer with tracking generator and amplifier. The electric field strength was 10, 20 and 30 V/cm and the average specific absorption rate (SAR) was calculated to be 0.12, 0.4 and 0.8 W/kg. Cell samples were cultivated in a temperature controlled atmosphere at 37 °C with 5% CO2 and high humidity. Previously prepared cells were exposed to a 915 MHz continuous wave frequency field for 3 hours. Cell viability was determined by Trypan blue method, whereas cell proliferation was determined by MTT test. The structure of microtubule proteins has been determined using the immunocytochemical method. Negative- and positive cell controls were included into the experimental procedure. Results showed that modulated NIR did not have impact on celullar viability and proliferation. In comparison with control cells, the microtubule structure altered after 3 hours of 30 V/m irradiation. It seems that the modulated 915 MHz, low-level NIR radiation affects microtubule proteins without influencing cell proliferation and viability

THE EFFECTS OF X-RAY IRRADIATION ON THE INHERENT STEMNESS OF HUMAN EMBRYONIC STEM CELLS AND HUMAN MESENCHYMAL STEM CELLS

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Aim. Human stem cells hold great promise in cell-based regenerative therapies, disease modeling, drug screening, assessing genotoxic and mutagenic risks associated with exposures to a variety of environmental factors. X-rays irradiation is widely used in diagnostic and therapeutic procedures in medicine. We investigated the effect of sub-lethal dose of X-ray irradiation on viability, proliferation, expression of key markers and differentiation of adult mesenchymal stem cells (MSCs) and human embryonic stem cells (hESCs).

Material and Methods. Pluripotent hESCs (910C) were characterized by self-renewal, expression of Oct4, Nanog, Sox2, Ssea-4 and differentiation into 3 types of embryonic lineages – ectoderm, endoderm and mesoderm. MSCs derived from menstrual blood (eMSCs) were characterized by positive expression of surface markers CD146, CD105, CD73, CD90, differentiation into mesodermal lineage as well as secretion of BDNF (brain-derived neurotrophic factor). To investigate hMSCs and eMSCs response after irradiation we used MTT test, flow cytometry, immunofluoresce, β-galactosidase staining and ELISA.

Results. X-ray sub-lethal dose for eMSCs was 3 Gy, for hESCs -1 Gy. Higher doses cause premature senescence in MSCs and massive apoptosis in hESCs. We have revealed that irradiation induces DNA Damage Response (ATM, phosphorylation, gamma-H2AX foci) in hESCs and eMSCs during 1 h and 4 h respectively. X-ray exposure resulted in a temporary cell cycle arrest at the G2/M phase in hESCs and at G0/G1 in eMSCs. However, on day 4 following irradiation hESCs and eMSCs exhibited increased cell number and cell cycle recovery. Surviving hESCs continued to express pluripotent markers SSEA4, TRA-1-60, transcription factors Oct4, Sox2, Nanog, although Oct4 and Nanog expression was reduced. Surviving eMSCs expressed the same CD markers that non-irradiated cells, however secretion of BDNF was decreased compared to intact cells. HESCs and eMSCs retained the ability to differentiate after X-ray radiation, although osteogenic potential of eMSCs and neurogenic potential of hESCs were reduced in compared to nonirradiated cells. Surviving stem cells maintained their properties during 3–6 passages, then eMSCs exhibit premature senescence and hESCs increased level of spontaneous differentiation.

Conclusion. Sub-lethal X-ray irradiation reduces capacity to self-renewal of human embryonic stem cells and human mesenchymal stem cells.

ALLOZYME VARIABILITY AND QUALITY OF SEED PROGENY IN PLANTAGO MAJOR L. POPULATIONS FROM EAST-URAL RADIOACTIVE TRACE AREA

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The East-Ural Radioactive Trace (EURT) appeared in 1957 after the accident at the Mayak Radiochemical Plant, where a tank with radioactive waste exploded (Urals, Russia). The main contaminant was ^{90}Sr. Additional contamination of this area occurred in 1967 as a result of the wind transfer of radioactive sand from the shores of Lake Karachay, which had been used as a reservoir for radioactive wastes (with ^{137}Cs being the main contaminant). We analyzed the variability of 13 allozyme loci in *Plantago major* L. populations from the EURT zone and background plots. Furthermore, we characterized viability of *P. major* seed progeny.

For assessment of genetic variability seeds were collected from eight populations exposed for a long time to radioactive contamination, seven background plots were beyond the contamination area. Only two of these enzyme systems were genetic polymorphic: ADH (1 loci) and GOT (two loci – Got-1 and Got-2). Six enzyme systems (FDH, PGI, SKDH, 6-PGD, DIA, GDH) were monomorphic in all populations. Systems EST-c and EST-f, DIA, PGM, SOD, IDH have been rejected because they were not recognizable. We estimated standard genetics parameters: proportion of polymorphic loci, expected and observed heterozygosity, effective allele number, etc. The structure of populations was analyzed using Wright's F-statistics.

According to proportion of polymorphic loci and mean numbers of alleles per locus the lowest genetic variation was in EURT populations. Expected heterozygosity exceed observed heterozygosity in all populations, but differences were not significant. In all plantain populations high level of inbreeding was revealed, which has led to predomination of homozygote genotypes. This indicates high rate of self-pollination in *P. major* populations.

For assessment of viability we used seeds from three EURT populations and five background populations. Germination rates and seedling survival rates were identical in all samples. Variability of these parameters within background zone exceeded differences between impact and background areas. Therefore, germination rates, seedling survival rates of *P. major* samples from the EURT area did not differ significantly from background samples as well as proportion of seedlings with true leaves. Root length in one of background samples exceeded significantly value of this parameter in one of EURT samples.

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EVALUATION OF RADIOSENSITIVITY OF PLANT AND BACTERIAL BIOASSAYS EXPOSED TO LOW DOSES

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Field studies in the Yenisei River floodplain revealed spots of high concentrations of artificial radionuclides, including radioactive particles, which are sources of exposure of organisms in aquatic and terrestrial ecosystems. Laboratory experiments were performed to estimate the toxicity of low doses of radiation from radioactive particles and radioactive (Cs-137) sediments; five bioassays were used: submerged macrophyte Elodea canadensis (elodea), Allium test with bulbs and seeds, and two indicator bacterial strains Salmonella typhimurium (the Ames test) and Escherichia coli (the SOS chromotest).

Experiments with elodea roots exposed to gamma- and beta-radiation yielded the threshold dependence of bioassay endpoints (average root length, total chromosome abnormalities and their types) on the dose rate. For this bioassay, the lowest threshold dose rate was 3 μGy/h. Elodea remained sensitive to radiation exposure at the dose of gamma-radiation of 130 μGy/h or higher. In experiments with onion bulbs (Allium-test), with roots exposed to gamma- and beta-radiation, bioassay endpoints were not inhibited, but radiation exposure was found to stimulate elongation of onion roots. In experiments with onion seeds, no root growth stimulation was observed, and the incidence of total chromosome abnormalities was significantly higher than that in the control at a dose rate of 2300 μGy/h.

Experiments with two indicator bacterial strains – Salmonella typhimurium (the Ames test) and Escherichia coli (the SOS chromotest) – showed their high sensitivity to low doses of external gamma-radiation. At a dose rate of about 70 μGy/h, genotoxicity effects caused by gamma-radiation were observed for 72 and 96 h in the experiments with the Ames test and the SOS chromotest, respectively. In the first 24 h, a significant response of bacterial test systems was even detected at lower doses, about 3.0 μGy/h, but later in the experiment, no response to such doses was observed. The lower threshold levels of exposure doses that caused genotoxicity effects in bacterial tests and toxicity response in endpoints of elodea roots were the same (3 μGy/h). The threshold levels of exposure dose rates obtained in our experiments were several-fold lower than 10 μGy/h, which is accepted by the International Commission of Radiological Protection (ICRP) as the critical dose for discerning radiation effects on biota. For the first time, we revealed the effects of low doses of radiation on the living organisms used as bioassays in this study.

MOTILITY OF ESCHERICHIA COLI AFTER IRRADIATION WITH GAMMA-RAYS

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Escherichia coli can swim in liquid medium by rotating peritrichous flagella. The flagellar motors of E. coli are driven by the electrochemical potential of protons across the cell membrane. The electrochemical potential of protons is maintained by proton pumps in the electron transport chain, for which the metabolism of organic molecules supplies the electron donors. We examined the motility of E.coli irradiated with an accelerated proton beam (*Appl. Phys. Lett. 100, 193702*) and gamma rays (*Cent. Eur. J. Biol. 9, 909-914*), and found that the bacterial flagellar motor was robust against ionizing radiation at a dose sufficient to stop bacterial growth. This means that certain levels of enzyme activity are ongoing to maintain the metabolic network in cells after irradiation. In the present study, to estimate the durability of bacterial motility after irradiation, we investigated the swimming ability of gamma-irradiated cells after maintaining in non-nutrient motility medium for several hours at room temperature or in the refrigerator. Hence, the motility of the gamma-irradiated cells that showed no colony-forming ability lasted for more than 16 hours. Swimming speed and motile fraction were not significantly different between intact (unirradiated) and irradiated cells while they decreased gradually with incubation time. The cells stored in the refrigerator did not swim; however, they recovered their motility after reaching room temperature.

microRNA CARGO OF EXTRACELLULAR VESICLES IS ALTERED BY IN VIVO RADIATION AND CAN BE A MEDIATOR OF RADIATION-INDUCED BYSTANDER EFFECTS

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Radiation induced bystander effects (RIBE) are results of signals received by cells not directly hit by radiation from directly irradiated cells. Although RIBE are well known phenomena, the mechanisms governing them are still not entirely clarified. Extracellular vesicles (EVs) are small, membrane coated bodies released by the cells into extracellular medium. They participate in intercellular communication by carrying proteins and nucleic acids. The role of EVs in mediating RIBE has been raised by several recent *in vitro* studies but *in vivo* investigations are still lacking.

We investigated the role of EVs in mediating RIBE in the hematopoietic system *in vivo*. We irradiated C57Bl/6 mice with different doses of ionizing radiation, isolated EVs from bone marrow (BM) and injected them in the tail vein of unirradiated mice. The effect of EV transfer was studied by comparing molecular and phenotypic changes of BM cells, splenocytes and plasma of these bystander mice to the directly irradiated animals. DNA double strand breaks in splenocytes were measured by ⁄H2AX assay. While in directly irradiated mice the frequency of ⁄H2AX foci increased in a dose-dependent manner, in bystander mice ⁄H2AX foci were present after both low and high dose irradiation at almost equal levels. The cytokine profile of plasma, measured by cytokine array was altered in both directly irradiated and bystander animals. Phenotypical changes in both BM and spleen of bystander mice were present but restricted to certain cellular subpopulations

Total RNA was isolated from EVs derived from plasma and BM of directly irradiated mice. miRNA profiling was done from the total RNA isolated from EVs originating from irradiated mice. Changes were assessed by bioinformatical tools. Irradiation induced changes in the miRNA profile: 8 miRNAs were altered dose-dependently in both 0.1 and 2 Gy irradiated BM samples. Several pathways related to DDR and hematopoietic system were altered.

In conclusion, we showed that whole body irradiation of mice alters the miRNA cargo of EVs and that EV transfer to non-irradiated mice can mediate certain RIBE *in vivo*.

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LOCAL CRANIAL OR THORAX RADIATION-INDUCED NON-TARGETED EFFECTS IN BONE-MARROW-DERIVED ENDOTHELIAL PROGENITOR CELLS IN ApoE DEFICIENT MODEL

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The endothelial cells are always included in the radiation field during radiotherapy and their damage might be involved in the development of late radiation-induced sequels in elderly atherosclerotic patients. Given the importance of radiotherapy in the cure of malignant diseases, it is of pivotal importance to clarify how ionizing radiation influences the endothelial progenitor cell pools and endothelial cell regeneration. In this study we have compared the alterations in the circulating endothelial progenitor cell pool (EPCs) and in the serum level of growth differentiation factor-15 (GDF-15) in irradiated wild-type and atherosclerosis-prone ApoE knock-out (KO) mice. Mice received local cranial or thorax irradiation with different dose (0.1 Gy, 2 Gy, 10 Gy or 16 Gy) of X-ray, followed by the analysis of the bone marrow and blood plasma cellular fractions at different time points using FACS. Circulating EPC counts in the blood were higher after medium and high dose cranial irradiation in ApoE KO than in wild–type mice 24 h post-irradiation. However at later time points the mobilization of these cells has been observed only in the 10 Gy exposed groups. This suggests that the radiation caused vascular damage induced the acute mobilization of EPCs. The persistently elevated number of EPCs after irradiation with 10 Gy might suggest that late cerebrovascular damage might develop in these mice. GDF-15 levels, which are an emerging biomarker of cardiovascular risk and disease, in the blood of irradiated mice were elevated only in the wild-type mice at 24h after irradiation.

Local heart irradiation with 16 Gy also resulted in the elevation of both bone marrow and circulating EPCs in ApoE KO mice when compared to controls. Interestingly, this increase in the number of EPCs persisted even 6 months after irradiation. GDF-15 levels were elevated both in control and ApoE KO mice, but in the ApoE KO mice the GDF-15 concentration was still elevated at 6 months post-irradiation. The detected increase in the number of EPCs suggests that the tissue damage due to radiation exposure activates the stem cell niche and activates EPCs in the peripheral blood for angiogenesis. The association of GDF-15 with early EPC mobilization is novel finding and warrants further investigations.

THE POSSIBILITY OF USING NOS INHIBITORS AS RADIOPROTECTIVE AGENTS AND IN THE THERAPY OF COMBINED RADIATION INJURIES

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At the present time, the ionizing radiation is an inherent part of human life. In this connection, there is the risk of radiation accidents, accompanied by explosions, fires and radionuclide emissions. Emergencies peacetime and wartime are dangerous not only due to radiation exposure, but also thermal burns, mechanical and chemical influences. Each of these component significantly burdens manifestations of acute radiation sickness, and increases the likelihood of fatalities. Our medical research center, A. Tsyb MRRC, has extensive experience research in the province of searching tools therapy of combined radiation-thermal injuries (CRTI). Recently, we have obtained our own data about the high efficiency of NOS-inhibitors from the class of N, S-of substituted derivatives of isothiourea, both as radioprotectors, and as radiomitigators, that suggests its high perspective in the treatment of combined radiation, in particular radiation-thermal injuries .

The investigations have been done in male mice F1 [CBA×C57BL6j], 12 animals per group. Mice exposed to lethal doses of 6 Gy and 10 Gy γ-radiation of ^{60}Co at a dose rate of 0.4 - 0.8 Gy/min. Combined injury included total body γ - irradiation at a dose of 7 Gy and III B degree thermal burn of 10 % body surface with the aid of powerful flash light. Mice of experimental groups were injected with NOS inhibitors at doses of 1/8 - 1/2 LD_{16}. The effectiveness of NOS inhibitors were studied using 30-day survival test and survival of endogenous colony-forming cells in the bone marrow.

Research results of radioprotective properties of NOS inhibitors have shown its high efficiency (60-75% survival) in relatively low doses (1/8 LD_{16}). Moreover, the use of NOS inhibitors before the radiative forcing 3-3,5 times increased the survival of hematopoietic colony-forming cells in the bone marrow.

On the model of combined radiation-thermal injuries we demonstrate that the use of NOS inhibitors after 5 minutes and 4 hours after the combined injury increased the survival of animals to 90-100%, whereas in the control group the survival rate was only 20%. The use of NOS inhibitor after the combined radiation-thermal injury 15-30% increased the survival of hematopoietic colony-forming cells in the bone marrow.

These studies have shown high promise NOS inhibitors as radioprotective tools and treatments of combined radiation-thermal injuries.

THE INVESTIGATION OF THE OUTCOME OF CYTOGENETIC EFFECTS IN ONCOGYNECOLOGICAL CANCER PATIENTS UNDERGOING EXTERNAL AND INTERNAL RADIOTHERAPY

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The investigation of the cytogenetic effects in peripheral blood lymphocytes of cancer patients is an important task in the development of radiobiological basis of radiotherapy. In order to estimate the risk to health resulting from medical irradiation, it is necessary to evaluate the mechanisms of fractionated partial-body radiation action at chromosomal level.

Chromosome and chromatid type aberrations were analyzed in lymphocytes of 26 radiotherapy patients with uterine body cancer divided on three groups depending on radiotherapy regimen: external, internal and combined irradiation. Blood sampling was performed before treatment, at the middle and at the end of radiation therapy course. Lymphocytes were cultivated by conventional technique, FPG-staining control of cell division was applied.

The aim of the study was to assess the cytogenetic effects in lymphocytes of cancer patients following external and internal radiation treatment, depending on the exposure regimen.

It was shown the excess of chromosomal exchanges before treatment over spontaneous level in all groups of patients. The different character of chromosomal type aberrations accumulation in groups of patients depending on the various exposure regimen was found. The monotonic increase of radiation-induced aberrations from beginning to end of treatment in groups of patients following external and combined irradiation and less pronounced changes in these parameters in patients during internal irradiation was demonstrated and the pace was different depending on radiotherapy regimen. Thus at the middle of radiotherapy course the ratio of mean unstable chromosome type aberrations levels was 1 : 0,96 : 0,18 for patient groups during external, combined and internal irradiation, and at the end of the course – 1 : 0,86 : 0,12 respectively. The distribution of the dicentrics 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 frequency of chromatid type aberrations did not depend on dose or regimen of exposure. The correct assessment of the impact of therapeutic irradiation on normal cells at the chromosomal level will be discussed.

CHANGES IN BLOOD CELLS, MICRONUCLEI AND 8-HYDROSY-2'-DEOXYGUANOSINE IN HOSPITAL WORKERS OCCUPATIONALLY EXPOSED TO IONIZING RADIATION

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The health risk of chronic occupational exposure to low doses of ionizing radiation (IR) can includes changes in the genome that increase chromosomal instability as one of the main forces driving the onset and progression of carcinogenesis. To estimated risk for professionally exposed healthy workers to ionizing radiation, various methods were used until today. Therefore, the aim of this study was to determine changes in blood cells count, the level of DNA damage in blood and urine from 200 hospital workers professionally exposed to low-doses of ionizing at the Institute for Oncology and Radiology of Vojvodina. Subjects were exposed to one of the sources of radioactive radiation for the purpose of medical treatment or during diagnosis performance at various departments. The blood cells subsets are analyzed by classical method including determination of the number of leukocytes, lymphocytes and the rate of sedimentation. The frequency of micronuclei (MN) were analyzed by cytokinesis-block peripheral blood lymphocytes, while level of urinary 8-oxo-7,8-dihydro-2'deoxyguanosine (8-OHdG) was analyzed by the ELISA system.

The results show that there is a significant difference in the blood count and values of MN significantly depending on department (the type of radiation sources which are exposed to health workers). The biggest changes have been observed in workers in the department of radiology, bronchoscopy, and gynecology. When we look at all the subjects together, found a statistically significant positive correlation with the length of service to the hospital and increasing MN. The regression model showed that with the increase in length of service (length of exposure) changes occur mostly in micronuclei ($P < 0.0005$, RSquare = 0.326). The regression model also suggests that at the same values of other parameters including blood count, with each year of service at the exposed leads to an increase in MN increases for 0356. Results also showing increase the level of 8-OHdG in the exposed group, but non-significant difference in values, depending on the departments. 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 Based on results and literature data it is possible to conclude that combining of measuring DNA damage in blood by MN test simultaneous with 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.

RADIOMODIFICATION OF CELL CULTURES OF LINE HELA BY CERIUM OXIDE NANOPARTICLES TO X-RAY IRRADIATION

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Postradiation complications that appeared after radiotherapy are considered the most serious problem in the treatment of various types of cancer diseases. Therefore, research of radiomodification properties of nanoparticles are high relevant. The aim was to study the biological activity of cerium oxide nanoparticles (CONP).

CONPs were obtained by pulsed electron beam evaporation in the low gas pressure on installation NANOBIM-2 [1]. A feature of this method is the preparation of nanoparticles with a large number of structural defects of various kinds, which gives them the unique physical properties, and allows expecting a high biological activity [2]. Solution of CONPs was introduced into normal breeding medium of the cells cultures in Petri dish to a concentration of 50 - 500 μg/ml. To stabilize the CONPs we used sodium citrate. Samples were irradiated on arrangement Xstrahl 300 with 200 keV energy of X-ray after three days CONPs have been added. The samples were irradiated to absorbed doses of 5, 7.5, 10 Gy. To control absorbed doses we used the DTG - 4 thermo luminescent dosimeters (LiF). Analysis of biological response was performed using Goryaeva chamber and the MTT test. The results allow us to make preliminary conclusion that the early adding low concentrations (up to 50 μg / ml) of CONPs increase the sensitivity of cancer cells line Hela to radiation. Thus, the CONPs could be universal radiomodifiers to radiotherapy and their properties require subsequent studies.

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APPEARANCE AND RESUSCITATION OF VBNC BACTERIA INDUCED BY DIFFERENT FACTORS

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Introduction: Viable but nonculturable (VBNC) bacteria are formed under stresses (gamma-radiation at dose 0.5-2 kGy and UV-radiation at dose about 300 mJ/sm², starvation, oxigenization, temperature, osmotic pressure etc.) [Saroj S. 2009, Shenghua Zhang 2015, Xu H. 1982, Trainor V.C. 1999, Besnard V. 2002, Oliver J.D. 2005]. Bacteria in VBNC state can't generate colonies (CFU/ml). VBNC cells remain alive and have dormant capacity to metabolic activity. Cells can return to proliferation after the appropriate induction. Bacteria in a VBNC state may be resuscitate with help serum, aminoacids, vitamin K, blood-substitute etc. [Oliver J.D. 1995, Whitesides M.D. 1997, Pakhomov Yu.D. 2013, Blinkova L.P. 2016]. The presence of VBNC bacteria in food, water, soil, organisms etc. may significantly reduce the total number of pathogens, i.e., there is a danger of infection. Thus, it's necessary to study formation VBNC state and reversion cells. It was the aim of our work.

Materials and Methods: We used probiotic and opportunistic bacteria: The starvation was the main stress factor. For this purpose the strains were inoculated in minimal media. Monitoring was performed in period up to 1 year. The live and dead cells were counted under luminescent microscope after staining with Live/Dead. VBNC value was determined by using total, alive and CFU/ml number. Statistical reliability of the date was at the level £0.05. The inactivated homologous strain biomass and aminoacids were applied as the factors of resuscitation. Control - culture liquid without supplements.

Results: VBNC cells of opportunistic strains formed with the first days of incubation. After 1 year of incubation *Klebsiella pneumoniae* 1954, *Alcaligenes faecalis* 415, *Enterobacter aerogenes* 418, *Proteus vulgaris* HX19222, *Salmonella Typhimurium* value VBNC values were statistically equal (97.1 - 99.9%).The probiotic *Lactococcus lactis* (3 strains) after 1 day of stress didn't form colonies up to 60-80%, after 5 days to 82.1 - 99.6%, after 1 year – 99,9%. Unwashed from the culture fluid the inoculated cells proliferated and passed to VBNC faster. With that inoculation the nisin productive activity of cells was lower at 10 - 78 times, depending on strain of *L. lactis*. The study of resuscitation factors have shown that supplement of homologous inactivated biomass of *L. lactis* (0.1%, 0.5%, 1%) was effectively with 1% (a magnification of 2.65 at $p<0.05$) and 0.5% (magnification of 3.75 at $p<0.05$) only for strain MGU. For strain *S. lactis* F-116 marked 4-fold increase in the ability to the cultivation after the addition of 7 aminoacids: (glutamine, methionine, leucine, isoleucine, histidine, arginine, valine).

Conclusion: The quantitative level of VBNC cells, which formed in the first days of incubation, after 1 year was the same for opportunistic and probiotic cultures (97.1% - 99.9%). All studied resuscitation factors were individually effective for bacterial strains.

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CONVERSION OF OXYGEN-CONTAINING COMPOUNDS OF Sr, Mo, Zr, AND U(VI) IN NITRATING MEDIA

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One of the promising technologies of short-cooled spent nuclear fuel (SNF) reprocessing is voloxidation (volume oxidation). The SNF oxidative recrystallization (voloxidation) process is considered to be a promising trend for modification of the head operations of the Purex process. This method allows not only removing volatile fission products, such as Xe, Kr, and ^3H, virtually in full during UO_2 conversion into U_3O_8, but also carrying out the embrittlement of zirconium alloy shells of fuel elements by transforming metal Zr into powder ZrO_2. The most promising development of the above-mentioned oxidative recrystallization method is treatment of the oxidation products with nitrogen oxides to obtain water-soluble fuel components and fission products, rather than dissolution of the oxidation products in nitric acid. After voloxidation, U(VI), Sr, and Mo may occur in SNF as not only oxide phases, but also as other compounds. According to literature data, U, Sr, and Mo can be present in SNF as $UMoO_x$, $SrUO_4$, and $SrMoO_4$. Therefore, the aim of this work was to check experimentally the possibility of the gas-phase conversion of U_3O_8, MoO_3, SrO, and their mixtures, ZrO_2 and the above-mentioned compounds of U, Mo, and Sr in nitrating media into water-soluble compounds.

The U_3O_8, MoO_3, SrO oxides and their mixtures, ZrO_2, $UMoO_x$, $SrUO_4$, and $SrMoO_4$ were kept for 1 to 12 days at room temperature (20-25°C) or at a temperature of 130 to 150°C for 3-5 h in the atmosphere of (NO_x + vapor H_2O) or HNO_3 (vapor). The powder diffraction patterns of the resulting compounds were obtained, and the solubility of the compounds in water was measured. The U(VI) content in the aqueous phase was measured using spectrophotometric analysis, content of Sr, Mo and Zr - using ICP mass-spectrometric method. The phase composition of the resulting conversion products was determined using X-ray powder diffraction analysis.

The research has found that depending on the conditions of the experiment, the gas-phase conversion process in nitrating media leads to a virtually full conversion of U_3O_8 and SrO into water-soluble compounds, whereas MoO_3 and ZrO_2 do not suffer any changes. The possibility of separating U_3O_8 from MoO_3 and ZrO_2 by gas-phase conversion in nitrating media has been established.

The gas-phase treatment of $UMoO_x$ leads to formation of new phases. Uranium partially converts to water-soluble compounds, whereas Mo remains in the insoluble phase virtually fully. For $SrUO_4$, a complete conversion of the compound takes place, with both U and Sr taking insoluble forms. Gas treatment of $SrMoO_4$ does not lead to the conversion of the compound, and Sr and Mo remain insoluble. Thus, in contrast to U, Mo, and Sr oxides, the gas-phase conversion of their compounds in nitrating media does not allow carrying out a complete separation of U from Mo.

THE DEVELOPMENT OF THE LIQUID CHROMATOGRAPHY PROCESS FOR THE SPENT NUCLEAR FUEL REPROCESSING TECHNOLOGY

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The principal hydrometallurgical schematic of spent nuclear fuel (SNF) reprocessing accepted nowadays consists of the process stages in which all mass-transfer interactions are carried out using conventional equipment that provides mixing of the contacting phases to form an emulsion and their subsequent gravitational segregation. However, at the stages of U-Pu extract washing, separation, final uranium extract purification where it is necessary to remove trace amounts of the impurities, significant amounts of water streams to provide the mass-transfer process are required. The volume of these streams subsequently becomes a liquid radioactive waste (LRW). The reducing of the waste solutions volume (analogs of washing solutions in a classic PUREX-process), that corresponds to minimizing of the liquid radioactive waste volume in the general spent nuclear fuel recycling process, based on the use of alternative mass-transfer process - liquid chromatography (LC). In the LC process a much less volume of an aqueous solution is used at a ratio of extract flow/aqueous solution flow from 40 to 100.

The LC process is proposed to be implemented in the column unit (LCC) with a highly porous granular packing saturated with an aqueous purifying solution. When the extract passes through the column, the re-extraction of separable impurities into the aqueous phase containing in the packing pores occurs. As the extract passes through the LCC there is a constant contact with a fresh reducing solution.

The search and study of possible porous inert granular materials for the LC column packing were carried out. Uranium-plutonium extract purification in the simulating SNF reprocessing process was carried out. The dynamic experiments on a laboratory glass column packed with a porous granular high surface material were successfully performed, and the effectiveness of the purification process was evaluated. On laboratory LCC a series of dynamic experiments were carried out in order to obtain the original data for the pilot unit design. Electrical harness of the LCC assembly by control and measuring devices was designed and tested. At the refinery testing facility of the pilot demonstration complex at the JSC "SCC" site the main SNF reprocessing cycle which includes two LC assemblies each consisting of two columns was tested on uranium and plutonium solutions.

PERFORMANCE CHARACTERISTICS OF A SORBENT BASED ON TITANIUM PHOSPHATE IN LIQUID RADIOACTIVE WASTE TREATMENT SYSTEMS

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Liquid radioactive wastes (LRW) are multicomponent solutions containing elements of all groups of the periodic table. Alkali and alkaline earth metal ions get into LRW with technical water and reagents; 3*d*-metal ions are present as products of corrosion of structural materials. The major radionuclides determining the biological hazard of LRW, namely, fission products ^{90}Sr and $^{134,137}Cs$ and activated corrosion products ^{54}Mn and ^{60}Co, belong to the same metal types. They are present in incommensurably smaller amounts than their chemical analogs. Methods of solution decontamination via precipitation or coagulation followed by filtration do not allow the concentrations of nonferrous metal ions, and hence of their radioactive analogs, to be reduced to the levels required of wastewaters or process solutions. Furthermore, introduction of excess precipitants in some cases negatively affects the quality of process flows. Therefore, to attain the required decontamination level, it is necessary to develop schemes with ion exchangers exhibiting group selectivity to chemical analogs. Among such materials are metal(IV) phosphates, in particular, titanium phosphates. Their high selectivity is ensured by phosphoryl oxygen atoms whose lone electron pairs are capable of interacting with unoccupied orbitals of 3d metals. This study deals with sorption properties of commercially produced sorbent based on amorphous titanium hydroxophosphate $Ti(OH)_{1.2}(HPO_4)_{1.28}(H_2PO_4)_{0.24}{\cdot}2{,}5H_2O$.

The sorption isotherms of the metal cations studied are described by Langmuir isotherms taking into account the difference in the charge of the exchanging ions. With respect to the distribution coefficient, the ions can be ranked in the following order: $Mg^{2+} < Ca^{2+} < Mn^{2+} < Ni^{2+} < Zn^{2+} < Cu^{2+} < Co^{2+< /\mathrm{co}}$. It was found that radionuclides of corrosion nature (^{54}Mn, ^{60}Co) are efficiently removed even at high electrolyte concentrations, which may be due to fixation of nonferrous metal ions in the sorbent phase predominantly in the form of weakly dissociated complex species. Redistribution of ions between different forms in the sorbent will lead to a decrease in the fraction of the sorbate ionic species relative to the equilibrium value, favoring an increase in the dynamic exchange capacity relative to *s*-metal ions. It is this fact that makes the titanium phosphate-based inorganic exchangers versatile materials for treatment of LRW of irregular composition.

REAGENTLESS CATALYTIC OXIDATION OF ORGANIC DERIVATIVES OF HYDRAZINE AND Pu (III) WITH NITRIC ACID

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In the technological recycling scheme of high-burnt irradiated nuclear fuels that is being developed, before the extraction stage the organic reductant that is used during the previous stage needs to be decomposed, and Pu(III) should be oxidized to Pu(IV). For this, a reagentless method of oxidation using a carbon catalyst was proposed, and a search of different types of granulated carbons with stability in nitric acid environments, stability under high doses of ionizing radiation, high porosity in internal surfaces and resistance to physical deformation was performed.

Carbon catalysts were tested in nitric acid of 2-4 M, 25-50° C and different ratios of solid to liquid. After several static experiments with several types of granulated carbon catalysts (OS-3, SKNO(VP), AG-3,VNIITU-1), carbon used for hemosorption was chosen (VNIITU-1). In equal conditions, these carbon types may be sorted according to the rate of decomposition of our organic reductant as follows: OS-3 < SKNO(VP) < AG-3 < VNIITU-1. It should be noted, that increasing the acidic concentration increases the rate of decomposition of the reductant for all types of granulated carbons, but to differing degrees.

Dynamic experiments on test solutions of Pu(III) were performed in laboratory scale plant. The organic reducing agents used in the experiments were diformylhydrazine and carbohydrazide. During the experiments, evolution of a colorless gas is observed, proving the existence of a decomposition process. Spectrophotometric analysis of the samples showed a complete oxidized of Pu(III) to Pu(IV), which also confirms the absence of reducing agents in the solution.

Optimal quantities of nitric acid concentration and temperature were chosen for conducting the pilot decomposition in a nonstop test unit.

DISSOLUTION OF URANIUM AND NOBLE METALS INTERMETALLIC COMPOUNDS IN NITRIC ACID SOLUTIONS

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Thermo-dynamic calculations of chemical and phase composition of spent mixed uranium and plutonium nitrides nuclear fuel have showed the noble metals (Pd, Ru, Rh) and actinides intermetallic compounds as a most stable phase. The recycling of actinides and their deep recovery (> 99,9 %) are necessary for decreasing of amount control storage time of radioactive waste. The knowledge of noble metals (Pd, Ru, Rh) and actinides intermetallic compounds metal behavior in nitric acid solutions is necessary to development of mixed nitrides spent fuel dissolution.

Noble metals and uranium intermetallic compound (UPd_3, URh_3, URh_3) were prepared of melting U and noble metals in stoichiometric ratio in an high purity helium medium. An induction furnace with beryllium oxide crucible was used. One homogeneous e phase in prepared samples were determined by X-ray.

UPd_3, URh_3, URh_3 samples were crashed for particles less than 0.5mm by ball mill. The dissolution of crashed samples was performed under boiling temperature with steering. Nitric acid solutions with different concentration were used.

It was showed, that UPd_3, URu_3, URh_3 dissolution degree increases with increasing of nitric acid concentration. The highest tested concentration of nitric acid (8M) allowed to dissolve 75.5, 59.5 and 4.74 % of UPd_3, URu_3, URh_3, respectively, during 6 hours. Dissolution rate is increases in the order UPd_3>URu_3>URh_3.

Sodium fluoride was added to the nitric acid solution for an increase of dissolution degree. An increase of fluoride-ion concentration increases dissolution degree same as an increase of nitric acid concentration. 5.8 M nitric acid containing 1 g/l of fluoride-ion dissolves 98.5% of UPd_3. However 7.9 M nitric acid in a presence of 5 g/l fluoride-ion dissolves only 6.5% and 26% of URu_3 and URh_3, respectively.

Insoluble residue was enriched with ruthenium and rhodium, due to leaching of uranium noble metals and uranium intermetallic compounds. The lack of Ru in residue and in solutions shows that Ru partially volatilized as RuO_4. The black precipitate on reflux condenser confirms this guess.

KINETICS OF THE INTERACTION OF Pu(VI) AND Np(VI) WITH CARBOHYDRAZIDE IN NITRIC ACID SOLUTIONS

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During the development of new hydrometallurgical technologies of spent nuclear fuel processing, different organic reducing agents (substituted hydrazine, hydroxylamine and urea, oxime and others) are suggested for use in the extraction of plutonium and neptunium and their subsequent treatment. One of the most promising agents is carbohydrazide, a derivative of hydrazine and urea. When the SNF is dissolved in nitric acid, the neptunium components are oxidized to Np(VI), and the plutonium components form Pu(IV) and Pu(VI). These valent forms are a high-extractive tributyl phosphate. To control the re-extraction process of plutonium and neptunium, it is necessary to know the rate at which their reaction with a reducing agent passes. Carbohydrazide recovery kinetics of Pu(VI) and Np(VI) in an aqueous nitric acid solution was researched spectrophotometrically.

Regarding Pu(VI), it was established that in the intervals of $[HNO_3]$ = 0.75-3.0 M and $[CO(N_2H_3)_2]$ = 0.1-0.4 M, the reaction rate is proportional to the concentration of Pu(VI). Reaction order relative to Carbohydrazide is determined to be 2.3, and -3 to nitric acid. The activation energy of the reaction was specified at 111 $kJ \cdot mol^{-1}$.

Regarding Np(VI), it was established that in the intervals of $[HNO_3]$ = 0.75-3.0 M and $[CO(N_2H_3)_2]$ = 0.03-0.12 M, the reaction rate is proportional to the concentration of Np(VI). Reaction order relative to Carbohydrazide is determined to be 1.15, and -1.35 to nitric acid. The activation energy of the reaction was specified at 85 $kJ \cdot mol^{-1}$.

Based on this kinetic data, a possible fundamental reaction mechanism was theorized.

A WAY TO INCREASE THE ^{18}F-FDG YIELD ON A "DOSE ON DEMAND"® CYCLOTRON BY OPTIMIZING THE SYNTHESIS TIME

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2-[18F]fluoro-2-deoxy-D-glucose ([^{18}F]FDG) is the most commonly used radiopharmaceutical in clinical molecular imaging. The process of FDG synthesis is under constant development to optimise and increase yields.

Aim: Review of [^{18}F]FDG radiopharmaceutical production with ABT cyclotron and radiochemical module.

Materials and methods: The ^{18}F radionuclide we work with, is the product of a ^{18}O (p, n)^{18}F nuclear reaction by irradiation (30-45 min) of enriched [^{18}O]H_2O. Our process of choice for FDG production is fluorination using mannose triflate as precursor and Kryptofix because of the proven high yields and short reaction time. Synthesis itself is achieved by nucleophilic substitution and acid hydrolysis with passive cooling (air at room temperature) or an active one (CO_2 gas).The quality of each dose is checked by an automatic quality control (QC) system and 4 manual QC tests. The QC module automatically performs pH determination, residual solvents (acetonitrile and ethanol), radiochemical identity/purity, Kryptofix 2.2.2. determination, and filter integrity test.

Results: We have observed a difference in dose activity when using the two different types of cooling. Between 10 and 16 mCi with passive cooling and 14 and 26 mCi when using active CO_2 cooling. The heightened dose activity is a result of cutting the overall synthesis time.

Conclusions: Active CO_2 gas cooling leads to shorter synthesis times and higher yields without affecting the quality of the end product [^{18}F]FDG.

Keywords: [^{18}F]FDG, Radiopharmaceuticals, PET/CT biomarkers, [^{18}F]FDG synthesis

RADIOIODINATION AND IN VITRO EVALUATION OF PHENOLIC PHYTOCHEMICALS IN CLOVE EXTRACT

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Phenolic phytochemicals are a broad class of nutraceuticals found in plants which have been extensively researched by scientists for medicinal potential. Clove is one of these potential plants.

Clove includes some essential oils such as eugenol, caryophyllene, alpha-humulene, alpha-terpinylacetate, eugenyl, methyleugenol, actyleugenol, naphthalene, chavicol, heptanone, sesquiterpenes, methylsalicylatepinene and vanillin. Eugenol (EUG), which is main compound of clove, is a phenolic natural compound available in the essential oils primarily extracted from clove plants.EUG has been exploited to various medicinal applications. It possesses antioxidant, antimutagenic, antigenotoxic, anti-inflammatory and several anticancer properties. Additionally, there are researches which have shown that the active matter in clove, EUG, provides analgesic, anticarcinogenic and antioxidant features of it. Likewise, clove has been used as home-made remedy for centuries by common folks.

The objective of current study is radioiodination of EUG isolated from clove extract and evaluation of its *in vitro* potential on adenocarcinoma cell lines.With this purpose clove was extracted, EUG was isolated from clove extract and EUG is radioiodinated. After these steps, potential of radioiodinated EUG (^{131}I-EUG) was investigated on human colonic carcinoma cell lines (Caco2), human breast adenocarcinoma cell line (MCF7) and human prostate cancer cell line (PC3) adenocarcinoma cell lines.

Clove was extracted and EUG which is one of the active ingredients in clove extract, was isolated by High Performance Liquid Radio Chromatography (HPLC) method. Structural analysis of EUG was confirmed by Liquid Chromatograpy Mass Spectroscopy (LC-MS). As follows, EUG was radioiodinated (^{131}I-EUG) with iodine 131 (^{131}I) by utilizing iodogen method. ^{131}I was preferred because of its well known properties for both imaging and therapy in Nuclear Medicine. The radiolabeling yield of ^{131}I-EUG was calculated by Thin Layer Radio Chromatography (TLRC) method. Additionally, lipophilicity and stability studies of ^{131}I-EUG were performed. Furthermore, efficacy of radioiodinated EUG was examined on different cancer cell lines. Time dependent (60, 120 and 240 min.) incorporation of ^{131}I-EUG and ^{131}I on cell line Caco2, MCF7 and PC3 were investigated.

It was seen that EUG was radiodinated in high yields (% 98.59±1.02) and its stability was appropriate during the study period. Radioiodinated EUG was more lipophilic than EUG.

The half maximal inhibitory concentration (IC_{50}) values which express the influence of a compound on inhibition of biological function were determined for EUG on Caco2, MCF7 and PC3 cells. It is seen that EUG has higher IC_{50} on MCF7 cell line than PC3 and Caco2. Incorporation studies were designated that EUG has considerably high uptakes in Caco2, MCF7 and PC3 cells.

Consequently, it is observed that plant oriented radioiodinated EUG would have potential on therapy and imaging due to its notable uptakes on studied cells. Furthermore, *in vivo* studies should be performed to promote current results of present study.

ISOLATION AND RADIOLABELLING OF GINGER COMPONENTS: 6-GINGEROL AND 6-SHOGAOL

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Use of plants in the treatment of many diseases is increasing day by day. There are several plants that can be used for almost every type of disease diagnosis and treatment. Nowadays, *Zingiber officinale Roscoe* which is called ginger is one of the plants and its family is *Zingiberaceae*. Ginger is a spice used in foods and beverages.

Today, one of the known positive effects on healthy eating plant *Zingiber officinale Roscoe*, *Zingiberaceae* family is from the ginger plant which is widely known. It is reported that ginger supports the programmed cell death called apoptosis. As a consequence of that; it is protective against cancer and it could be used for therapeutic purposes. Main bioactive components of ginger are 6-gingerol (6G), 8-gingerol (8G), 10-gingerol (10G), and 6-shogaol (6S). In the literature, several researches emphasized that 6-gingerol and 6-shogaol as the most active bioactive components of ginger thanks to their potential in conducted studies.

In present study, it is aimed to extract the two most active bioactive components of ginger and to radioiodinate them for investigation their radiolabeling potential as novel agents in Nuclear Medicine. With these objectives, ginger roots were extracted. Fresh ginger roots were utilized for extraction. It is known that fresh ginger includes much more 6-gingerol. However, dry ginger contains more dehydrated 6-gingerol (which means that the dry ginger has more 6-shogaol). This is why we preferred to extract fresh ginger. As a result of extraction process; 6G was purified using the fraction collector in high performance liquid chromatography (HPLC) system. Then, the dehydration process was performed starting from purified 6G and 6S achieved by success. 6S was also purified using HPLC system. Liquid Chromatograpy Mass Spectroscopy (LC-MS) was utilized to structural analysis for both isolated component of ginger. Isolated components 6G and 6S were radiolabeled with iodine-131 (^{131}I) which is a convenient radioisotope for therapy including imaging potential.

The purified 6G and 6S components were radioiodinated using iodogen method. The radiolabeling yields of ^{131}I-6G and ^{131}I-6S were determined by Thin Layer Radio Chromatography (TLRC). Additionally, stability and lipophilicity studies of radioiodinated components were carried out.

Radiolabeling potentials of the most active bioactive components (6G and 6S) of ginger were investigated in present study. Both components were radiolabeled in high yields. Further *in vitro* and *in vivo* studies should be performed to promote current results to suggest these components as potential agents for cancer diagnosis and treatment.

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EFFECTIVE STATES OF HEAVIEST ATOMS IN COMPOUNDS: LOCAL AND GLOBAL APPROACHES

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The concept of effective states (effective electronic configurations) of atoms in compounds plays a key role both in representing the results of electronic structure modeling in conventional "chemical" language and in the interpretation of the data obtained by numerous non-destructive experimental techniques, including X-ray and Moessbauer spectroscopy. Strong spin-dependent relativistic effects in heavy element compounds which manifest themselves as large spin-orbit splitting of atomic levels imply the description of effective atomic states in terms of relativistic configurations, discerning the fractional populations of valence subshells with the same orbital angular momentum (l) and different total angular momenta (j). There are at least two main general approaches to determine such configurations of heavy atoms in compounds. The most common approach is based on the analysis of global molecular one-electron density matrices, using some pre-chosen reference atom-centered spinors to separate the atomic contributions to these entities. An alternative strategy, employing our new Atoms-in-Compounds (AiC) theory, consists in the local analysis of molecular density matrices in the vicinities of heavy nuclei through simulating their basic features in the fractional-occupancy calculations of the corresponding free (or confined in a spherical cavity) heavy atoms. In contrast with the case of common global analysis, the resulting configurations are directly related to certain measurable (spectral) characteristics of the compounds, namely, to those associated with the effects and processes localized in the core domains of heavy atoms, such as the positions of X-ray emission lines. A series of applications of the "local" (AiC-based) method and the "global" one (projection analysis technique which we have modified to avoid the dependence on the reference atomic configuration) to simple compounds of several transuranium elements is presented. The results of "global" and "local" effective configuration analysis are qualitatively consistent. The difference in populations of valence subshells with the same l and different j is demonstrated to be essential for understanding the peculiarities of chemical bonding in transactinide compounds, for instance, in those of Cn, Nh and Fl. In contrast, similar effects in actinide compounds seem not to be of crucial importance, thus partially justifying the use of scalar relativistic models neglecting spin-dependent interactions in intermediate-accuracy computational chemistry of actinides.

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COLUMN STUDIES OF STRONTIUM ADSORPTION BY ZIRCONIUM-ANTIMONY OXIDE/PAN COMPOSITE

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Zirconium-antimony oxide/PAN composite spheres were synthesized and characterized. Adsorption behaviors of synthesized material towards strontium were analyzed via column technique using experimental design approach. The effect of basic parameters on strontium adsorption such as flow rate, initial strontium concentration and bed height were investigated and the surface graphics showing the strontium adsorption dependency to the related parameters were constructed. As a result of the experimental studies, the maximum adsorption yield was obtained at a flow rate of 0.2 $mL.min^{-1}$, initial strontium concentration of 10 ppm and a bed height of 9.0 cm. The breakthrough graph of zirconium-antimony oxide composite spheres towards strontium was drawn and analyzed. The breakthrough and saturation points (t_b and t_s (min.)) of the column and the related capacities (q_b and q_s($mg.g^{-1}$)) were calculated.

Key words: Zirconium-antimony oxide, polyacrylonitrile, composite, Box-Behnken, strontium

DETERMINATION OF ^{90}Sr IN ENVIRONMENTAL SAMPLES – COMPARISON OF TWO METHODS

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The aim of this work is to present a newly introduced in Radiation Protection Measurements Laboratory (LPD) at the National Centre for Nuclear Research (NCBJ) strontium determination method based on extraction chromatography using Sr Resin (Triskem Int.) and ^{85}Sr as a yield tracer. The developed method has been compared to routinely used in our laboratory method based on liquid-liquid extraction with 5% HDEHP (bis-2-ethyl-phosphoric acid) solution in toluene.

Radiochemical analyses of ^{90}Sr activity in environmental samples are important due to high radiotoxity of strontium, its chemical similarity to calcium which enables easy incorporation into the body (skeleton) and its relatively long physical and biological half-life.

In Radiation Protection Measurements Laboratory strontium is being determined in various environmental and technological samples as well as in urine samples. Routinely used for the purpose of these determinations method is indirect (yttrium activity is being measured) and it does not allow to use yield tracer, therefore determination of chemical recovery is tedious and requires performing a series of analyses.

In this paper both methods have been described and compared. Water and milk samples were investigated. For the introduced method of strontium determination by extraction chromatography the applied procedure involved following stages: co-precipitation, mineralization, strontium separation with Sr Resin chromatographic column, tracer recovery determination by gamma spectrometry measurement, measurement in liquid scintillation counter Perkin Elmer Tri-Carb 2900 TR (Ultima Gold AB scintillation cocktail was applied) after 21 days when Sr-Y equilibrium is established.

Laboratory performance in strontium determinations (by the use of routine liquid- liquid extraction method) is regularly verified by participation in interlaboratory comparisons organized by Polish regulatory body – National Atomic Energy Agency. Selected results of these comparisons have been presented in this paper.

Additionally, accuracy of the developed method of strontium determination (based on extraction chromatography) was tested by conducting separate analyses of the samples derived from these comparisons. The samples were used as reference material. Obtained results have been presented and discussed.

Conducted studies have shown that the developed method of strontium separation by extraction chromatography is applicable to determinations in water and milk samples and might be used as an alternative for the routinely used method.

MANGANESE AS AN ORIGIN INDICATOR OF ILEX PARAGUAYENSIS SH FROM PARAGUAY BY EDXRF AND INAA

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Yerba mate, *Ilex paraguayensis*, is a plant of Paraguayan origin used in infusions/macerations by the ancient inhabitants of Paraguay as a “reviver”/energy beverage and mineral supplier which consumption is lasting up today; furthermore, it is extended almost worldwide. It has been recognized in *Ilex paraguayensis,* diuretic, CNS stimulant, hypocholesterolemic, hepatoprotective as well as other pharmacological properties. In regard to its elemental content few studies are known despite they play fundamental tasks in the structure and functioning of plants. One of them, Mn usually occurs in *Ilex paraguayensis* as a trace, at relatively high concentration and in this work its concentration in plants from Paraguay have been investigated by EDXRF at Josef Stefan Institut at Ljubljana using radioactive isotopic sources and by INAA technique in the Faculty of Chemistry at Asunción with an Am-Be neutron source. These plants are grown mainly in two regions, north and south of Eastern Paraguay and results show that their manganese content can be used as a geochemical indicator to identified their origin.

STABILITY OF ASTATINE - CARBONE BOUNDS IN COMPOUNDS WITH SMALL BIOMOLECULES

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Astatine-211 is an α-emitter with a short half-life. Its compounds with cell-specific molecular targets offer the exciting prospect in the α-particle targeted radiotherapy of human disease. Broad application of ^{211}At in radiotherapy will require its attachment to disease-targeting carrier molecules.

The nature and stability of that attachment in compounds with small biomolecules in gas phase is the focus of this report. The use of At-labeled small biomolecules for targeted radiotherapy is attractive as they can distribute and localize to diseased areas very rapidly, matching the pharmacokinetics of the targeting agent with the short half-life of ^{211}At. Due to the quantities required by standard spectroscopic tools, they are unsuitable to obtain structural information on astatine compounds; “direct” identification of these compounds is therefore practically impossible. Molecular modeling is thus of crucial interest to help in identifying astatine species.

Relativistic effects can be as important as the electron correlation and can largely influence the properties of astatine compounds. Even though astatine is a halogen, its chemistry is quite different from its nearest halogen neighbor, iodine. Note that the information on the bonding type is essential to sharpen up our chemical intuition on the astatine chemistry, that is, on the reactivity and the properties of its basic chemical forms. Computational studies are thus particularly indicated to guide the design of new labeled molecules for nuclear medicine.

In this report results of computations for compounds of astatine with The amino acids tyrosine, phenylalanine and histidine are presented. The calculations were performed within the two-component shape-consistent small-core pseudopotential model and employed the non-collinear version of relativistic density functional theory to treat electronic correlations.

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IMPROVED RADIOANALYTICAL METHODS FOR QUALITY CONTROL OF ^{68}Ga RADIOLABELED PEPTIDES

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Radiolabeled peptides have high affinity and specificity for their receptor and are used in therapy and Positron Emission Tomography diagnosis.

The increasing clinical demand of ^{68}Ga radiopharmaceuticals determined the need for optimization of the radioanalytical methods in the quality control laboratory. The objectives of this work was to discriminate the best method in determination of radiochemical purity of ^{68}Ga labeled peptides using high performance liquid chromatography and thin layer chromatography and, also, to optimize the quality control process. Chromatographic settings such as composition and flow rate of the mobile phase and column temperature were the independent variables used in the optimization process.

Several peptides (neurotensin, cRGD, octreotide) conjugated with macrocyclic chelators (DOTA, NOTA, NODAGA) were labeled with ^{68}Ga. Parameters of quality control were investigated to determine the purity and stability of the products. Quality control procedures of ^{68}Ga radiolabeled peptides are based on the general requirements for radiopharmaceuticals from European Pharmacopoeia, as there is no monograph for these products.

The HPLC and TLC methods were optimized and validated. The method was reproducible as the relative standard deviation of the peak area was less than 5%.

LEACHING CHARACTERISTICS OF SULFUR POLYMER CONCRETE (SPC) REGARDING IMMOBILIZED Cs-137 AND Co-60 RADIONUCLIDES

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

Selection of the proper waste matrix material depends mainly on the chemical properties, physical form and activity of the radioactive waste to be disposed. In case of low and intermediate level waste very often asphalts, bitumens, polymeric resins and cementitious composites are used. Technologies used for radioactive waste immobilization are being continuously improved. One of such new group of materials being developed are mineral-polymeric materials based on sulfur polymers – sulfur polymer concrete (SPC). Sulfur polymer composites seem to be very attractive materials due to their properties: good mechanical behavior, very good properties of radionuclides retention and very low diffusivity within the SPC matrix.

In this work, leaching behavior of SPC composites based on mineral fillers will be presented regarding immobilized Cs-137 and Co-60 radionuclides – the most common radioactive contaminants generated during nuclear power reactors operation. As a mineral fillers phosphogypsum, fly ash and lignite slag were used as the main radionuclides immobilization phases stabilized by various continuous phase components – sulfur polymers. Experimental procedure was based on hot mixing (ca. 140°C) and pressing of sulfur polymer and mineral fillers with Cs-137 and Co-60 radioactive tracers. For verification of immobilization efficiency of the prepared composites, an static IAEA long-term leaching test for solidified radioactive waste forms (ISO 6961:1982) was applied, as well as leaching in more harsh conditions: dynamic leaching and acid leaching. Experimental results suggest good and satisfactory leaching behavior of fly ash and slag based SPC composites and much worse in case of phoshogypsum based matrix. Minor effect is observed in case of application of different sulfur polymer phase component. Scanning electron microscopy (SEM) examination suggest for the stepwise dissolution – recrystalization mechanism of the radionuclides releasing processes.

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THEORETICAL STUDY OF CHEMICAL SHIFTS OF X-RAY EMISSION SPECTRA AND EFFECTIVE STATES OF NB IN NIOBATES AND YB IN FLUORIDES

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Capabilities of x-ray emission spectroscopy as a method for non-destructive testing the physical-chemical state of heavy atoms are limited, first of all, by difficulties in interpretation of experimental data. Establishing a straight and unambiguous link between the measured chemical shifts of characteristic x-ray emission spectra and the effective states of an atom in a chemical compound (material etc.) by modeling its electronic structure has obvious perspectives in applications.

However, this connection is still not well exploited due to the extreme cost of modern schemes of the relativistic study of materials and other systems of practical interest. The numerical instability of theoretical estimates of the values of the chemical shifts, which are up to six orders of magnitude smaller than the energy of x-ray transitions, is the main problem. It is shown earlier that rather economical calculation of the values of the chemical shifts of X-ray emission spectra for heavy-element compounds can be performed using the two-step schemes developed earlier (Progr. Theor. Chem. Phys., B15, 253 (2006)).

In the talk our results of the two-step calculation of the x-ray emission spectra chemical shifts on the Nb atom in the fersmite mineral (with basic formula CaNb2O6) with respect to the metallic Nb are presented and discussed. The calculations of the cluster's electronic structure for these structures are performed with using DFT and the generalized relativistic effective core potential method (Rev. At. Mol. Phys. 1, 63 (2010)). The values of the chemical shifts are obtained with using the methods developed in. The results of calculations of chemical shifts of Kα1-lines for ytterbium trifluoride relative difluoride ytterbium and metallic Yb are also presented and discussed.

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CALCULATION OF CHEMICAL SHIFT OF X-RAY EMISSION Kα LINES FOR YTTERBIUM FLUORIDES

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In the report a relationship between the experimentally observed shift of the $K\alpha_{1,2}$-lines of the X-ray emission spectrum (XES) of an atom in various chemical compounds where its valence states are different is discussed. For compounds containing heavy atoms we have proposed a two-step method for determining XES chemical shifts [1]. The first step is the calculation of the electronic structure using the approximation of the relativistic pseudopotential for given heavy atom [2]. At the second step a posteriori restoration of wave functions near the heavy atom nucleus is performed [3]. The experimental value of the chemical shift of ytterbium Kα lines in trifluoride (YbF_3) crystals with respect to difluoride (YbF_2) is used for comparison with our theoretical values. To describe the crystal structure, we use the method of a cluster embedded to a crystal, within the framework of which the values of chemical shifts are evaluated.

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THE IMPACT OF HEAT STRESS ON THE PLANTS' ROOT UPTAKE OF ^{137}Cs

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Meteorological conditions in the world, in general, and in the Republic of Belarus, in particular, are undergoing directed changes. Changing the primary climatic indices undoubtedly affects all ecological processes, including the transfer of pollutants in the food chain. Dowdall M. points to the uncertainty in the direction of changes of radionuclides accumulation by plants under the projected trends of climate change. He noted the need for a detailed study of this issue, since the behavior of radionuclides in the chain "soil - plant" is a fundamental element in the formation of the internal exposure to the ionizing radiation.

The vegetative experiment was organized in phyto-chamber with controlled climate. Sod-podzolic sandy loam soil from the Chernobyl exclusion zone mixed with peat soil for growing seedlings in a ratio 3:1 was used in the experiment. The activity concentration of ^{137}Cs in soil mix was 13 kBq/kg.

Spring wheat and white mustard grew at a temperature of 18^{o}C, relative humidity 40% and the optimal mode of soil moistening. At 21 day after planting the plants were exposed to heat stress -- the temperature was risen to 35^{o}C as long as 5 hours. After that, the temperature was restored.

Accumulation of ^{137}Cs by aboveground biomass of plants was assessed immediately after removal of the heat stress, as well as 1--9 days after that.

The experimental results showed, that heat stress, in conditions of optimum soil moisture, increases the accumulation of ^{137}Cs in the aboveground biomass of cereals. The maximum effect is achieved within two days after exposure to heat. Two days after heat stress wheat accumulates 40% more ^{137}Cs compared to the control. The Less significant increase of the radionuclide accumulation in plants after heat stress persists for a time more than a week.

Heat stress has a similar influence on dicotyledons (white mustard). Increased on 30-40% activity concentration of ^{137}Cs in plants' tissue observed immediately after the temperature effect, and on the fifth day after heat stress. However, significant differences with control are not noted within 12--48 hours after returning to normal temperature regime.

The probable mechanism of increasing ^{137}Cs accumulation in the aboveground parts of plants connects with increased demand for potassium in photosynthetic tissues due to the rise of reactive oxygen species concentration induced by heat stress. It enhances the activity on K-pump having a high affinity for the Cs unlike potassium passive transport channels in plant roots.

THE SITUATION WITH RADIATION IN THE REPUBLIC OF BELARUS DUE TO THE CHERNOBYL CONTAMINATION AND RADON VOLUME ACTIVITY

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The radiation situation has been essentially changed on the Belarus territory after 30 years of the Chernobyl accident. It was estimated that the dose irradiation values and the contamination area have been decreased more then in two times now. It was made the estimation of the radiation situation owing to the Chernobyl contamination and radon. It was shown these radiation factors have the different trends on the republic territory. The radon is very great irregular distributed on the Belarus territory.

The natural radio-nuclides dose irradiation on the people is caused mainly with radon. The radon risk mapping has been used for the radon dose assessment in the world practice. It was developed the Republic Belarus territory radon risk map and the dose irradiation assessments were carried out. These results were compared with the Chernobyl caesium dose irradiation. The basis for mapping was the radon volume activity values measured in the dwellings of settlements setting on the territory of the six Belarus regions. We have used more than 4000 measurement results. The radon volume activity was determined with using of the integral radon radiometers based on the polymer film Kodak LR-115. The exposure time was in the range of 90-120 days. The cartogram was built with using the MAPINFO software package. The low radon concentrations were determined in the Brest and Gomel regions, as well as in the southern districts of the Minsk and south-western districts of the Mogilev regions. The high radon concentrations were marked in some districts of the Vitebsk and Grodno region, as well as in the north-east districts of the Mogilev region. The maximum radon volume activity difference on the republic territory was more than 5 times. It was noted that the radon danger critical areas were in the concentration range 200-400 Bq/m^3.These areas were founded in the some districts of the Vitebsk, Grodno and Mogilev regions. The difference of the radon dose values on the some Belarus regions is in 4 times more than the absolute dose value being conditioned by Chernobyl caesium.

Mapping radon danger of the Republic Belarus territory gave the possibility to estimate the existing radiation risks. It is necessary to increase the radon countermeasures volumes or to change the radon normative documents taking into account the low efficiency of countermeasures after the Chernobyl accident now.

It is necessary that radon influence on the people health would be taken into account when the medical & biological radiation effects would be discussed.

RADIOACTIVITY IN MONOCALCIUM PHOSPHATE AND COMPLETE FEED MIXTURES FOR PIGS

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Mineral additives, such as monocalcium phosphate, that are commonly used on pig farms are obtained by processing phosphate mineral ore, and can contain high levels of ^{238}U. Since ingestion is the main route of radioactive contamination of both animals and humans, the goal of this paper is to measure specific activity of natural and artificial radionuclides in monocalcium phosphate and complete feed mixtures for pigs. Mineral additives with high levels of natural radionuclides can contaminate complete feed mixtures making them unsuitable for use. Investigated samples of monocalcium phosphate show the ^{238}U activity concentration of 13.2-2022 Bq/kg. Other naturally occurring radionuclides are also measured and the results give: 22.4-22.5 Bq/kg for ^{40}K, 7.7 -12 Bq/kg for ^{226}Ra, 0.5-2.9 Bq/kg for ^{232}Th, and 1.5-10 Bq/kg for ^{214}Bi. These radionuclides are further measured in complete feed mixtures and only one sample shows elevated concentrations of ^{238}U (3.1 Bq/kg) and ^{226}Ra (3.5 Bq/kg). Potassium-40 is detected in all samples, with the activity range 208-329 Bq/k, while other naturally occurring radionuclides, and artificial radiocesium are below the detection limits.

TEMPERATURE-DEPENDENT CHANGES OF RADIONUCLIDE SORPTION BEHAVIOR ON CRYSTALLINE ROCK SAMPLES OF THE YENISEISKY SITE (NIZHNE-KANSKY ROCK MASSIVE, KRASNOYARSK REGION, RUSSIA)

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Isolation of radioactive wastes, especially of high level wastes containing long-lived radionuclides, is one of the challenges for further development of atomic energy. The current approach is to incorporate HLW in an inert matrix for burial in a deep geological repository designed conceptually as a multilevel safety system formed with both engineered (matrix, container etc.) and geological (rock massive) barriers. The Yeniseysky site in the Nizhne- Kansky rock massive formed by Archean gneisses and granites was chosen as one of the probable locations for the first Russian underground deep geological repository for high (HLW) and intermediate level radioactive wastes.

The proposed site is designed for HLW that could cause an elevated local temperature because of heat-emitting decay. The purpose of this work was to study the influence of elevated temperatures on sorption and speciation of radionuclides.

All experiments were done using crushed or solid rock samples collected from the studied rock units using model underground water. Distribution coefficients (Kd) of radionuclides (^{137}Cs, ^{90}Sr, ^{233}U, ^{237}Np, ^{239}Pu, ^{241}Am) on gneiss and dolerite were estimated at 20 and 90 °C. It was shown that for most radionuclides uptake rises with temperature, while for Cs it slightly decreases. Depending on the radionuclide, it takes from several hours for Cs to several weeks for U for the sorption process to reach equilibrium. With temperature sorption time decreased significantly for actinides and Cs, whereas for Sr after a short period of rapid sorption there is a long period of slow sorption lasting to several weeks.

Speciation of sorbed radionuclides and time and temperature dependent changes were studied with a modified Tessier's procedure of sequential extraction. Speciation of sorbed radionuclides shows that for all studied radionuclides (excluding Cs) the proportion of strongly bound fraction increases with rising temperature. Temperature depend changes are more pronounced than time dependent changes. Increasing the temperature in some cases caused increasing of the strongly bounded sorbed radionuclide fraction. The distribution of sequential extraction fractions changes with time and the proportion of the strongly bound fractions slightly increases or the fraction related to iron oxides increases with decrease of all other fractions.

This shows that radioecological safety of repository will increase with time.

DETERMINATION OF ARTIFICIAL AND NATURAL ISOTOPE DISTRIBUTION IN SEDGE (CAREX L.) BIOMASS BY SEQUENTIAL ELUTION TECHNIQUE

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The study of migration pathways of artificial isotopes, available in the environment less than a century, is an urgent task of modern science. Information about isotope speciations in biogeocoenosis components is especially important. The living matter of biogeocoenosis has the ability to transfer the elements to both a mobile and more inert forms, concentrate and disperse elements, create geochemical barriers not only inside, but also affecting the surrounding inorganic matter in the process of vital activity and after termination of the life cycle. Information about isotopes localization in the plant structures in biogeocoenoses impacted by the nuclear fuel cycle facilities can help to understand isotopes migration pathways; this will provide the basis for various environmental forecast constructions.

The optimal method for determination of isotope speciations is the sequential elution technique (SET). The technique was originally developed to study atmospheric pollution by metals and it was applied to lichens, terrestrial and aquatic bryophytes. Due to morphological and physiological differences, it was necessary to adapt SET for new objects: coastal macrophytes growing on the banks of the Yenisei flood-land islands of near impact zone of Krasnoyarsk Mining and Chemical Combine (KMCC). In the first version of SET, 20 mM Na_2EDTA (Vazquez et al., 2000) is used as a reagent at the first stage; in the second version of SET, it is 1M CH_3COONH_4 (Bolsunovsky, 2011). Four fractions were extracted. Fraction I included elements from the intercellular space and those connected with the outer side of the cell wall. Fraction II contained intracellular elements; fraction III contained elements, firmly bound in the cell wall and associated structures; fraction IV contained insoluble residue. Adaptation of SET has shown that the first stage should be performed completely in the field. Separation of fractions III and IV can be neglected, since the output of isotopes into the IV fraction is at the level of error detection. The most adequate version of SET for terrestrial vascular plants is the version using 20 mM Na_2EDTA at the first stage. Isotope ^{90}Sr is most sensitive to the technique changes. Its distribution depends strongly on both the extractant used at stage 1 and duration of the first stage. Distribution of artificial radionuclides in the biomass of terrestrial vascular plants can change from year to year and depends significantly on the plant age. Young plants concentrate isotopes in the extracellular and intracellular fractions. Their maximal amount is associated with the intracellular fraction and, to a lesser extent, with the extracellular fraction. With plant aging, isotopes are either fixed in the cell wall structures, or washed out from the extracellular and intracellular spaces by different ways.

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IMPORTANCE OF RADIONUCLIDE MONITORING WITH PARTICULAR REGARD TO ENVIRONMENTAL IMPACT ASSESSMENT

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Observed from a global perspective, there is currently an increasing tendency directed to protection, at one hand, and efficient natural resources exploitation for the sake of daily society needs at other. Similarly, at the EU level, the European Union (through European Environment Agency - EEA) gives great significance to the protection and preservation of natural resources and living environment, treating them as the base of sustainable development within the 21st century. Moreover, the United States (through Environmental Protection Agency - US EPA) declares that scarcity of natural resources may be limiting factor to the further societal and economic development. With no less importance is the fact that US EPA promotes the concept of Natural Resource Damage (NRD) and Radionuclide Rule which takes into account the damage to the natural resources that have been occurred as a result of releases of hazardous substances such as oil or radionuclide as a result of natural resource injury related to man-driven action. Whilst the contemporary environmental quality monitoring schemes at the national level recognizes the significance of basic physical, chemical and biological parameters as environmental quality indicators, there is insufficient attention given to the radionuclide monitoring. Having the previous facts in mind, the aim of this paperwork is directed to: detailed analysis of sources of radionuclide in environment, mechanisms of their transfer in different environmental media and their final fate influencing environmental quality and environmental services. Also, the aim of this paper is to demonstrate the significance of radionuclide monitoring both from the perspective of environmental protection and natural resources availability. The paper relies on the environmental quality reports and studies performed by the numerous organizations and highlight the importance of interdisciplinary approach within the observed field.

THE EVALUATION OF DEFORESTATION EFFECTS ON THE SEDIMENTATION RATES OF ANTHROPOGENIC LAKES IN ROMANIA USING RADIOMETRIC DATING METHODS

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Studying sedimentary archives is not only important for measuring the sedimentation rate, but also useful to differentiate the autochthonous and allochthonous sediment sources, and understand the major processes connecting land use and climate change to lakes sedimentation. The present paper aims to highlight the major effects of land use in the watershed of three Romanian anthropogenic lakes located in the Someş River catchment area, as a first study in Romania that uses radiometric dating methods to assess the influence of deforestation on artificial lakes sedimentation rates. Sediment cores from Beliş, Tarniţa and Firiza lakes were sampled and dated using ^{210}Pb techniques. Measurements of ^{210}Pb concentrations were performed using gamma and alpha spectrometry. To combine spatial analysis of past deforestation activities and basin morphometry, GIS technology was used. Organic matter changes and pollen types in the cores were also assessed to estimate the lake response to forest activities. The results of the sedimentation rates were compared with reports from National Forests Administration and with lake and watershed morphometry. Streamside harvest, stream crossings and road construction are other factors that are identified as potential activities that contributed to increases in sediment yield. The results help to identify the risks and formulate suggestions for decreasing the negative effects in the studied areas.

Key words: ^{210}Pb dating method, deforestation, sedimentation rate, alpha spectrometry

RADIOACTIVITY ASSESSMENT IN RARE EARTH MINING SITES IN CHINA

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Bayan Obo mine in China has a deposit of iron and rare earth ores. In which, it is renowned as a large rare earths deposit in the world. The ores are rich in radioactive elements, with a 0.01-0.05% concentration of ThO_2 and a 0.0005-0.002% of U_3O_8. The deposit has been mined for about 60 years. More than 280×10^6 t of ores had been mine and about 600×10^6 tons of waste rocks produced.

The ores rich in thorium result a certain radiological impact on work places and the environment during mining. An assessment of radiological impact for the exploitation of Bayan Obo mine was sponsored by the Department of Nuclear Safety Management of Ministry of Environment Protection. As a result, higher radiation levels were found mostly in the mining area and their surroundings, including the mining sites and the dumping sites. The typical radiation levels were in the range of 200—800nGy/h covering an area of about 55Km^2 where the radiation levels vary from 600 to 2000nGy/h in mining sites, 400 to 800nGy/h in the dumping sites. Bayan Obo City area was influenced by open pit mining. The radiation levels of this area were in the range of 100nGy/h-150nGy/h, or average 121nGy/h, which is 50% higher than the background value. The miners who were working in the High Background Radiation Area received 0.24 mSv/a of additional external exposures. Mining workers received more than 1.0 mSv/a additional external exposures and 2.38mSv/a internal exposures of ^{220}Rn.The additional external exposure for public in the city area is 0.044 mSv/a, while the internal exposure of ^{220}Rn is 1.84 mSv/a.

THE EVALUATION OF OBSERVATION UNCERTAINTY IN ECOSYSTEMS DURING THE REGIONAL CONTAMINATION MONITORING OF THE CHERNOBYL EXCLUSION ZONE

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The estimation of statistical uncertainty was given during the selection and analysis of the content of radionuclides in the samples natural indicating resources used for radiation monitoring. Research was carried out in the Chernobyl Exclusion Zone (CEZ) during the years 1996–2015. The aim of the research was to determine the features of the statistical uncertainty associated with the use of the environmental objects as means of indication.

The studies were conducted in 15 key areas located at a distance of 1km to 12km from the Chernobyl Nuclear Power Plant (NPP) in the region’s typical ecosystem of pine forests and water bodies in the Prypiat floodplain. We also investigated the cooling pond of the Chernobyl NPP. The control samples were taken in the conditions of the local background radiation pollution in the ecosystem of the Prypiat River in the Chernobyl dam.

To evaluate the atmospheric deposition we used biological indicators: bark of Scotch pine (*Pinus sylvestris* L.), epiphytic lichens (*Physcia stellaris* (L.) Nyl., *Xanthoria parietina* (L.) Th. Fr.) and ground mosses (*Dicranum polysetum* Sw., *Pleurozium schreberi* (Brid) Mitt.). To evaluate the accumulation of radionuclides in the ecosystems we used soil cover and sediments, which we explored by layers. Soil layers: tree waste from the current year (A_0L), ferment level (A_0F) and humic level (A_0H). To evaluate the seasonal migration of radionuclides we used pine needles and certain herbs. In the samples we measured ^{90}Sr and ^{137}Cs content and Ca^{2+} and K^+ ions. In the sediments of the Glyboke Lake we investigated the distribution of physical and chemical forms of ^{90}Sr and ^{137}Cs.

The statistical observation uncertainties (u,%) was calculated as the ratio of standard deviation to the mean value corresponding to the data samples. Radionuclides geochemical mobility was evaluated considering the change in the primary (at the time of the disaster in 1986) ^{137}Cs and ^{90}Sr content in them, with the discrimination factor ($K_{Sr/Cs}$). The Chernobyl NPP emissions at the time of the accident had the value $K_{Sr/Cs}$=0.21.

The results showed that in the observation sites, bark, mosses and lichens retain radionuclides ratio that has corresponded with the primary loss for 5–15 years, with a gradual shift to the one supported by the cycle of chemical elements in the ecosystem or secondary manmade atmospheric depositions. The average specific activity of ^{37}Cs in the samples of pine bark is 40.000Bq/kg with u=50%. The average value of $K_{Sr/Cs}$ is 0.55. The average specific activity of ^{37}Cs in soil samples is 12.000Bq/kg. The value of $K_{Sr/Cs}$ is 0.31. In the examined ecosystems we observed ^{90}Sr migration more often. The median of the specific activity of ^{37}Cs in sediments is 2000Bq/kg, while the regional value of u=400%. The value of $K_{Sr/Cs}$ is close to the primary depositions. Analysis of the vertical distribution of physical and chemical forms in sediments shows the history of the ecosystems pollution in the catchment area

THE DISTRIBUTION OF ^{137}Cs AND Pu ISOTOPE ACTIVITY CONCENTRATIONS IN THE SOIL PROFILES OF THE LAKE SHORES

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The aim of this study was to evaluate the distribution of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$ activity concentrations in the soil profiles of the flooded and unflooded lake shores, to compare migration peculiarities of the tested isotopes and to evaluate the radionuclide origin.

Two soil columns up to the 30 cm depth were taken in Lake Juodis shores (flooded and unflooded) in summer of 2012. In the laboratory, the samples were sliced into layers of 1 cm thickness. The activity concentration of ^{137}Cs in each layer was evaluated by the gamma-spectrometric measurement. Activity concentrations of ^{238}Pu and $^{239,240}Pu$ were determined after the sample radiochemical analysis and alpha-spectrometric measurements were performed.

Analysis of the results showed that activity concentration of tested radionuclides in the flooded shore soil had only one sharp peak (^{137}Cs - in the layer of 1-3 cm, $^{239,240}Pu$ in the layer of 2-5 cm).

In the soil profile of the flooded lake shore was two peaks of activity concentrations of ^{137}Cs and Po isotopes were clearly seen. The peak of ^{137}Cs activity concentrations was 146 Bq/kgat the 5 cm depth, and another peak value observed at the 13-14 cm depth was 64 Bq/kg. It is interesting to note that over the first layer of soil - needles of pine were collected and they showed increased activity concentration of ^{137}Cs, which can be attributed to the Fukushima accident.

The activity concentrations of $^{239,240}Pu$ increased from 0.61Bq/kg to 2.88 - 3.15 Bq/kg at the 5-8 cm depth, while the socond less intensive peak was observed at the 12-15 cm depth.

Sources of the radionuclide origin were identified by the activity concentration ratios of $^{238}Pu/^{239,240}Pu$ and $^{137}Cs/^{239,240}Pu$.

SORPTION CHARACTERISTICS OF MATERIALS FOR PERMEABLE REACTIVE BARRIERS

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Permeable reactive barriers (PRB) enable physical, chemical or biological in situ treatment of contaminated groundwater by bringing it into contact with reactive materials. The reactive material is inserted underground in a natural aquifer and intercepts the pollution plume as it is carried along within the aquifer, and thus the contaminants are treated without either wholesale soil excavation or water pumping. This cost-effective clean-up technology has much less impact on the environment than other methods and is generally more economical over the long term as compared to other methods.

In this study sorption characteristics of different materials that can be used for creation of complex multi-layer PRB were specified. For apatite, vermiculite, lightweight expanded clay aggregate (LECA), wood sawdust, perlite, natural zeolite (TREYD) and shungite sorption coefficients (K_d) for ^{137}Cs, ^{90}Sr, ^{238}U, ^{239}Pu, ^{241}Am, ^{99}Tc and stable Cr(VI) were obtained. Speciations of these radionuclides on materials were investigated using the method of sequential extraction.

Since one component of complex multi-layer PRB is denitrifying bacteria immobilized on the carrier, microbiological influence on barrier materials should be estimated. Variation of K_d and changes in speciation of sorbed radionuclides after microbiological treatment were analyzed.

MOSSES AS A POTENTIAL BIOSORBENT FOR ^{137}Cs AND ^{239,240}Pu SORPTION AND MODELLING

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The aim of the current study is to use the mosses *Ptilium crista-castrensis* as a potential biosorbent for the cesium and plutonium isotope removal from aqueous solution and to apply modelling of the radionuclide behaviour in the moss bed column.

To test the ^{137}Cs and plutonium isotope possibility to be pre-concentrated by an environmental-friendly assay, the moss bed column was employed in situ on the shore of Lake Kaniava. The lake water of 200 L volume was loaded through column within 200 min. The moss sample was prepared in the laboratory for the gamma and alpha spectrometric measurement. Besides, 20 L of lake water was taken for the ^{137}Cs activity concentration evaluation followed by evaporation and the gamma spectrometric measurement. Three hundred litres of lake water was taken for the ^{238}Pu, ^{239,240}Pu activity concentration determination by the chemical co-precipitation method.

Results obtained from the in situ experiment showed that ^{137}Cs was washed out from the moss bed, while the plutonium isotopes were sorbed. Plutonium isotope activity concentration values in water, obtained using the moss column and the chemical co-precipitation method, were similar, 0.014 and 0.015 Bq/m^3.

To test the cesium possibility to be eluted from the environmental-friendly assay, the small moss bed column was employed in the laboratory.

A mathematical model based on mass balances in the fluid and in the sorbent was applied to represent the experimental fixed-bed column data. The proposed model divides the elution process into two kinetic processes. The tested empirical model was simply evaluated according to the values of the regression coefficient (R^2). The regression coefficient value was near unity (R^2=0.995), which was generally assumed for reliable models.

BERYLLIUM-7 IN SURFACE AIR – MULTIDECADAL MEASUREMENTS IN SERBIA AND SLOVENIA

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Beryllium-7 is a natural radionuclide produced in spallation processes in the upper troposphere and lower stratosphere. Descent through the atmosphere brings this isotope to the lower altitudes and its abundance at the surface is a result of an interplay between transport and removal processes, both of which are influenced by local meteorological parameters.

In this analysis we use the beryllium-7 specific activities measured in three locations to investigate spatial similarities and differences in the data sets. The measurement sites are: Belgrade, the capital of Serbia; Ljubljana, the capital of Slovenia, located around 500 km west of Belgrade; and Krško, a town in eastern Slovenia, located around 400 km west of Belgrade. The beryllium-7 measurements in Serbia and Slovenia started in 1991 and 1988, respectively. The specific activities were determined by standard gamma spectrometry at the Vinča Institute (Serbia) and Jožef Stefan Institute (Slovenia).

The annual cycles of the beryllium-7 specific activity at the three measurement sites show maxima occurring in the spring-summer season. The Belgrade site exhibits the earliest maximum which takes place in May, and is followed by a July and August maximum in Krško and Ljubljana, respectively. All of the sites show a December-January minimum in the annual cycle. The calculated Spearman's correlation coefficients are 0.69, 0.59 and 0.32 for the measurement pairs Ljubljana-Krško, Belgrade-Ljubljana and Belgrade-Krško, respectively.

Further, at each measurement site, the beryllium-7 time-series is significantly correlated with the monthly mean temperature, cloud cover and relative humidity. The correlation with the temperature records is positive, with the correlation coefficient of 0.65, 0.74 and 0.59 for Belgrade, Ljubljana and Krško, respectively. Correlations of similar strength, but negative, are obtained when the beryllium-7 data are correlated with cloud cover and relative humidity. In contrast, no statistically significant correlation between the beryllium-7 specific activity and mean monthly precipitation are obtained.

Our results show relatively strong similarities in the beryllium-7 activity concentration in surface air across a zonal distance of around 500 km. This consistent behaviour implies a large-scale driving mechanism which is dominant in the region over a time-scale of one month.

RADIONUCLIDE CONCENTRATIONS IN MOSSES

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Naturally occurring radionuclides ^{7}Be and ^{210}Pb together with the artificial ^{137}Cs are a useful tool in studying the environmental processes. The ^{7}Be is formed by spallation reaction between cosmic rays and nuclei of oxygen and nitrogen in the stratosphere and upper troposphere. After production, the ^{7}Be atoms are attached to aerosol particles and the fate of ^{7}Be will become the fate of the carrier aerosols. Since aerosol particles contain most of the air pollutants, the transport of the last ones can be investigated by tracking the ^{7}Be pathway. The radionuclide ^{210}Pb is widely found in the terrestrial environment and it is the final long-lived radionuclide of the ^{238}U chain. It is present in the atmosphere due to the decay of ^{222}Rn diffusing from the ground and its concentration depends on the ability of the radon to leak from the ground and enter the atmosphere. The artificial radionuclide ^{137}Cs was mostly released in the atmosphere during atmospheric nuclear weapon tests and the Chernobyl nuclear accident. After that, there were no other significant ^{137}Cs emissions, and the atmospheric ^{137}Cs was exposed to physical decay as well as wet and dry deposition.

Terrestrial mosses can be used for investigation and monitoring of airborne radionuclide depositions. Many mosses, obtain most of their nutrients directly from precipitation and dry deposition. The absence or strong reduction of the cuticle and thin leaves allows easy uptake from the atmosphere. Lack of an elaborate rooting system also means that uptake from the substrate is normally insignificant. These properties make mosses an ideal sampling medium for metals and airborne radionuclides deposited from the atmosphere, as they are accumulated by the moss, producing concentrations much higher than those in the original wet or dry deposition. The sample collection is so simple, that a high sampling density can be achieved, in contrast to the conventional precipitation analysis and the air sampling. High resolution gamma spectrometry measurements can be carried out with the moss technique, without any chemical treatment of the samples.

The aim of this study is to measure activities of the radionuclides ^{137}Cs, ^{7}Be and ^{210}Pb in mosses and investigate their possible variabilities over different places in Northern Greece. The different meteorological conditions, the wind direction and precipitation can influence the deposition of airborne radionuclides, as well as their activities in mosses.

Samples of *Hypnum cupressiforme* were collected in Northern Greece. All samples were collected in a short time interval during the end of summer 2016. After sampling, mosses were dried at 105°C for 2 hours and all the impurities were removed manually. After the preparation, mosses were put in two cylindrical plastic containers, diameter 67 mm and height 31 mm. They were measured in a low-background HPGe detector with relative efficiency 36%.

Values of ^{7}Be activity concentrations in moss samples vary from 69 to 1280 Bq/kg and of ^{210}Pb from 148 to 2049 Bq/kg and of ^{137}Cs from 1.8 to 590 Bq/kg. Between the concentrations of ^{7}Be and ^{210}Pb there is a good correlation. It can be observed that the major quantity of ^{210}Pb in mosses has arrived from aerosol deposition. A big number of sampling sites was covered and the information obtained using mosses as biomonitors, provide the spatial distribution of all the radionuclides over Northern Greece.

THE MEASUREMENTS OF LEAD-210 ACTIVITY CONCENTRATION IN THE GROUND-LEVEL AIR IN FINLAND AND BULGARIA

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Airborne lead-210 is useful tracer for studying air mass origin and transport. ^{210}Pb is produced in the atmosphere by decay of radioactive noble gas ^{222}Rn, emanating after ^{226}Ra decay from the earth crust. In the present paper the results obtained for ^{210}Pb concentration in total suspended particulate (TSP) are presented based on gross alpha counting of Po-210 daughter and gamma-spectrometry of the combined on semi-month base aged aerosol filters collected in Sofia during the period 2001 – 2003 and 2006-2007. The TSP filters are collected in the frame of atmospheric radioactivity monitoring in NIMH, Bulgaria and were measured for short and long lived beta radionuclides.

The methodology developed in FMI, Finland based on alpha counting of the in-grown daughter nuclide polonium-210 six months after the sampling was applied.

The tendency for higher ^{210}Pb concentrations during the warm period of the year (June –October) is observed for Sofia. This is different than in Finland where winter maximum for Nurmijarvi is reported. Mean annual concentration during the period 2001-2007 vary in the range of 180-280µBq/m3 in Nurmijarvi and 170-270 µBq/m3 in Sofia. In addition to gross alpha/beta counting the Pb-210 was measured directly by gamma spectrometry with N-type coaxial HPGe-detector Ortec GMX-45200-P with a 40 % relative efficiency. Because of in principal lower efficiency the detection limit in gamma spectrometry is higher and larger sample is required. Two months composed samples from the period 2006-2007 were analyzed. The results show similar seasonal variation, whit higher uncertainty, few values below MDA, and less time resolution.

The first results for ^{210}Pb in particulate matter, fraction below 10 µm (PM_{10}), collected with Tecora low volume sampler in February 2012 in Sofia were obtained. The alpha counting methodology was successfully applied for daily PM10 quartz filters with counting uncertainty of *≤20%*. Lead-210 daily concentration is compared to the PM_{10} mass concentration and elemental lead concentration, determined by EDXRF technique. The comparison between ^{210}Pb, elemental lead and PM10 mass concentration reveal different time variation for days with cyclonic weather and mass transport from south-west (06.02 and 13.02) and anticyclone episode with increasing from day to day PM_{10}, Pb-210 and lead concentrations. Lead-210 is long-range transported. Thus an increase in the PM_{10}/Pb-210 ratio indicates local sources of particulate mass.

THE ECOTOXICOLOGICAL IMPACT OF THE NUCLEAR FACILITIES' EFFLUENT AND ^{137}Cs ON THE TEST ORGANISM LEPIDIUM SATIVUM

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The significant quantities of artificial radionuclides have already entered and may enter in the future the environment during operation of NPPs, after their shutdown and during decommissioning process in conjunction with dismantling works, after nuclear accidents (Chernobyl NPP, Fukishima NPP, etc.), during the implementation of development projects of nuclear power. The dispersion of artificial radionuclides and their distribution in biotic and abiotic ecosystem components are associating with the decommissioning of the Ignalina NPP currently in Lithuania. For the above reasons, the investigation of biological effects caused by artificial radionuclides is always relevant. It is very important to assess the effects caused by artificial radionuclides on biota. However, the consequences of ionizing radiation impact on biota have not been sufficiently investigated yet. Thus far, ionizing radiation doses are rated only for humans. Therefore, it is necessary to find the assessment ratio of radiation safety criteria for humans and biota. However, due to the high biodiversity and different environmental conditions the data about biological effects derived by ionizing radiation are still limited. The aim of this study is to assess the impact resulting from the sum of various stressors arising from the nuclear facilities on seed germination and growth of the test organism *Lepidium sativum* as well as to assess the biological effect of ^{137}Cs on roots (meristematic cells) and sprouts (cells of parenchyma) test organism *Lepidium sativum*. The investigations were played on water and bottom sediment from monitoring station of Lake Drūkšiai (the cooling-pond of the Ignalina NPP) as well as from the Ignalina NPP's effluent channels IRD-1,2 (industrial rain drainage channel) and TWO (technical water outlet channel) before the INPP shutdown (2007–2009) and 6 years after (2010–2015), also it was investigated separately ^{137}Cs impact on the test organism using low activity concentration solutions of 25 and 250 Bq/L.

INVESTIGATION OF TRANSFER FACTOR FOR AMERICIUM UPTAKE FROM FUEL PARTICLES INTO BIOMASS OF CLADOSPORIUM CLADOSPORIOIDES WITH RADIOADAPTIVE PROPERTIES

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Now very important problems and prospects are evaluate a current state of the collection, storage, and disposal of radioactive wastes alienation Zone, special attention needs most dangerous fuel components for humans and the environment - plutonium and americium, due to their high radiotoxicity, carcinogenicity and very long half-life (433 year). Requires learning the possible use micromycetes for destruction of fuel containing materials (waste) and transfer them in a form that facilitates their recycling.

Ability of the transfer for radionuclides Am and Cs from Chernobyl's fuel particles in a biologically available form by strains *C. cladosporium*, with and without radioadaptive properties were studied. In our work used two fuel particles which had the following activity of radionuclides - the first SL-15: ^{241}Am - 364 Bq and ^{137}Cs - 3420 Bq, and the second SL - 4 - ^{241}Am - 908 Bq and ^{137}Cs - 6590 Bq. Two strains were used in the work: *C. cladosporium* 4061, isolated from the area with the background levels of radiation, which has no radioadaptive properties and *C. cladosporium* 4 isolated from area of Chernobyl Exclusion Zone and has radioadaptive properties. The experiment was carried out by cultivation micromycetes on liquid Chapek's medium.

We monitored specific activity of radinuclides in biomass and cultural medium after interaction *C.cladosporium* 4061 and fuel particle SL - 15.

There were found that the activity in fungal biomass consisted for - ^{241}Am – 0.27 Bq, and for ^{137}Cs – 0.35 Bq, in grams, based on the biomass ^{241}Am - 5.6 Bq/g, and ^{137}Cs – 7.4 Bq/g. When we analyzed specific activity of radinuclides in biomass and cultural medium after interaction *C.cladosporium* 4 with fuel particles with SL - 4 shown that the activity of radionuclides in the fungal biomass were: ^{241}Am – 0.51 Bq and ^{137}Cs – 1.35 Bq, and in grams, based on the biomass - ^{241}Am - 17 Bq/g and ^{137}Cs - 45 Bq/g.

It was established that both strains so control as with radioadaptive properties able to transfer radionuclides from the fuel particles in a biologically available form. It was shown that transfer factor for ^{241}Am at control strains was – $7.8 \cdot 10^{-4}$ and strain with radioadaptive properties was – $5.6 \cdot 10^{-4}$.

It was shown that ^{241}Am was practically not transfer to the culture fluid, allowing assert its absence soluble form. It should be noted that the rate of uptake by micromycetes ^{241}Am exceeded the rate of uptake ^{137}Cs despite the fact that activity last in fuel particles was higher in the 7 - 10 times.

The ability of fungi to translate a highly toxic transuranic element as an ion exchange ^{241}Am mobile forms must be considered in the formation of long-term forecasts of the effects of chronic exposure action on the migration of radionuclides.

HYDROCHEMICAL BEHAVIOR OF DISSOLVED URANIUM IN SELECTED GROUNDWATERS OF THE SUDETY MOUNTAINS

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Uranium isotopes $^{234,238}U$ due to their geochemical properties can be used to study water – reservoir rocks interactions and also allow to investigate mixing of waters from different sources. A diagram of $^{234}U/^{238}U$ activity ratio as a function of reciprocal ^{238}U content is commonly used to study ground water origin and mixing relation between waters from different sources.

The samples from selected water intakes from the Sudety Mts. were collected and analyzed for uranium radioactivity $^{234,238}U$ and $^{234}U/^{238}U$ activity ratios over a period of several years. The investigated waters, mostly of deep circulation contain admixture of shallow circulation waters and these waters are mixed before their outflow to the surface. The previous investigation of authors indicated that the uranium concentrations varied greatly despite water close locations.

The uranium was measured with the use of α – spectrometer 7401VR (Canberra – Packard, USA) equipped with the Passivated Implanted Planar Silicon detector. The separation of uranium from other alpha isotopes was performed with the use of the anion exchange resin Dowex 1×8 (Cl^- type, 200-400 mesh).

Obtained results of uranium concentrations and $^{234}U/^{238}U$ ratios in investigated waters from different years were used to study variability of water compositions and the mixing of water of different origin. The detailed analysis of application of uranium “fingerprint” in water behavior study will be presented at this work.

NON-DESTRUCTIVE METHOD OF ^{90}Sr MEASUREMENT IN SMALL ANIMALS

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^{90}Sr is a pure beta emitter, so the determination of the activity of this radionuclide, as a rule, carried out by radiochemical methods. These methods lead to the irretrievable loss of the measuring living objects. We have developed a method of measuring ^{90}Sr for study the processes of ^{90}Sr accumulation in small living objects such as various rodents, birds, various amphibians, etc. This method is based on measuring of the spectra of electrons that are emitted by the investigated objects. The obtained spectra are processed by fitting of calibration spectra of electrons from the decay of ^{40}K, ^{90}Sr and ^{137}Cs "phantoms" into the measured beta spectra of living objects. The standard radiochemical investigations of the same living objects were performed for control the accuracy of the proposed method. The comparative analysis of researches was made on small rodents with mass of bodies from 14.1 g to 45.1 g and with a specific activity of ^{137}Cs from 0.7 to 393 Bq/g. We would like to note the high correlation coefficient R = 0,942 of this spectrometrical method. The vast preponderance of total activity of ^{137}Cs above ^{90}Sr (from 2.6 to 7.8 times) did not affect the estimate accuracy. But we observed a tendency to increasing of errors from 16% to 40-60% if the activity of ^{90}Sr was less than 10 Bq/g.

RADIOACTIVITY MONITORING OF CONTAMINATED SITES IN NORTHERN GREECE BY IN SITU GAMMA SPECTROMETRY

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The main objective of this work was the development of a rapid and low cost radioactivity monitoring method of contaminated sites due to anthropogenic activities, by in-situ gamma spectrometry and the validation of the in-situ method.

The location that has been studied is a site near a Coal Power Plant in Northern Greece.

Radioactively contaminated sites due to anthropogenic activities by various industrial activities, or pollutants related with NORM activities lead to the exposure of citizens near the areas of activities to higher ionizing radiation levels, resulting in negative health effects.

Lignite (coal) contains trace quantities of naturally-occurring primordial radionuclides. Therefore, the combustion of lignite results in the release to the environment of some natural radionuclides (e.g. ^{226}Ra) in high concentration levels and their redistribution in the surface soil in the vicinity of coal-fired power plants.

In Greece, coal-fired power plants are the main source of electricity. Four thermal power stations with more than 4000 MW total installed capacity are located in the Eordea basin, in western Macedonia, Northern Greece ("Agios Demetrios", "Kardia", "Ptolemaida", "Amyntaio"), producing more than 70% of the country's power requirements. For this present work, the study area was "Agios Demetrios" power station. The area has suffered in the past from high levels of total suspended particles (TSP).

The traditional characterization procedures of a radiologically impacted site are time and money consuming by collecting and analyzing samples. In-Situ techniques offer certain advantages over traditional characterization procedures, such as fast determination of contaminated sites, cost reduction and also optimization of the sampling strategies.

A survey around the coal power plant has been conducted by using portable gamma ray spectrometers, studying an area of 25000m^2 in a grid of 500x500m in places that were accessible and 1000x1000m at non accessible places. Three different instruments have been used: 1) Saphymo-Stel 1'' NaI(Tl), 2) Thermo electron Corporation, 3) Identifier, target system electronic gmbh.

Direct measurements of the dose rate on the level of 1m above the ground detected in each sampling point.

In order to validate the results obtained from the in-situ measurements 36 soil samples have been collected. The samples have been measured by gamma-spectrometry in the lab.

The estimated external doses are in agreement with the measurement external doses by in situ gamma spectrometry method.

The observed external doses (30-93 nSv h^{-1}) are in agreement with the population weighted average absorbed dose rate in air from terrestrial gamma radiation 57 nGy h^{-1} and the reported in Greece average absorbed dose rate in air from terrestrial gamma radiation 42 nGy h^{-1}.

In the present work, a validation of the in-situ gamma spectrometry method has been achieved.

BIOGEOCHEMICAL ASPECTS OF U AND Tc MIGRATION MODELLING IN SAND AQUIFERS

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This study is devoted to radioecological problem of long living radionuclides in highest oxidation state migration. Uranium and technetium are highly migrable and hazardous metals and it can course high risk of toxic effect more than 10^4 years after water pollution. Natural microbial processes in subsurface water are the main mechanisms of U and Tc immobilization on host rock due to processes of bioprecipitation, bioreduction and biotransformation. This influence may be both positive (for example, due to an increase in cation exchange capacity because of microbial interaction with clay minerals) of negative (like raise of porosity of the rocks etc). However, in general, the biogeochemical processes that will occur in this environment, and the extent to which they will impact on radionuclide migration, are currently poorly understood. New information about it can be used as basis for in situ sand aquifers remediation.

The aim of this study is to make general biogeochemical model of U and Tc migration in sand aquifers. Here we use water samples from aquifers, contaminated with Tc, U and nitrate from 10-20, 180-200 and 350-380 depth (Tomsk region, Russia). The focus of the work is microbial metal bioreduction capacity, mineral phase formation and biofilms growth on sand, clays and host rocks and its role in me sorption/precipitation.

INVESTIGATION OF RADIOACTIVITY LEVELS IN SOILS AND DRINKING WATERS OF ANDON REGION (RIZE CITY, TURKEY)

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In this study, radioactivity measurements were performed in soil and drinking water samples collected from the area of Andon in the Eastern Black Sea Region of Turkey. This region is well known as a place for spring waters rich in minerals. This region is being visited by many people around the world for its special water having a healing character. The measurement of radionuclide activities (^{238}U, ^{232}Th, ^{40}K and ^{137}Cs) in the samples were carried out through gamma-ray spectrometry. Also, radon (^{222}Rn) concentration measurement in the samples was done using radon gas analyser (Alpha Guard PQ 2000PRQ). From the activity of radionuclides, the corresponding radiological parameters such as total absorbed outdoor gamma-ray dose rates and the corresponding annual effective dose rates were computed. The results obtained were compared with other works and internationally recommended values. The findings may be used for the preliminary estimation of the population exposure to radionuclides.

RADIOACTIVE ATMOSPHERIC EMISSIONS OF THE EUROPEAN AND RUSSIAN NUCLEAR PLANTS

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The analysis of radioactive atmospheric emissions of Russian and European nuclear plants conducted. The purpose of this analysis was the comparison of the emission intensity per GW·h of the different types of nuclear power plants in Russia and Europe. The correlations between different radionuclides in atmospheric discharges were analyzed for 20 PWR nuclear plants in France, 8 PWR nuclear plants in Germany and 7 PWR by Russian design (VVER) in East European countries. Demonstrated, that for all analyzed nuclear power plants in the sum of the emitted activity are predominant the radioactive inert gases. The ratio between activities of inert gases per GW·h are different for French or German PWR nuclear plants and East European VVER nuclear plants. For all types of reactors, the activities of radioactive atmospheric emissions, excluding radioactive inert gases, caused by tritium (67 – 75 %) and radiocarbon (25 – 33 %). In general, the atmospheric emissions of different radionuclides per GW·h for VVER type reactors exceed the emissions for French or German PWR reactors from 2 to 6 times. The tritium emissions (GBq/GW·h) for different European nuclear plants are in the range from $3.55 \cdot 10^{-4}$ (RBMK, Lithuania) to $3.22 \cdot 10^{1}$ (CANDU, Romania). The typical values of tritium emission for PWR reactors are in the range $(6 – 12) \cdot 10^{-2}$ GBq/GW·h.

In Russia, the radioactive atmospheric emissions of 7 radionuclides (Cs-134, Cs-137, Co-58, Co-60, Cr-51, Mn-54, I-131) and the sum activity of radioactive inert gases are under control. The control of tritium and radiocarbon will be started in the nearest years. The emissions of tritium and radiocarbon for Russian nuclear plants were estimated on the base of reactor type and power production of the plant. The estimated tritium emissions for different nuclear plants are in the range 1.3 – 3.8 TBq/year, for radiocarbon 0.5 – 1.4 TBq/year.

It was demonstrated that for some radionuclides there is good correlation between their activities in radioactive emission. Therefore, it is possible to estimate emission of the group of radionuclides by controlling of emission of single radionuclide (for example Co-60 or I-131). It should be taken into account that there are no radionuclides in radioactive atmospheric emissions, which correlate with tritium and radiocarbon.

RADIONUCLIDES IN DRINKING WATER AND RISK ASSESSMENT

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Drinking water can contain radioactive isotopes which represent potential risk to human health. In case of nuclear accident and uncontrolled releasing radionuclides from nuclear power plants, it is necessary to rapidly implement control of radioactivity level in the surrounding waters, air and soil.

Method of gamma spectroscopy analysis in scientific research is one of the most common experimental methods for quantitative analysis of radioactivity content in the samples.. In this paper content of natural radioactive isotopes: ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U and artificial radioisotope ^{137}Cs in 40 samples of drinking water from the territory of Vojvodina (from water supplies, wells, fountains and from wellsprings) were determined. The annual effective dose due to consummation of these waters was estimated. Based on the results, it was concluded that most samples contain activity concentration of ^{226}Ra over the legally regulated.

Key words: *Radionuclides, gamma spectroscopy, effective dose, drinking water*

EXPERIMENTAL ASSESSMENT OF ATMOSPHERIC EMISSIONS OF RUSSIAN NPP WITH DIFFERENT KINDS OF REACTORS

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Radioactive atmospheric emissions of the Russian nuclear power plants are characterized by low values of activity. Regular NPP radiation monitoring systems allows monitoring of 5-6 radionuclides in ventilation stack. Most radionuclides generated in the active zone of NPP are usually presents in atmospheric emissions with concentration below than detection limit. Both IAEA recommendations and legal acts of the Russian Federation required necessity monitoring of atmospheric emissions in NPP up to 94 radionuclides.

The equipment allowing more precise measurements of radionuclides in NPP airborne discharges was used in this study.

Assessment of effective annual doses on the critical group of population from measured activity in the nuclear power plant atmospheric emissions demonstrates that the lowest value of effective dose is produced by fast breeder reactor emissions:

Kursk-3.4 NPP, LWGR-1000: 6.54E-08 Sv/year;

Balakovo-1 NPP, PWR-1000: 3.95E-09 Sv/year;

Beloyarsk-4, FBR-800: 5.95E-11 Sv/year.

It was demonstrated that Beloyarsk-4 NPP with fast breeder reactor has significantly less impact on the environment due to radioactive atmospheric emissions in comparison with others Russian NPPs.

Total list of most dose-forming radionuclides in atmospheric emissions of Russian NPPs consists only 15 radionuclides: ^{41}Ar, ^{85m}Kr, ^{87}Kr, ^{88}Kr, ^{133}Xe, ^{135}Xe, ^{3}H, ^{14}C, ^{24}Na, ^{54}Mn, ^{60}Co, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs. This result is well-correlated with radioactive airborne discharges of European NPPs.

IMPACT OF MYCORRHIZAL FUNGI ON ^{137}Cs ACCUMULATION BY BARLEY BIOMASS

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Bacteria, fungi and algae that inhabit soil environment actively participate in the processes of minerals destruction and formation, and have a powerful indirect effect on the physical and chemical state of radionuclides. Also, they can absorb radioisotopes on the cell walls and in other components of the cell.

Microorganisms can be a factor of direct enzymatic biotransformation of radioactive metals and metalloids in less bioavailable form. Products released by microorganisms can react with bioavailable forms of radionuclides that lead to the formation of complexes, precipitation and coprecipitation with iron and manganese oxides, minerals formation.

Microorganisms in natural ecosystems determine the rate of litter destruction and release of radioactive isotopes from it. The ability of fungi to greatly accumulate radioactive isotopes of cesium and strontium makes them one of the key groups of organisms that contribute to the extraction of radionuclides from hardly available forms and their involvement in the biological cycle.

Complexity of the soil system limits the possibility for practical implementation of microbiological techniques in agricultural radiology. The second obstacle is the limited choice of means and methods for purposeful change of microbiological processes in the soil.

In Institute of Radiobiology of National Academy of Sciences of Belarus conducted a complex of investigations showing that using of microbiological preparation EM-1 and prepared with it compost (bokashi) allows to achieve a significant reduction in the accumulation of ^{137}Cs, ^{90}Sr and transuranic elements by crops, while increase their productivity. An even more pronounced effect is achieved by the combining EM-1 with biochar, mineral-sorbent trepel or potassium fertilizers.

Mycorrhizal fungi play an important role in the mineral nutrition of plants. They may increase biological availability of elements and increase sucking area of root systems. It is known that edible mushrooms have a high ability to accumulate cesium in fruit bodies. But impact of mycorrhizal fungi on root uptake of radioactive isotopes of cesium is not clearly known.

We investigated influence of barley seeds treatment by commercial endomycorrhiza inoculant MycoApply SuperConcentrate on accumulation of ^{137}Cs in the aboveground biomass of plants. The greenhouse experiment was organized in phytochamber. Mix of sod-podzolic soil from Chernobyl NPP exclusion zone and peat (1:1) was used as substrate for plant growing.

In the control variant activity concentration of ^{137}Cs in the aboveground biomass of barley was 583±17 Bq kg^{-1}. Optimal dose of the inoculant (2 mg per 100 seed) increase accumulation of the radionuclide on 60%. Increasing the dosage of the mycorrhizal inoculant to the 15 and 30 mg per 100 seed causes the reduction of ^{137}Cs accumulation to 450±50 and 434±74 Bq kg^{-1} correspondingly.

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COMPARATIVE DISTRIBUTION OF Cs-137 AND MINERAL NUTRIENTS IN ABOVE- AND BELOWGROUND BIOMASS OF GRASSY ECOSYSTEMS

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Caesium has been assumed as microelement with indeterminate significance in plant nutrition, but was beyond the main interests of specialists for a long. A different situation aroused with Cs-137 entering into environment after nuclear tests in the atmosphere and accidents at nuclear power plants when biogeochemical cycle of the radionuclide began to take on a new meaning due to its radioecological consequences.

To gain greater insight into Cs-137 behavior in grassy ecosystems in comparison with main flux of mineral nutrients the field observations within post-Chernobyl landscape of Plavsky radioactive hot spot (Tula region, Russia) have been performed. The major cultures of crop rotation in chernozem region (wheat, spring barley, potatoes, soybean, amaranth, perennial grass mixture with galega and bromegrass) as well as semi-natural vegetation of dry and wet meadows were selected for the study. Above- and belowground parts of biomass were separated for examination of Cs-137 and mineral nutrients (ash elements) content.

Current level of Cs-137 contamination of dominant arable chernozems of the area is 140-210 kBq/m^2, in geochemically subjected alluvial soils it increases to 220-280 kBq/m^2. To avoid the difference in Cs-137 content in soils of different plots the transfer factor (TF) values (the ratio of Cs-137 activities in vegetation and in soil) were calculated.

It has been found that TF of Cs-137 in total biomass varied from 0.01-0.08 (galega, potatoes, soybean, amaranth, meadow herbs) to 0.15-0.32 (wheat, barley, meadow grasses) when ash elements content was in a range 5.2-16.4%. As this takes place, the order in which TFs and mineral nutrients content tend to rise is quite different: some crops with high content of ash elements are characterized by relatively low TFs of Cs-137 (potatoes, amaranth), and some crops with low ash content are characterized by relatively enlarged TFs of Cs-137 (wheat, barley). In sum, there is not any pronounceable correlation between Cs-137 and mineral nutrients in plants – correlation coefficient is not significant (-0.44).

Moreover, given mineral nutrient distribution between aerial and belowground parts of vegetation is more or less homogeneous, when Cs-137 is deposed in roots of cultural and wild cereals.

Commonly the portion of Cs-137 in ash elements of plants is negligibly small and falls between $2 \cdot 10^{-12}$ and $1 \cdot 10^{-11}$% for dicotyledonous (minimal for galega) and between $1 \cdot 10^{-11}$ and $5 \cdot 10^{-11}$ % for monocotyledonous (maximal for wheat and barley). This is strengthened the case for significant discrimination of Cs-137 root uptake from contaminated soils.

By this is meant that Cs-137 is not a neutral trace element consumed with total nutrients fluxes, but looks like ecotoxicant with reference to which plants are adopted on the basis of rhizofiltration anr rhizostabilisation strategy.

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RADIOECOLOGICAL SITUATION AT THE CHERNOBYL NPP COOLING POND

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The Shelter encasing the 1986 destroyed unit 4 of the Chernobyl NPP still remains a dangerous nuclear facility. Inside the Shelter remained about 96 % of the irradiated nuclear fuel inventory of the reactor before the accident, i.e. 180 t of Uranium of total radioactivity $7x10^{17}$ Bq, which exists now as radioactive fuel dust, fragments of destroyed fuel elements, molten fuel lava and solutes of Uranium and Plutonium in water. Although the Shelter erected in autumn 1986 reduced the radioactive effluents from inside towards the environment through cracks, leaks and the ventilated air stream trough the chimney, nevertheless a remarkable amount of radioactive aerosols was released over the last years. Such releases were observed especially in situations when mechanical work was performed inside e.g. drilling of holes trough concrete walls etc. Vibrations of building constructions caused rise of dust loaded at surfaces which got airborne and followed the air stream. To reduce such releases in the future years significantly when the Shelter will be dismantled and the radioactive materials will be removed the New Safe Confinement (NSC) was erected in the last years and shifted over the Shelter and the machinery hall in November 2016. It will however be unlikely that the NSC will completely isolate the environment from the radioactive inventory inside. Besides the original radioactive ground contamination at the Shelter site covered after the accident with gravel, sand and concrete layers which partly were removed in connection with the buildup of the NSC at the western industrial site the cooling pond of the NPP more and more gets a source of radioactive aerosols. Due to the fact that in recent years the spent fuel elements of units 1-3 have been removed from the spent fuel pools and transported into the wet interim fuel storage facility at the NPP site there is no more need to maintain the water level of the cooling pond at nominal height over the level of the adjacent Pripyat river. In the last years already a big part of the banks contaminated with radioactivity fell dry and got in contact with air. In the present paper the development of the water level during the last years as well as the radioactive contamination in the water and in the sediments of the cooling pond are reported. These data compiled in a comprehensive data base are the results of a systematic multiyear measurement program allowing also conclusions for future developments.

Co-60 MICROPARTICLES AS MARKERS OF THE REDISTRIBUTION OF ARTIFICIAL RADIONUCLIDES IN THE BOTTOM SEDIMENTS OF THE YENISEI RIVER FLOODPLAIN (RUSSIA)

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For decades, the Yenisei River has received artificial radionuclides from the Mining-and-Chemical Combine (MCC) ROSATOM (Krasnoyarsk, Russia). Bottom sediments (BS) of the River accumulate radionuclides from water. Thus, BS both store information on the range of contaminants present in the water and provide habitat for many species of living organisms, which may be adversely affected by high concentrations of these contaminants. Therefore, it is important to obtain the data on the distribution of radionuclides in BS. Sediment layers located downstream of the MCC discharge point contain a wide range of artificial radionuclides: Eu isotopes, ^{137}Cs, ^{60}Co, ^{90}Sr, and transuranium elements.

The present study investigated the vertical distribution of ^{60}Co, ^{137}Cs, and ^{152}Eu in cores of bottom sediments in three stretches of the River downstream of the MCC discharge point: (1) within the limits of the 30-km zone, (2) at a distance of 240-260 km, and (3) at a distance of 750-860 km. The vertical distribution of radionuclides in bottom sediments is rather complex, with a number of extrema. The usual distribution of 60Co in core layers is the same as the distribution of ^{137}Cs and ^{152}Eu, with some vertical shift due to different mobility of the radionuclides. At the same time, ^{60}Co has a shorter half-life (5.27 years) than ^{137}Cs and ^{152}Eu, and, by now, its activity concentration in the BS has decreased to levels that are 1-3 orders of magnitude lower than those for ^{137}Cs and ^{152}Eu.

After a great flood at the Yenisei River in 2006, layers of silt about 2 cm thick were found in the 30-km zone of the River floodplain; activity concentration of ^{60}Co in them reached 1500 Bq/kg, with ^{137}Cs activity concentration no higher than 140 Bq/kg. That could be due to the washout or discharge of ^{60}Co with the MCC process water. After that event, since 2007, new ^{60}Co maxima have been detected in the upper layers of the cores as far as 860 km downstream of the MCC discharge point. In these sediment layers, ^{60}Co was present in the form of microparticles, which had been extracted by sequential quartering of the initial sample. The layers containing ^{60}Co microparticles were found in all three stretches of the River, and this suggests the conclusion that their source was MCC operation rather than a “lost” industrial point source. The presence of the anomalous layer with ^{60}Co microparticles in the upper part of the sediment core can be a marker of the formation of this layer during the 2006 flood or 1-2 years after it. This fact can be used as the basis for more accurate dating of the sediment layers downstream of the MCC discharge point. Thus, because of the complex hydrological regime of the Yenisei River, radionuclides are both buried in the bulk of bottom sediments and periodically transported to the upper layers of the sediments downstream of their initial location.

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COLONIAL RODENTS IS USEFUL MODEL FOR PREDICTION OF STRONTIUM TRANSFER TO TERRESTRIAL MAMMALS

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Concentration ratio of radionuclide ($CR_{wo\text{-}soil}$) is the ratio of activity concentration of radionuclide in whole organism to the activity concentration of radionuclide in soil. Calculation of these coefficients is necessary for assessment of the exposure of wildlife to ionizing radiation. The $CR_{wo\text{-}media}$ approach has some limitations; in particular, it assumes equilibrium in the environment between the media and the exposed wildlife (IAEA, 2014). There is a lot of time for establishing of equilibrium strontium-90 in soil-mammal system because of a long period of accumulation and excretion of this radionuclide (Malinovsky et al., 2013).

Modern estimates of $CR_{wo\text{-}soil}$ for terrestrial mammals (herbivorous) have a very high level of indeterminacy (arithmetical mean is 2.5, standard deviation of arithmetical mean is 3.0) (IAEA, 2014). In previous research we supposed $CR_{wo\text{-}soil}$ of sedentary animals for better accuracy of $CR_{wo\text{-}soil}$ (Modorov et al., 2017). The model object were juveniles of root vole (*Microtus oeconomus*) with body weight less then 12.5g which not so far leave the nest and still occupy mother territory. For this animals from East Ural Radioactive Trace zone (EURT) trapped in July $CR_{wo\text{-}soil}$ is 0.2±0.04. So standard deviation of $CR_{wo\text{-}soil}$ is 20% from mean. The goal of our research is to find other group of sedentary animals for accurate estimate of $CR_{wo\text{-}soil}$.

Narrow-sculled vole (*Lasiopodomys gregalis*) formed colonies partly consisting from relative individuals (Modorov, 2016). The number of animals is really high on the territory of EURT zone in some years so it possible to get representatives sample from there. We supposed relatives animals from the same colony (family) will had similar level of strontium-90 accumulation like *Ellobius talpinus* (Starichenko, 2011).

There are 4 sites with square no more than 1 ha located in EURT zone were used for trapping voles. Strontium-90 concentration in bones was defined using not destroying bones method (Malinovsky et al., 2013). Data about variability of 6 microsatellites (Ruda et al., 2009) used for definition of relatives relationships. Structure 2.3.4 (Pritchard et al., 2000; Falush et al., 2003) used for samples clustering. Animals with support of one from the 5 clusters more than 75% from the same colony supposed to be relatives. In total 108 animals were analyzed. For estimate of strontium-90 accumulation variability we used comparison of coefficient of variation (CV) in whole voles sample from this site and CV strontium-90 accumulation for individuals from the same family.

We distinguish 5 vole families on 4 sites with number from 7 to 25 individuals. CV of strontium-90 accumulation of animals from the same family was lower than CV of strontium-90 accumulation for animals from the whole site in 1.04-4 times. So using narrow-skull voles family like a model for estimate of $CR_{wo\text{-}soil}$ strontium-90 can be used for uncertainty reduction for existing index values.

THE MIGRATION ACTIVITY OF RODENTS IN THE TERRITORY OF EURT: COMPARISON OF ESTIMATIONS

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The dynamics of rodent population in the territory of the East Ural Radioactive Trace (EURT) passes a number of stages connected with the development of the hereditary radioadaptation. Acute radiation deaths, devastation are replaced by colonization "clean" immigrants. They form flowing population. Individual physiological radioadaptation develops in the background of high sickness rate. On its base grow up hereditary radioadaptation. The condition of stability– decrease of going away adapted individuals and inflow of non-adapted ones. The proportion of migrants in terrestrial rodents we evaluated how 10% or less, in the control areas - 10-30%. But such reduction of migration is not effective enough and leads to the imperfect adaptation which is accompanied by a great number of nonlethal cytogenetic, hematologic, immune deviations. Perfect adaptation (without defects) discovered (Lyubashevsky et al, 2002; Starichenko, 2004) in colonial underground northern mole voles (Ellobius talpinus Pallas, 1770). There are no immigrants in the colony. This requirement is a perfect adaptation. The settled life of rodents in EURT is confirmed by the works (Vasilyeva, etc., 2003; Bolshakov, etc., 2011, 2012). Development of specific frequency of not metric alternative signs of cranium and lower jaw morphology changes were microevolutionary events and a lot of settled generations had required. However on Chernobyl and in EURT (Meeks, etc., 2006, 2009; Modorov, Pozolotina, 2010) genetic distinctions in impacted and contiguous groups have not been revealed. It can be regarded as the negation of isolation of the impacted populations. But this contradiction is imaginary: the complex of hereditary distinctions has epigenetic nature (Vasilyev, etc., 2003), which agrees with experimental data (Kovalchuk, 2010; Lyubashevsky, Starichenko, 2012). Over against (Grigorkina, Olenev, 2004, 2007; 2013, 2016) migration changes are denied that also denied possibility of radioadaptation. The authors argue the flowing population of rodents for the "configuration" of EURT (long narrow strip). Really, rodents in intact environments run 6-8 km easily (the width of EURT). However, the reduction of mobility in unfavorable environment is behavioral adaptation providing selective advantages. The authors oppose radioadaptation of northern mole voles to aboveground rodents, explaining this by its little mobility. But in the background territories its migration is authentically higher than in the other rodents (Evdokimov, 2012). The isolation has occurred exactly for absolute radioadaptation formation.

Thus, microevolutionary processes developing in the irradiated populations lead naturally to their functional isolation giving an opportunity of further morphophysiological transformations.

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SORPTION OF FISSION PRODUCTS AND ACTINIDES ON MONOCATIONIC TYPES OF BENTONITE CLAYS

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Processing and disposal of radioactive wastes of various degrees of activity is one of the most serious and urgent problems of the world nuclear power.

In recent years, methods of radioactive waste of disposal in near-surface or deep geological formations have been developed to prevent the uncontrolled spread of radionuclides into the environment. Given concept presumes the use of multi-barrier protection system. It includes various combinations of both engineering and natural, geochemical barriers.

Bentonite clays can serve as natural protective barriers for low- and intermediate-level waste storage. They possess such advantages as low water permeability, large sorption capacity for the majority of radionuclides, considerable swellability, relatively high heat resistance, thermal conductivity and ductility. Bentonite clays have high sorption capacity that exceeds this property of other natural sorbents.

This is due to the specific structure of the crystal lattice framework and extended surface.

In this paper we were investigated the nature of the sorption of actinides and fission products on monocation forms of bentonite clays. Forms of sorbed radionuclides in the studied samples of bentonite clays were identified by Tessier method.

This paper presents the study of the surface, the capacitance and adsorption properties of bentonite clays in monocation forms regarding the sorption of actinides and fission products.

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PERMEABLE BIOLOGICAL REACTIVE BARRIERS FOR NITRATES AND RADIONUCLIDES IN ENVIRONMENT

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Since the beginning of the XX century the development of industry has led to the increase in pollution of underground waters suitable for consumption and domestic needs with toxic metals, radionuclides, nitrogen compounds, pesticides and hydrohalogenic substances. Such pollutants might migrate with the flow of underground waters for an unlimited time and cause toxic effects in peoples' organisms.

The project meets the objectives of the selected priority, as it affects the comprehensive study of reservoir fluid samples near to the conserved storage of radioactive waste and is aimed at reducing the risks of spreading the migrable toxic waste components.

The aim of this work is to find and study the properties of natural materials and their modifications, as well as the features of the biofilm formation by microorganisms of different physiological groups and their metabolic capacity to establish biogeochemical permeable (reactive) multifunctional barrier in underground waters to prevent the spreading of radionuclides (U, Tc, Pu), heavy metals (Cd, Cr), and nitrate ions.

Materials such as natural zeolite, shungite, perlite and vermiculite and their modifications were studied. Distribution coefficients (Kd) and desorption rate for radionuclides on these materials considering different geochemical characteristics of natural waters.

High effective stains of microorganisms (Pseudomonas veronii, Pseudomonas mandeli, Pseudomonas asplenii, Pseudomonas putida, Shewanella putrefaciens, Shewanella putrefaciens, Shewanella xiamenensis, Shewanella oneidensis, Pantoea agglomerans) with ability to reduce metals from higher oxidation state and nitrate to molecular nitrogen were isolated from radionuclides contaminated aquifers. Biocompatibility of this microorganisms and inorganic materials and ability to form biofilms on such mineral porous materials were investigated.

We found high efficiency of shungite for pertecnetate and zeolite for uranyl removal.

It was found that microorganisms where able to form stable biofilms on mineral surfaces and cause uranium, technetium, chromium and nitrate reduction due to cell respiration processes under anaerobic conditions.

In lab modelling experiments with natural microflora of subsurface water samples from polluted with nitrate ions horizons we found high levels of nitrate reduction to molecular nitrogen. The decrease of Eh in these systems from +120-150 to -60 - -80mv showed the alteration of conditions during the experiment and could cause metal immobilization in lowest oxidation state.

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DETERMINATION OF GAMMA-EMITTING RADIONUCLIDES IN PISTACHIO SAMPLES FROM SOUTHEASTERN ANATOLIA REGION, TURKEY

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As an important component of earth, natural radionuclides such as uranium and thorium series radioisotopes and natural ^{40}K should be determined due to their existence in water, soil, sediment, plants and air. Hence several health effects such as chronic diseases occur through inhalation and ingestion of radionuclides in a long term exposure. However, the radioactivity levels of pistachio in Turkey, one of the most prominent appetizers in Southeastern Anatolia region, were not studied previously in spite of its contribution to the external doses absorbed by the population. In the present study, pistachio samples collected from seven districts in Gaziantep city of Southeastern Anatolia, Turkey has been analyzed for ^{226}Ra, ^{232}Th and ^{40}K by using gamma ray spectroscopy to obtain natural radioactivity levels as a part of environmental monitoring. The measured activity concentrations showed that the mean values are comparable with the reported International average (UNSCEAR, 2000).

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HOMO/HETEROGENEITY OF Cs-137 DISTRIBUTION WITHIN PLOUGHED HORIZON OF ARABLE CHERNOZEMS – 30 YEARS AFTER CHERNOBYL ACCIDENT

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Plowing is certainly the most significant factor for Cs-137 penetration deep into the arable soils profile. It is expected that after an accident of radioactive fallout Cs-137 distribution within ploughed horizon becomes rather homogeneous upon 2-3 years of agricultural practice as a result of agroturbations when plowing, disking, harrowing, ets.

To test the assumption of Cs-137 homogeneous distribution within ploughed horizon of arable soils the study in the area with chernozem soil cover that ~30 years earlier was affected by Chernobyl fallout (Plavsky hotspot, Tula region of Russia) have been conducted. The 30-cm top layer involving current ploughed (Ap, 0-13 cm) and old ploughed (Aop, 13-29 cm) horizons have been examined separately and on a number of depths: 0-10 cm, 10-20 cm, 20-30 cm, as well as thin 3(5) cm layers.

Cs-137 activities in Ap were 454±52 Bq/kg (81 kBq/m^2), in Aop 420±37 Bq/kg (86 kBq/m^2), and they add up to >98% of total Cs-137 in soil. This clearly demonstrated the use of deep plowing after Chernobyl accident as a countermeasure against radioactive pollution.

At the same time more detailed study of Cs-137 distribution within Ap horizon have revealed incomplete homogeneity of the radionuclide in soil mass. The difference between separate layers of Ap reached 50-80 Bq/kg when analytical error for Cs-137 activity in soil not exceeded 10% (40 Bq/kg). As a rule maximal activity of Cs-137 was fixed at the depth 10-20 cm (especially in the layer 12-15 cm), which is usually excluded out of agroturbations when cereals are cultivated. So to some extent the radionuclide root uptake by cereals occurs from relatively less contaminated soil layer. The probable reason of a small decreasing in Cs-137 activities and supplies in 0-10 cm layer could be accelerated erosion in constantly ploughed topsoil accompanying with losses of thin Cs-containing soil particles.

Distribution of Cs-137 within Aop horizon or within 20-30 cm soil layer also demonstrated definite heterogeneity. In this case Cs-137 activities regularly reduced with a profile depth in ≈20-25% each 5 cm, that reflecting, on the one hand, periodical input of the radionuclide from Ap during deep plowing under potatoes, and on the other – transition to subarable horizon of chernozem.

Therefore, some heterogeneity of Cs-137 distribution within ploughed horizon of arable chernozems of Plavsky radioactive hotspot may be noticed even nowadays, 30 years after Chernobyl accident. Preliminary profile distribution of Cs-137 by genetic horizons and then more detailed Cs-137 quantification in ploughed (+ old ploughed) horizon(s) taking into account agrotechnical characteristics of various crops cultivation should be done for the purpose of representative radioecological assessment in this connection.

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^{210}Pb, ^{7}Be and ^{137}Cs in snow deposits in different landscape zones of the South of Western Siberia

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The preliminary estimation of ^{7}Be, ^{210}Pb and ^{137}Cs fallout in different landscape zones of the extensive region of the South of Western Siberia (Russia: The Novosibirsk region, Altai territory, Altai Republic) during the winter period was carried out. Studying of snow samples allowed to receive fallout density estimates for $^{210}Pb_{atm}$, ^{137}Cs and ^{7}Be atmospheric deposition in this region. It should be noted several features. First, fallout density of ^{137}Cs deposition in comparison with $^{210}Pb_{atm}$ and ^{7}Be is slight and does not exceed 1 Bq/m^{2}. Secondly, fallout densities of $^{210}Pb_{atm}$ and ^{7}Be deposition are comparable on absolute values. During four winter months this parameter for ^{7}Be was equal 32-34 Bqm^{2} in a mountain taiga zone and 68-85 Bqm^{2} in foothill and forest-steppe zones. For $^{210}Pb_{atm}$ it was 15-40 and 34-57 Bqm^{2} respectively.

Investigation of the studied radionuclides distribution on granulometric fractions of suspended substance of melt waters showed: 1) The largest part of $^{210}Pb_{atm}$ in the studied samples (56-84%) is associated with coarse fraction (> 3 microns). The part of this fraction in the general activity of ^{7}Be is lower and it does not exceed 66%. The minimum value is equal to 6,2%. 2) Considerable part of these isotopes is connected with fine-dispersed fraction (< 0,45 microns: nanoparticles, colloids and the dissolved component). So, the part of $^{210}Pb_{atm}$, being in this fraction, is equal to 8,4-14,4% in samples of mountain taiga and foothill landscape zones, 20,5% in a forest-steppe zone of Altai territory and 42,9% in the northeast of the Novosibirsk region. For ^{137}Cs these values are from 32 to 65%. |The part of this component in total activity of ^{7}Be is even more considerable and can reach 87%. 3) The part of fine-dispersed components of suspended substance with a size of fraction from 3 to 0,45 microns is small in all studied snow samples. For $^{210}Pb_{atm}$ and ^{7}Be it does not exceed 9%, and in most cases it is much lower.

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PRIMORDIAL AND ARTIFICIAL RADIOACTIVITY LEVELS FOR SOIL SAMPLES OF HATAY REGION, TURKEY

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In this study, the radioactivity analysis was performed for soil samples of Hatay province which is in the Southeast region of Turkey. By gamma-ray spectrometry method, the average Radium (Uranium), Thallium (Thorium), Potassium and Cesium activity concentrations of totally 55 soil samples were measured as 23.35±1.40 $Bqkg^{-1}$, 14.55±0.97 $Bqkg^{-1}$, 242.36±20.12 $Bqkg^{-1}$ and 8.20±0.68 $Bqkg^{-1}$ respectively. There are a few values for the Uranium which are a little bit up to the limit value of 33 $Bqkg^{-1}$. All values for the Thorium were lower than the limit value of 45 $Bqkg^{-1}$. Only a few values for the Potassium were little bit up to the limit value of 420 $Bqkg^{-1}$. Nearby the average for Hatay province is still under the limit values which were recommended by United Nations Scientific Committee On The Effects Of Atomic Radiation (UNSCEAR). Finally, by using these activities, ADRA is calculated to get the outdoor Terrestrial Gamma Dose.

Key words: Uranium, thorium, potassium, cesium, activity, ADRA, AEDE, soil, Hatay

PRACTICAL ASPECTS OF LEAD-210 DATING METHOD FROM SAMPLE PREPARATION TO AGE DEPTH MODEL

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The aim of this study is to identify the potential systematic uncertainties and limitations regarding the ^{210}Pb dating method starting with the sampling, radionuclides measurements methodologies and age depth model calculation. The timing of different past processes can be accurately determined solely through absolute dating methods. ^{210}Pb is a radiometric dating method that is increasingly used for dating recent events (150 years). This method should be considered a tool for finding sediment ages and for constructing age depth models. However, the method has a series of limitations which is induced by the precise determination of ^{210}Pb in sediment. For a proper age depth model the identification and attenuation of the systematic uncertainties has a great importance. The determination of the ^{210}Pb activity through gamma spectrometry is not a trivial task due to the low energy (46.5 keV) of its emission and appropriate corrections for attenuation have to be developed. Using the relative method, during the measurement, more than 50% deviation in activity concentration is induced because of different self attenuation coefficient for different sediment layers. A more precise method consists in the measurements through its daughter element ^{210}Po, which is alpha emitter. During the chemical separation, the non-dissolving silicates don`t induce a high deviation in activity concentration, but the wet tracing method has a significant source of systematic error. On the other hand, the different chemical behavior of the ^{210}Po and ^{210}Pb in sediment layer leaves some questions which will be answered in this paper.

MEASURING THE CURRENT STATE OF RADIOACTIVITY OF AIR, WATER AND SOIL IN THE CITY OF NOVI GRAD, REPUBLIC OF SRPSKA

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Subject of this survey is measuring of background artificial and natural radioactivity of air, water and soil in the city of Novi Grad, Republic of Srpska. This is a first step of environmental monitoring of this area before opening of the nuclear waste material disposal nearby in Trgovinska gora in Croatia. Trgovinska gora is located not more than half kilometer beeline from the city of Novi Grad. Previous underground military ammunition repository is turned into nuclear waste disposal nearby natural border (river Una) between Croatia and Republic of Srpska. In order to be able to measure potential leakage of nuclear waste outside of disposal, we made background radioactivity measurements of ^{226}Ra, ^{232}Th, ^{40}K, ^{238}U, ^{235}U, ^{137}Cs, ^{210}Pb, ^{90}Sr, ^{3}H, in the soil, water and mud. Also, we measured ^{222}Rn in the soil and air and gamma dose rates. Measuring places were chosen upstream and two downstream in the city. Measuring results showed typical background concentration for this part of continental Europe.

PLANTS AND MUSHROOM IN REMEDIATION OF RADIOACTIVELY CONTAMINATED AREAS

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Cleaning up of the environment through plants is considered in diverse environmental pollution problems – either through direct uptake of toxic elements, followed by subsequent transformation, transport, or their accumulation in less toxic forms. Moreover, remediation processes are being augmented by plant root exudates and enzymes that induce microbial diversity in the rhizosphere, biochemical activity in the bulk soil and mineralization. Plants deal with contamination through the strategies of stabilization, exclusion, detoxification and/or their storage in specific cells or cell organelles (vacuoles, cell walls).

Plant families such as Brassicaceae, Papilionaceae, Caryophyllaceae, Poaceae and Asteraceae are the most important and offer best potential for metal phytoremediation. Amongst these, species belonging to family Asteraceae shows bio-removal potential of heavy metals and radionuclides, such as Sr, Cs and U. Uptake of radionuclides like radioactive Cs and Sr and other heavy metals by plants is thus affected by several factors naturally present in the soil. Phytoremediation of radionuclides has many advantages over the traditional treatments like the excavation of large volumes of soils and their disposal at an (interim-) storage sites. Firstly, in phytoremediation the soil is treated in situ, which does not cause further disruption to the soil dynamics. Secondly, once plants are established, may remain used for sequential harvests for constantly removing pollutants.

In case of mushrooms several factors influence the bioaccumulation of trace elements. Under natural conditions, elemental accumulation may vary due to major factors like, the substrate on which it is growing (and related bedrock geochemistry), fungal lifestyle (as for example, growing as saprotrophs), species etc. Other factors like, organic matter content, pH/Eh conditions, moisture availability, porosity as well as the source term of the contaminants influences the elemental uptake, however, the uptake process is poorly understood in case of macro fungi.

Wildly growing mushrooms are rich in minerals (including radionuclides), the amount of which varies considerably in different species collected from the same area. Several reports suggest that mushrooms are efficient accumulators and bio-indicators of radionuclides like caesium (^{137}Cs); potassium (^{40}K) and therefore they are susceptible. Some mushroom species are reported to accumulate a specific trace element within their fruiting bodies much more (least about 100 times) than the normal values on the same substrate in other species. Very high concentrations of elements like Hg, Cd, As, Se, Sb, Ag, Au, Cs, Rb, V, and Zn are reported to be accumulated by some mushrooms.

The details of both plants and mushroom remediation strategy are going to be discussed in the meeting.

DETERMINATION OF GROSS ALPHA AND GROSS BETA ACTIVITY CONCENTRATION IN MARINE SEDIMENTS IN THE MARMARA EREĞLISI (TEKIRDAĞ, TURKEY)

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Environmental radioactive contamination increased as the consequences of the loss of control of radioactive materials originate from the anthropogenic activities as well as natural radionuclides presences. A survey of gross alpha and gross beta activity concentration in core sediment specimens was carried out in a district affected by industrial wastes, discharges from settlements and touristic resorts, marine transportation, fishing and agricultural activities. The core samples were collected from seven stations in Marmara Ereğlisi, where is a small island, on the northern coastline of the Marmara Sea. The counting system used in this study is a low-background counter (Berthold, LB 770 10- channel α–β low-level counter). The gross alpha activity concentration in sediment samples ranges from 162,48- 439,07 Bq/kg and the gross beta activity concentration varies from 39,77-1146,52 Bq/kg. In general, the gross beta activities were higher than the corresponding to the gross alpha activities. The results show sediment from the investigated area may be an anthropogenic pollution affecting human health and organism in this biota.

Key words: Gross alpha, Gross beta, Marmara Sea, pollution, radioactivity, sediment

Radiology

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SAFETY OF RADIOGRAPHIC IMAGING IN PREGNANCY

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There are many false assumptions, both in the general population and among physicians, regarding the influence of radiation on pregnant patients and the fetus during diagnostic procedures, in spite of scientific facts based on studies. These false assumptions are mostly based on the idea that every diagnostic procedure using ionizing radiation is a cause for serious concern and that artificial abortion as a possible solution might be considered. We analyzed data from counseling of pregnant patients exposed to ionizing radiation during diagnostic procedures in the Merkur University Hospital during a 4-year period. In this period, 26 patients presented for counseling after exposure to diagnostic ionizing radiation during pregnancy. Results showed most of these patients to have been exposed to radiation between the 2nd and 3rd week of gestation (36%), between the 4th and 5th week 32%, before the 2nd week 24%, and after the 6th week of gestation less than 8%. To provide reasonable estimate of fetal doses, Report No. 174 from the National Council on Radiation Protection and Measurements (NCRP) was used. Data from the Report include estimate of the fetal dose from direct and indirect exposures. The mean doses were up to 0.01 cGy in 46.2%, 0.01-0.15 cGy in 19.2%, 0.2-1 cGy in 26.9% and 1 cGy or more in 7.7% of patients. None of the counseled patients had medical indication for abortion, even though in a small percentage of patients abortion was a personal subjective decision. Considering that there are no Croatian guidelines for counseling patients exposed to ionizing radiation during pregnancy, it is recommended to use the International Commission on Radiological Protection guidelines in the management of pregnant patients exposed to ionizing radiation.

RADIOLOGY OF RARE CYSTIC FORMATIONS OF THE PANCREAS

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Purpose. To identify the opportunities of preoperative differential diagnosis of rare cystic formations of the pancreas (RCFP).

Materials and methods. 156 patients with RCFP were examined and treated (2004-2016). Preoperative examination: ultrasound, CT and MRI with bolus contrast enhancement. Morphology: intraduct papillary mucinous tumor (IPMN-49), solid-pseudopapillar tumor (SPPT-32), cystic form of duodenal dystrophy (CDD-72), cystic teratoma (1), lymphangioma (1), echinococcus cyst (1).

Results. IPMN: 77.5% male. Diagnosed with three types: from the main pancreatic duct (MPD) (29(59.2%), of the branched-ducts (11(22.4%), mixed (9(18.4%). Radiology criteria: advanced duct, fusiform with lesions of MPD or cystic cluster structures in branched-ducts and mixed; seal its walls; parietal papillary growths, there may be a single extended branched-ducts and tumor masses around MPD. Preoperative verification IPMN 83.7%. Priority - MRI.

SPPT: 93.8% women. Radiology criteria: formation size <5,0 cm in diameter: heterogeneous solid structure with a small cystic inclusions, fluid-filled with a hemorrhagic component; formation size >5,0 cm in diameter: heterogeneous solid structure with cystic inclusions or cystic structure with a slightly pronounced parietal solid component. Preoperative verification SPPT 68.8%. Priority - MRI.

CDD: 86.1% male. Radiology criteria: thickening of the duodenum wall with cystic formation, varying degrees of duodenal stenosis. Location gastro-duodenal artery on the right of formation is the main differential diagnostic criterion for the localization in the duodenum wall. Preoperative verification CDD 94.4%. X-rays is also necessary.

Conclusion. Radiology criteria of IPMN and CDD are well-defined.

Development of diagnostic criteria SPPT requires the accumulation of more observations in one hand and analysis of information. Currently, an important complement to the diagnosis of SPPT is anamnesis.

MRI should be preferred in the algorithm of the survey at suspicion of RCFP.

DIAGNOSTIC EFFICACY OF CONTRAST-ENHANCED ULTRASOUND FOR RENAL CELL CARCINOMA

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Clear cell is the most frequent histologic form of renal cancer, 70-80% of all cases of renal cell carcinoma. Ultrasonic echocontrast characteristics of clear cell renal cancer are described in literature rather well.

Purpose: to define possibilities of contrast-enhanced ultrasound (CEUS) in assessment of clear cell form of renal cancer degree of malignancy.

Materials and methods. The results of CEUS (SonoVue) at 42 patients with the verified cell form of renal cancer, treated at A.V. Vishnevsky Institute of surgery (from April, 2011 to March, 2015) were retrospectively studied. Patients have been divided into two groups (according to S.A. Fuhrman (1982): the first group - 27 (64.3%) patients with Grade I-II degree of malignancy; the second - 15 (35.7%) patients with Grade III-IV.

Results. Our results suggest that CEUS features of diffuse heterogeneous enhancement, washout in the late phase, and perilesional rim-like enhancement allow confirmation of renal cell cancer.

The average amount of neoplasm in the greatest measurement in the first group was 43.51±14.75 mm, in the second group 76.12±25.41 mm ($p<0.05$).

Contours of neoplasms in the first group were accurate and equal mainly, were traced throughout; in the second group indistinct, uneven, were not traced in places.

Contrast enhancement:

in an arterial phase at neoplasms of the first group came earlier and was more intensively, than at neoplasms of the second group;

in a venous phase at neoplasms of the first group was more intensive, in comparison with the second group;

in the delayed phase contrast substance washouted rather evenly at neoplasms of the first group, washing out happened slowly and unevenly in the second group.

The structure of neoplasm at contrast enhancement in the first group was more uniform with insignificant sites without contrast (tumor necroses); in the second group the structure was expressed heterogeneous with considerable sites without contrast of bigger or smaller degree of expressiveness (massive necroses in a tumor) ($p<0.05$).

Conclusion. The parameters allowing at CEUS to differentiate the degree of malignancy of clear cell renal cancer with a bigger share of probability are determined.

MORPHOMETRIC CHARACTERISTICS OF THE INFRAORBITAL FORAMEN ON VOLUME-RENDERED CT SCANS

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Background. The infraorbital foramen (IOF) is an opening present bilaterally on the anterior surface of the maxillary body. It transmits infraorbital vessels and nerve. Earlier studies have shown clear population variations in morphological characteristics of IOF. Knowledge of their precise localization is essential to avoid injury neurovascular bundles passing through this foramen.

Aim. In this study, we aimed to analyze the variability in the size and localization of IOF with respect to the surrounding anatomical bony landmarks using three-dimensional computed tomography (3D-CT) with the volume rendering and evaluate these morphometric parameters in relation to gender and side.

Material and methods. The cranial CT scans of 60 living adult subjects, without any trauma or malformation of facial bones were included in study. Data of the subjects were collected in the Center of Radiology, Clinical Center Nis, Serbia. Morphometric measurements made included transverse and vertical diameter of IOF foramen, distance from IOF to facial midline, distance to lateral margin of the piriform aperture, distance to infraorbital margin and distance to maxillary alveolar border. All measurements were done bilaterally and performed with a digital coordinate caliper. Obtained results were statistically analyzed.

Results. Observation of 120 hemi-skulls revealed that the IOF was present in all of them. The average transverse diameter of the foramen was 2.8±0.9 mm and the average vertical diameter was 3.4±0.9 mm. The IOF was located at an average distance 26.2±1.7 mm from facial midline, 14.9±1.3 mm from lateral margin of the piriform aperture, 9.1±1.0 mm below the IOM and 28.41±2.9 mm above maxillary alveolar border. There were no statistically significant differences between right and left sides or between male and female ($p > 0.05$).

Conclusion. These morphometric characteristics may have important implications for surgical and local anesthetic planning.

Key words: Infraorbital foramen, morphometry, computed tomography, volume rendering

A NEW PROTOCOL FOR CT COLONOGRAPHY

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Colonography CT is performed in supine and prone decubits. We compared this standard technique with another in supine and right lateral decubits. A beginner radiologist evaluated 57 Patients in the new way and 42 in the standard one. A middle experience radiologist evaluated 113 Patients in the new way and 40 in the standard one. A great experienced radiologist evaluated 93 Patients with new technique and 47 in standard way. Every Patient was evaluated from a second good experienced radiologist also. The new technique improves the diagnostic accuracy in the low and middle experienced radiologist because it increases sigmoid distensibility.

COLONBODY: CAN THIS NEW PROTOCOL BECOME THE STANDARD IN THE STAGING OF PATIENTS WITH COLON OR RECTUM NEOPLASM?

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Colonbody is a new protocol to evaluate Patients with colon or rectum neoplasm. It consists in a total body ct where the abdomen is acquired with the ct colonography protocol after iodine contrast administration.

The distension of bowel is obtained before contrast administration, then an arterial and venous phases are performed. After a change of decubit another bowel distension is performed and a urographic phase is obtained.

48 Patients were evaluated with a 64-slice CT: 24 with incomplete optical colonoscopy. In all cases, this protocol allowed the evaluation of colic and extra-colic elements and improvement of the diagnosis.

For every Patient in this exam, a reduction radiation exposure is obtained; in fact we have three post contrast administration phases. Patients analyzed with standard protocol can have the two post contrast phase in staging ct and a double position scan for CT colonography.

CORRELATION BETWEEN SONOGRAPHIC FEATURES AND CYTOLOGY FINDINGS IN THYROID GLAND NODULES

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Purpose: To assess the reliability of sonography in differentiating benign from malignant thyroid nodules and selecting lesions for fine-needle aspiration (FNA).

Methods: During a 2-year period, the following 7 sonographic parameters were assessed in 129 patients with thyroid nodules: size, number, echogenicity, echotexure, margin regularity, presence of calcifications, and presence of a hypoechoic rim. Sonographically guided FNA was performed on thyroid nodules ≥5 mm in diameter. Out of 184 FNAs, we obtained 168 specimens adequate for cytologic analysis and 16 (9%) nondiagnostic specimens.

Results: FNA diagnoses included 150 (89%) benign and 18 (11%) malignant nodules. Among 53 solitary nodules, 11 were carcinomas and 42 were benign ($p < 0.01$). The mean size of the carcinomas was 28 ± 12 mm versus 18 ± 10 mm for benign nodules ($p < 0.01$). The following sonographic features were significantly associated with malignancy: hypoechogenicity, irregular margins, calcifications, and absence of a hypoechoic rim. Differences in echotexure between malignant and benign nodules were not statistically significant.

Conclusion: Sonographically guided FNA should be performed on thyroid nodules ≥5 mm in diameter with sonographic characteristics that suggest malignancy.

STATISTICAL DIFFERENTIATION OF STAGES IN PARKINSON'S DISEASE BY MAGNETIC RESONANCE IMAGING

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The present research is aiming to provide a refined differentiation between stages of Parkinson's Disease (PD) by analyzing brain magnetic resonance (MR) images and implementing a support vector machine (SVM) classifier. In order to carry out classification, specific features were proposed and extracted from susceptibility weighted images (SWI) at individual level. SWI employs a specific type of contrast that consists in a fully flow compensated, long echo, gradient recalled echo (GRE) pulse sequence for data acquisition. SWI exploits the susceptibility differences between tissues and uses the phase image to detect such differences. The magnitude and phase data are combined to produce an enhanced contrast magnitude image, which is particularly sensitive to iron storage. SWI modality offers a better contrast between tissues, providing relevant information on brain iron deposition, comparatively to proton density, T1, and T2 weighted images. Previous studies showed a correlation between PD and iron deposition in some specific brain areas. The results were validated using a different classification approach like spatial independent component analysis (ICA) and neural networks (NNs). SVM are supervised learning models with associated training algorithms that analyze data in classification task and regression analysis. SVM classifiers perform the analysis of forms based on multivectors, which can successfully be applied on MRI data. SVM was proved to allow the differentiation of healthy subjects from patients diagnosed with PD, and to tell apart two subgroups of patients corresponding to incipient and advanced form of PD, respectively. All data used in this research work were acquired from 41 subjects, divided in two groups: 16 patients with PD and 25 healthy subjects. The group of patients was split in two subgroups: advanced stage patients and initial stage patients. A 1.5T MR scanner was employed for SWI acquisition in all experiments. The rationale of the present study consisted in finding means for faster PD diagnosis and appropriate treatment options, with clear benefits in healthcare and wellbeing of population.

RADIATION EXPOSURE DURING INTERVENTIONAL NEURORADIOLOGY PROCEDURES

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Background: Neuroradiology interventional procedures show great benefit to patients in need but can also result in very high radiation doses. This happens due to the complexity of the procedure, longer time of fluoroscopy and high dose rate in image acquisition mode. The aim of this study was to determine the doses received by patients during interventional neuroradiology procedures.

Materials and methods: This study was designed asobservational clinical study conducted from January 2015 to January 2017 at the Department of interventional neuroradiology, Clinical Center Kragujevac. Data was divided into subgroups based on 200interventional procedures done on Angiodiagnost Pfillips Alura. For each procedure, three dosimetric parameters were recorded: dose-area product, fluoroscopy time, and number of images.

Results: Results showed interdepartment variations, up to four-fold for diagnostic procedures and seven-fold for therapeutic procedures. However, applying the 85th percentile method to the entire dataset, reference standards can be proposed for three types of procedures including diagnostic cerebral angiography (220 $Gycm^2$), follow-up selective cerebral angiography (75 $Gycm^2$), aneurysm embolization (330 $Gycm^2$). Reference standards are also proposed with regards to fluoroscopy time and number of images.

Conclusion: Interventional neuroradiology procedures show significant variability in radiation dose for individual cases, due to patient constitution, radiologist expertise and equipment factors, unlike diagnostic procedures where data are collected for standardized examinations performed on a standard-size patient.

Key words: Radiation, interventional neuroradiology, dosimetry

PROBLEMS OF DIFFERENTIAL DIAGNOSIS BETWEEN TUBERCULOSIS AND LUNG CANCER USING CT SCAN

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In this paper we analyzed the CT and radiographic findings during follow-up of the patients with lung cancer but also we here discussed the problems and doubts about the diagnosis of tuberculosis of the lungs. The patient, 50 years old, from Kragujevac, occurred during the year 2012 due to the symptoms: dry cough and fatigue, which is a smoker almost 32 years and up to 60 cigarettes/day. Immediately after hospitalisation CT chest was done and results showed heterogeneous tumor mass in left lung, measuring 94x65mm in size. Both sides, in other parties of pulmonary parenchyma shows diffuse the oval focal lesions, indicating of secondary deposits, but without mediastinal lymphadenopathy and pleural spaces involvements. Histology confirmed diagnosis of adenocarcinoma, low degree of malignancy and EGFR negative. Tumor was classified as T3NxM and the patient was in clinical stage IV and in the ECOG performance status I. After diagnosis confirmation, chemotherapy was applied including Taxol-CBDCA protocol for tumor treatment, during 6 cycles. After completed 6 cycles of therapy a new CT scan showed that previously described tumor change decreased for more than 50% in volume and focal changes in the lung parenchyma showed also a light regression. After 9 cycles of therapy in December 2012 due to elevated temperature (up to 38C), productive cough, coughing up yellow mucus, pain in the left hemothorax, loss of body weight CT lung re-done again. CT scan of the lungs at that time shows that earlier described changes in the anterior segment of the upper lobe of the left hemothorax have now dimension 50x24mm in size, with a peripheral zone pneumonitis in the upper lobe of the left posterolatera hemeothorax. In the upper lobe of the lung in the front part of the side close to the pleura are present consolidation with the present hypodense zone that resembles the attenuation of fluid and may indicate the softening of the tissue. Bronchoscopy examination revealed a common finding in the larynx, trachea, and both trachea bronchial tree. Cell culture taken from the biopsy of lung tissue was positive for the tuberculosis bacillus and direct scopy revealed the presence of 4 basiclus on 100 investigated field of view. It was concluded that it is tuberculosis and immediately began antituberculotics therapy. The six months after the therapy, CT scan was done again and rsults showed that the earlier described changes in the lung parenchyma are now stationary characteristics in size 54x31mm in right lung parehnim and soft tissue shadow in size 23x28mm. The 4 years after diagnosis of metastatic adenocarcinoma of the lung, in good general condition, ECOG is 0. Tuberculosis appearance are increasingly being during the treatment of tumors, or with the appearance of imunodepession during tumors progression such as lymphomas, leukemia, lung cancer, head and neck and stomach. Differential diagnosis between tuberculosis and lung cancer is difficult and can pose a real clinical challenge, in favor of that is very similar to the symptomatology since involved fever, malaise, sweating, loss of body weight. Imaging methods routinely used in clinics and involving RTG, CT, PET-CT are of great help in such cases. The existence of the TB infection makes it difficult to adequately determine the nodal status in patients with lung cancer. The newly established lymph nodes may be not only the occurrence of tumors may already active tuberculosis or may be progression of TB infection. Only the correct diagnosis can lead to successful treatment as described in this case.

VOLUME COMPUTED TOMOGRAPHY PERFUSION (VCTP) IMAGING OF METASTASIZING RCC: COMPARISON BETWEEN CHANGES IN PERFUSION AND CHANGES IN SIZE IN THE EARLY FOLLOW UP AFTER TARGETED THERAPY - PRELIMINARY RESULTS

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Introduction: The aim of this study was to compare changes in perfusion with changes in size in the early period after targeted therapy of metastasizing RCC using VCTP imaging.

Material and Methods: VCTP imaging was performed in eight patients with histologically verified metastasizing RCC before and one month after initiation of targeted therapy using a 320-slice Volume CT scanner. Blood flow (BF, ml/min/100ml), blood volume (BV, ml/100ml) and clearance (CL, ml/min/100ml) were calculated for both time points using compartmental analysis algorithms. In addition, the longest tumor diameter (LD, mm) was measured. Perfusion parameters and LD before and after treatment were compared using Wilcoxon Signed Rank test and correlation between perfusion and size changes with time to progression (TTP) was performed using the Spearman correlation.

Results: BF and CL were significantly lower after targeted therapy, while BV did not change significantly. Median values before and after therapy were: BF (144 vs.83; p=0.012); BV (4 vs. 4, p=0,483); CL (119 vs.44 p=0.017). Median relative change in BF was -29% and CL -58%. Changes in long diameter LD were not significant, median values before and after therapy were 43 and 37, respectively (p=0.122). Changes in CL showed strong negative correlation with TTP (r=-0.78, p=0.41) whereas BF, BV and LD were not correlated to TTP.

Conclusion: Our preliminary study results indicate that VCTP is able to detect changes in perfusion of RCC in the early period after targeted therapy in which the size of the tumors remains stable. Therefore, VCTP may assess the response to targeted therapy sooner than the currently used changes in tumor size. In addition, CL may be a promising parameter for prediction of TTP.

Key words: Volume Computed Tomography Perfusion (VCTP), tumor angiogenesis, response to treatment

Radiopharmacology

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THE USE OF MILK THISTLE FRUITS FOR THE CORRECTION OF THE RESULTS OF γ-IRRADIATION OF PARENTS IN 2 GENERATIONS OF THEIR POSTERITY IN VIVO AND IN VITRO

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Radiation now is the condition for the existence of humankind. The development of nuclear power is unfortunately associated with the risk of accidents and periodic leak of radiation. Together with the nuclear weapon testing, it leads to an increase of radiation background, and hence to the irradiation of living organisms. Low doses of radiation do not cause an acute radiation sickness, but their consequences are not less destructive than that of high-dose - not so much for the irradiated organism, but for its progeny, which is manifested primarily with genome instability. The complete elimination of the negative effects of radiation is possible only in the 7-10 generation, so the search for ways to correct the effects of exposure does not lose relevance. Among the methods of correction, more attention is increasingly focused on herbal preparations, which, along with low toxicity and broad spectrum of activity have a mild prolonged effect. One of these products are the fruits of milk thistle Silybum Marianum (G.), which along with the flavonoid silymarin contain a complex of biologically active substances with antioxidant and membrane-protective properties. The small intestine, which is responsible for the final steps in the process of digestion and where occurs the absorption of resulting nutrients is one of the most radiosensitive organ, on the activity of which substantially depends the functioning of the whole organism. Therefore, in vivo and in vitro we investigated the impact of a complex of biologically active substances fruits of milk thistle on the functional activity of the small intestine of two generations of posterity of once irradiated male rats. It was established a differentiated effect of milk thistle remedies on the systems of hydrolysis and transport of nutrients from different origin and different degrees of polymerization in the small intestine of irradiated male rats' posterity. It was shown a stable radioprotective effect of milled milk thistle fruits and their hydroalcoholic extract for hydrolysis and transport systems for carbohydrate substrates both in vivo, and in vitro respectively. Specific features of the implementation of the radio corrective action of milk thistle fruit in vitro and in vivo for different substrates were established. The prospects of using herbal remedies from milk thistle to prevent and correct the effects of irradiation of the parents in their offspring were discussed.

Radiotherapy

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COMPARISON OF 3D AND 2D METHODS WITH THE USE OF THREE-DIMENSIONAL IMAGES IN HDR ENDOBRONCHIAL BRACHYTHERAPY

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Purpose: The purpose study is to demonstrate significant differences in dose distribution between 3D and 2D method in the area of the tumor and the tissue located in close proximity to the PTV.

Material and methods: The studies involved a group of 31 patients with advanced lung cancer treated in the Brachytherapy Department of the Subcarpathian Cancer Center in Brzozów from 2011 to 2013. In total, 31 patients and 76 treatment plans were analyzed. The treatment plans 2D and 3D were compared to the PTV dose coverage for V_{85} and V_{100}, and the dose of critical organs, $D_{0,01cm^3}$, D_{1cm^3}, D_{2cm^3} for the heart, spinal cord, esophagus, and V_{20} for the heart and lung healthy.

Results: The results clearly show that the method 3D allows to individually dose distribution for every treatment plan which allows for high control of the dose comprising the tumor while reducing treatment toxicity.

Conclusions: Reference doses with 85% coverage of the PTV in treatment applied with the 3D method are 36% higher than when applied with the 2D method. Treatment plans made by using 3D method based on three-dimensional images. Treatment plans made based on images from the CT scanner contain very precise information on the location and volume of the target and allow for visualization of critical organs that are in the near volume of PTV.

YTTERBIUM SOURCES FOR BRACHYTHERAPY

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Despite the effectiveness of high dose rate (HDR) brachytherapy with iridium sources, the use of heavily shielded canyons and a special technology of source delivery and replacement make brachytherapy with such sources less widespread. The relatively hard radiation of Ir-192 requires heavy and expensive afterloaders and complicates the collimation of emitted photons, leading to possible damages to neighbor critical organs. These problems of brachytherapy can be resolved by using Yb-169, which has an average photon emission energy of 93 KeV (the half-life is 32 days). Compared to other isotopes for HDR brachytherapy, ytterbium requires a much lighter shielding. For example, a tungsten shield of only a few centimeters makes a HDR therapeutic ytterbium source harmless for personnel. A compact and inexpensive desktop device may be used as a source loader with ytterbium. Moreover, treatment quality may be significantly improved due to ytterbium radiation collimation. For example, a layer of only 2 mm of tungsten makes it possible to sufficiently collimate source radiation, the corresponding dose gradient is of the order of 10. These effects are even more important for pulse does rate (PDR) brachytherapy, when a single source is repeatedly introduced in the tumor region in a pulse regime and this procedure continues for many hours. PDR brachytherapy is recommended for treatment of several tumors since, according to oncologists, it combines the clinical benefits of both HDR and low dose rate (LDR) brachytherapy. One of the main problems preventing wide use of PDR brachytherapy is the inconvenience for patients to stay for long periods of time in a concrete canyon. But canyons become unnecessary with ytterbium sources. The use of Yb-169 as an active material can be a way to resolve the shielding problem for PDR, as well as for HDR brachytherapy. We have built an original facility that produce stable start isotope Yb-168 using the AVLIS laser technology. This facility allows us to raise the Yb-168 enrichment level to 50 %. Moreover, it consumes significantly less energy than alternative electromagnetic enrichment facilities. In cooperation with the High Pressure Physics Institute of RAS, we have also developed a new technology for manufacturing high-density ceramic cores of ytterbium oxide. Ceramics density reaches the limit of the theoretical value of 10 g/cm3 for the monoclinic phase. Source cores made from ceramics have high mechanical characteristics and a glassy surface. The use of this ceramics makes it possible to increase source activity without changing the external dimensions of the source. A new compact afterloader specially designed for ytterbium sources is now being developed.

DOSIMETRIC EVALUATION OF TWO DIFFERENT BRACHYTHERAPY TECHNIQUES FOR INOPERABLE UTERINE CERVIX CANCER

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Objective: To evaluate an alternative brachytherapy technique for inoperable uterine cervix cancer, without increasing the risk of toxicity and trying to achieve the same local control of the disease.

Materials and methods: Comparative study was undertaken in order to two different high-dose rate intracavitary brachytherapy applicators to be compared: intrauterine tandem/ring applicators and vaginal cylinder. Prescribed doses were 7 Gy at point A for tandem/ring applicators and 7 Gy at 10 mm from the top of the cylinder applicator. Doses delivered to the rectum, bladder and sigmoid colon were kept below the tolerance limits. Volumes covered by the 100% isodoses, (V100), were compared.

Analyzed were 40 patients, treated in University Clinic of Radiotherapy and Oncology - Skopje in period from May to July 2016, all with locally advanced cervical cancer and realized percutaneous definitive chemoradiotherapy. In 13 of them (32.5%) intracavitary brachytherapy was made with tandem/ring applicators (tandem being 4 cm long) and prescribed dose of 7Gy at point A. The remaining 27 patients (67.5%) due to lack of conditions for tandem/ring application, brachytherapy treatment was implemented with vaginal cylinder and prescribed dose 7 Gy at 10 mm from the top of the applicator.

Results: In order to obtain net tissue which is included in 100% isodose volume, the volumes of cylinder applicators and ring buildups were excluded from the treated volume. The 100% tissue volumes formed in tandem/ring applications and cylinder applications were on average 50.64 cc and 34.80 cc respectively after they were diminished on average by 7.04 cc and 12.90 cc respectively. Because the process of finding tissue volume for the cylinder applications had several steps the uncertainty in determining this volume was 1.24%. Comparing 100% isodose volumes we can conclude that their means differ at the 0.05 level of significance, p value being less than 0.001.

Conclusion: Vaginal applicator may not be used as an alternative therapy technique for patients affected by uterine cervix cancer who does not allow application of tandem/ring applicators.

Keywords: Cervical cancer, intracavitary brachytherapy, dosimetry

DOSE COMPARISON OF ORGANS AT RISK IN CERVICAL CANCER INTRACAVITARY BRACHYTHERAPY: ORGAN WALL VERSUS WHOLE ORGAN CONTOUR

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Introduction. Migration from two-dimensional to three-dimensional intracavitary brachytherapy (ICB) in treatment of inoperable cervical cancer caused the use of dose volume histograms (DVH) in order to observe volume distribution of doses in target volume and/or organs at risk (OAR). However, question remained whether the calculated dose distribution in OAR was the one that corresponded to the one present in real-life conditions, thus emerging the dilemma – what is more real to contour – whole organ or organ wall only?

Material and methods. In this study 15 patients were included with diagnosed inoperable cervical cancer. Prior to brachytherapy all patients received external beam radiotherapy (EBRT) with dose received in 28 daily fractions with total dose of 50.4Gy. ICB consisted of 3 applications (once per week), applied dose of 7Gy in point A, total of 21Gy for whole ICB treatment. ICB used CT simulator, scans were contoured and plans were calculated using the BrachyVision treatment planning software. OAR contours consisted of 5mm outer wall margin contour and contour that encompassed the whole organ. DVH were used for plan evaluation of absorbed doses in 2 ccm organ volume for the whole brachytherapy treatment. OAR dose restrains were 22.32Gy (average of 7.44Gy per brachytherapy fraction) for bladder and 11.91Gy (average of 3.97Gy per brachytherapy fraction) for rectum.

Results. Average values of absorbed doses in bladder for the whole brachytherapy treatment were 4.71Gy for whole organ contour and 4.24Gy for 5mm outer wall contour. Average values of absorbed doses in rectum were 3.47Gy for whole organ contour and 3.28Gy for 5mm outer wall contour. Average dose difference was 0.47Gy for bladder and 0.19Gy for rectum, respectively.

Conclusion. Observed average absorbed doses were lower in OAR contoured as an organ wall (for both bladder and rectum) compared to absorbed doses in OAR contoured as a whole organ. Organ wall contours gave more realistic picture of absorbed OAR doses in ICB treatment.

Key words: Intracavitary brachytherapy, cervical cancer, organ wall

THE WAY TO IMPROVE CONFORMITY OF PROTON AND ION THERAPY WITH PASSIVE SCATTERING

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Proton therapy has remarkable advantages over conventional photon radiation therapy. The proton and ion dose distribution (Bragg peak) allows to spare healthy tissue while delivering maximal dose to a tumor. Today proton therapy is represented by two techniques of dose formation: methods of passive scattering and scanning. The first one implies installation of various beam-forming devices on the beam path for Bragg peak's modification. In the technique of active scanning target is scanned by pencil beam deflected with magnets. The letter technique is considered as more advantageous as it provides the conformance of dose delivery to a tumor of any size with no significant radiation damage to healthy surrounding tissues. However, small targets with the size comparable to the beam's width can be a problem for this technique. In these cases the "old" method of passive scattering may be more effective since it allows to irradiate the whole target simultaneously. But in this case distal edge formation with compensators of standard type inevitably leads to the emergence of hot lesions in the proximal region beyond the borders of target volume. Traditional passive scattering techniques of dose formation with a standard ridge filter a compensator and a collimator fails to provide the conformal dose distribution: either the maximal dose exceeds the tumor volume on its proximate site or the dose changes too much within the target. To solve this problem we suggested a new construction of two component ridge filters. It is supposed to eliminate maximal dose "wings" exceeding the limits of the target volume. We have performed a series of calculations with the help of the original Monte-Carlo code SRNA in order to find the optimal ridge filter construction. The resulting 95% isodose lines do not notably exceed the tumor volume. The usual "wings" of high-dose distributions on their proximate side are absent with the new device. We conclude that the new construction of ridge filters allows to improve the proton/ion therapy quality, especially in case of small targets such as e.g. eye tumors or small brain metastasis. The experimental tests of this method with proton beams of INR linac are now in progress.

SETUP COMPONENT OF PTV MARGIN IN PREOPERATIVE RADIOTHERAPY OF RECTUM CARCINOMA

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Background/Aim. Neoadjuvant concurrent chemoradiation therapy has become the standard for locally advanced rectal cancer. Previous studies showed that preoperative chemoradiation therapy reduced recurrence rate and increased sphincter preservation rate when compared to postoperative chemoradiation therapy. External beam radiotherapy for these patients is conducted in one phase. We aimed to investigate an appropriate setup component of clinical target volume (CTV) to planning target volume (PTV) margin during first phase, without setup protocol.

Methods. External beam radiotherapy was delivered to twenty patients with carcinoma of the rectum. Total prescribed dose was 45 Gy in 25 fractions. The introduction of intensity modulated radiotherapy for neo-adjuvant chemoradiotherapy treatment of patients with rectal cancer has led to a more conformal treatment with less normal tissue irradiated. To ensure target coverage and compensation for both internal and setup uncertainties a PTV margin is needed. PTV is a geometrical concept that takes into account all possible geometric variations and is used for treatment planning to ensure that the prescribed dose is delivered to CTV. The setup margin takes into account uncertainties in patient positioning and alignment of the therapeutic beams during the treatment planning, through all treatment sessions. This leads to a larger treatment volume and possible overlap with organs at risk (OAR), resulting in a higher OAR dose and thereby more toxicity. Patient's skin markers were aligned to the laser system in the treatment room. Everyday kV imaging was made before treatment and we have collected 890 orthogonal images. Systematic (Σ) and random (σ) setup errors were evaluated based on the 2D/2D matched kV images in the longitudinal (lng), lateral (lat) and vertical (vrt) direction. The values of setup component for CTV to PTV margins were calculated using ICRU Report 62 recommendations, Stroom's and van Herk's formulae.

Results. Group of twenty patients included patients with a mean age of 61.8 years with standard deviation of 11.03 years. The standard deviations of systematic (Σ) setup errors were in range from 2.07 to 2.93 mm while the standard deviations of random (σ) setup errors fell in between 1.04 and 3.63 mm. Calculated setup component of CTV to PTV margins were between 2.32 and 9.85mm according to ICRU, Stroom's and van Herk's models.

Conclusion. CTV to PTV margin of 16.85 mm, should ensure that 90% of the patients treated without imaging protocol for rectum cancer irradiation, will receive a minimum cumulative CTV dose greater than or equal to 95% of the prescribed dose. Treating patients with image-guided radiotherapy (IGRT) decreases CTV to PTV margin to 7 mm and decreases volume of PTV 1.8 times (SD=0.26).

Key words: Rectum cancer, radiotherapy, CTV, PTV, margin

ON THE FEASIBILITY OF USING RADIOACTIVE ION BEAMS FOR HADRONTHERAPY

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The use of ions in hadrontherapy leads to a more effective and localized dose distribution. However, in order to fully exploit these advantages the use of range verification techniques are required in clinical practice. In this work, the Monte Carlo particle transport code FLUKA was used to simulate Spread-Out Bragg Peaks (SOBP) of comparable dosimetric performance in an anthropomorphic head phantom, and evaluate how radioactive ion beams can improve Positron-Emission-Tomography (PET)-based range verification. The results obtained, indicate that the use of O-15 and C-11 enhance greatly the reconstructed signal quality for in-beam and in-room PET, respectively, with respect to their stable ion counterparts. Furthermore, although the improvement is greater for on-line PET modalities, off-line imaging acquisition also benefits significantly from the higher, and more localized, activity of positron emitters.

THE COMPARISON OF THE DOSES TO THE HEART AND THE LEFT ANTERIOR DESCENDING CORONARY ARTERY FOR VARIOUS MODES OF RADIATION TREATMENT OF THE BREAST CANCER PATIENTS

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The comparison of the radiation doses to the organs at risk for three modes of radiation treatment of the breast cancer patients.

Methods and materials. The research includes the dosimetric radiation treatment plans for the 20 breast cancer patients with the left-side localization. They all underwent a computed tomography (CT) scan in standard supine position in free-breathing (FB), supine position with Active Breathing Control (ABC) device in deep inspiratory breath hold, and prone position in free-breathing (PP). Three-dimensional treatment plans were made for all 3 CTs. The dose valuations for 3D-planning were carried out for three CT- series. For each mode of radiation the doze-volume parameters of organs at risk were estimated.

Results. For all cases, the contoured heart volume varied from 477 cm^3 - 1056 cm^3, with medium volume 769 cm^3. The best marks such as $V_{25heart}$, medium doses to the heart and LAD, were achieved with on ABC methods ($V_{25heart}$ 4.26%, $D_{mean\ heart}$ 3.13Gy, $D_{meanLAD}$ 13.8Gy) in comparison FB ($V_{25heart}$ 9.49%, $D_{mean\ heart}$ 4.97Gy, $D_{meanLAD}$ 19.55Gy) and PP ($V_{25heart}$ 12.8%, $D_{mean\ heart}$ 9.06Gy, $D_{meanLAD}$ 24.18 Gy) ($V_{25heart}$ P = 0.00153, $D_{mean\ heart}$: P =0.000; $D_{mean\ LAD}$: P = 0.00088), when both the breast and the axillary nodes were included in the volume.

The advantage of the dosimetric indexes for FB and ABC did not change while axillary and supraclavicular nodes were added to the radiation volume ABC ($V_{25heart}$ 3.49%, $D_{mean\ heart}$ 3.08Gy, $D_{meanLAD}$ 13.88Gy) in comparison with FB methods ($V_{25heart}$ 7.91%, $D_{mean\ heart}$ 4.99Gy, $D_{meanLAD}$ 19.89Gy) ($V_{25heart}$ P = 0.00205, $D_{mean\ heart}$: P =0.004; $D_{mean\ LAD}$: P = 0.03).

Radiation treatment in the position on the back with controlled delay of breath on inspiration height contributed to the statistically significant reduction of the heart volume exposed to more than 25 Gy ($V_{25heart}$), mean dose to the heart and mean dose to LAD.

THE ESTIMATION OF THE RADIATION DOSE TO THE LEFT LUNG FOR VARIOUS MODES OF CONFORMAL RADIATION THERAPY OF THE BREAST CANCER PATIENTS

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Objective. The comparison of the radiation dose to the ipsilateral lung for three modes of radiation treatment of the breast cancer patients.

Methods and materials. The research includes the dosimetric radiation treatment plans for the 20 breast cancer patients with the left-side localization. They all underwent a computed tomography (CT) scan in standard supine position in free-breathing (FB), supine position with Active Breathing Control (ABC) device in deep inspiratory breath hold, and prone position in free-breathing (PP). Three-dimensional treatment plans were made for all 3 CTs. The dose valuations for 3D-planning were carried out for three CT- series. For each mode of radiation, the doze-volume parameters of organs at risk were estimated.

Results. For all cases the contoured volume of the left lung varied from 757.1cm^3 -2923.8 cm^3, with medium volume 1751.6 cm^3. The best marks such as V_{25pulm} (with α/β 3.1) и V_{28pulm}(with α/β 9), mean doses to the ipsilateral lung were achieved with the PP (V_{25pulm} (α/β 3.1) - 10,19%, V_{28pulm} (α/β 9) – 9.19%; $D_{mean\ pulm}$ 7.42Gy) in comparison with the FB (V_{25pulm} (α/β 3.1) – 20.72%, V_{28pulm} (α/β 9) – 19.6%; $D_{mean\ pulm}$ 10.42Gy) and ABC (V_{25pulm} (α/β 3.1) – 20.17%, V_{28pulm} (α/β 9) – 19.01%, $D_{mean\ pulm}$ 10.11Gy) and when the breast and the axillary nodes were included in the volume. V_{25pulm} (α/β 3.1) - P=0.00000**, V_{28pulm} (α/β 9) – P=0.00000**; $D_{mean\ pulm}$ - p=0.00002**. There were no revealed advantages of the dosimetric indexes for FB and ABC methods while subclavian and supraclavicular lymph nodes were added to the radiation volume. ABC (V_{25pulm} (α/β 3.1) – 21.49%, V_{28pulm} (α/β 9) – 20.17%; $D_{mean\ pulm}$10.85Gy) in comparison with the FB (V_{25pulm} (α/β 3.1) – 23.07%, V_{28pulm} (α/β 9) – 21.64%; $D_{mean\ pulm}$ 11.72 Gy). V_{25pulm} (α/β 3.1) - p=0,438, V_{28pulm} (α/β 9) – p=0.461; $D_{mean\ pulm}$p=0,2964.

Conclusions. The present research is the first in Russia to compare the dosimetric indexes of dose-volume distribution to the organs at risk for three modes of radiation. The study revealed that the least dozes to the ipsilateral lung are achieved for the position lying on the stomach breathing freely while the breast and the axillary lymph nodes are included in the radiation volume. These results are comparable with the results of few foreign studies. Unlike the published works of the foreign authors the comparison of the FB and ABC methods in our research did not reveal the statistically significant differences of the radiation dose to the left lung in cases when the subclavian and supraclavicular lymph nodes were additionally irradiated.

Key words: Breast cancer, 3D conformal radiation treatment, ipsilateral lung, controlled breath delay, radiation treatment in prone position

THE ASSESSMENT OF THE BIOCHEMICAL PARAMETERS OF THE LIVER AFTER THE CT-GUIDED BRACHYTHERAPY OF METASTASIS TO THE LIVER

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Introduction: The liver is one of the most often localizations of metastasis of colorectal cancer, breast cancer, melanoma, eye cancer and neuroendoctrine tumor. The basis of the topical treatment of secondary liver tumors is surgical procedure. Non-surgical treatment of liver tumor involves: radiofrequency ablation (RFA), TARE – transarterial radioembolization, TACE – transarterial chemoembolization, cryotherapy, laser treatment as well as different methods of radiotherapy. Stereotactic teleradiotherapy and three-dimensional conformal radiotherapy predominate in the methods of radiotherapy. The brachytherapy under control of imaging has gained more popularity during recent years. It results from the possibility of application of high dosage in the area of the tumor and lower dosage in remaining, healthy parenchyma of the liver which has parallel texture. This method enables to escalate the radiation dosage above the approximate dose tolerated by the whole liver.

This paper describes the influence of different dosages in the healthy part of liver's parenchyma on early biochemical toxicity with patients undergoing liver brachytherapy treatment. Toxicity was evaluated on the basis of most often clinically used parameters of liver: alanine transaminase ALT, aspartate transaminase AST and bilirubin (BIL).

Material and Methods: Patients' characteristics: 46 patients, who underwent brachytherapy metastasis treatment in the liver during years 2013 and 2014, were included in preliminary analysis. Patients, who experienced the progress of cancer, underwent chemotherapy, were operated and patients with active cancer located differently than the radiated metastasis, were excluded from the group. 16 patients were included in the final analysis.

Conclusions:

1. In the analyzed group of patients biochemical toxicity dependent on the dosage was not exhibited.

2. Correlation of the volume of radiated tumor with the growth of transaminases indicates the possible existence of a certain borderline size of a tumor at which brachytherapy may occur toxic.

3. Further research assessing the influence of brachytherapy of liver tumors on the toxicity for the liver's parenchyma is needed.

Radon and Thoron

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MAPS OF INDOOR RADON IN MONTENEGRO

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First attempt to conduct a national indoor radon survey in Montenegro has begun in the year 2000. After preparing methodology for the survey, which comprised annual radon measurement with CR-39 nuclear track detectors during two six-month periods in one permanently inhabited dwelling, on the ground or first floor, in each cell of a 5 km x 5 km grid covering the country, with increasing sampling density in urban areas (sampling of one dwelling in each 0.5 km x 0.5 km cell), and door-to-door approach in sampling, radon measurements were performed during 2002-2003 in the Coastal and Central region. These two regions cover a half of the Montenegrin territory, with approximately two thirds of the national housing stock. Planed sampling of the third, the Northern region of the country was not possible to realize in that time due to a lack of financial means. Following the same methodology, radon measurements indoors continued in 2014-2015 and radon survey in the whole country has been finished recently.

Total number of the 5 km x 5 km cells in Montenegro is 552. Radon was successfully measured in 482 of them, while in 31 cells detectors were lost or damaged and 39 cells are without permanent dwellers. In total, average annual radon activity concentration was obtained in 1095 dwellings, which means that sampling ratio was 1:170 related to the total national housing stock (Census 2011).

After statistical elaboration of the data within cells of 10 km x 10 km greed and within municipalities, three types of radon maps of Montenegro have been produced: 1. Map of arithmetic means of annual radon activity concentrations in the cells of 10 km x 10 km greed, 2. Map of arithmetic means of annual radon activity concentrations in the municipalities, and 3. Map of the expected percentage of homes, in the municipalities, with annual radon activity concentrations exceeding a level of 300 Bq/m^3. These maps are presented in this paper.

THE ESTIMATION OF RADON CONCENTRATION IN DWELLINGS AND GEOLOGICAL ENVIRONMENT ON THE TERRITORY OF AZERBAIJAN

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According to the International Committee on Radiation Protection 50-75% from common dose of people's exposure by natural radioactive sources comes from radon. In many countries radon is the second leading cause of lung cancer after smoking. Among the non-smokers it is a major cause of lung cancer.

Indoor radon studies in Azerbaijan were carried out for the first time in 2010-2011. In 2014-2015 the investigation of radon problem in Azerbaijan has been continued in the framework of Azerbaijan State Program (2014-2018). Measurement of radon levels in dwellings, soil, thermal waters and mud volcanoes) radon levels, medical examination of population, development of actions for reducing radon risk, creation of regulatory acts, public education, etc. are the main objectives of this program.

Measured indoor radon concentrations varied in a wide range: from 20 to 1109 Bq/m^3. About 7% from total amount of measurements exceeds maximum permissible limit in Azerbaijan (200 Bq/m^3). Based on obtained data the map of distribution of indoor radon volume activity in Azerbaijan for the first time was created. The elevated radon concentrations are mainly observed in mining and folded arrays of the Greater and Lesser Caucasus and Talysh region. Results of measurements of radon concentrations in indoor air are in good agreement with data of radon content in the soil air. The content of radon in thermal waters generally isn't high, except the waters of carbon source in Talysh region, where its concentration is above the maximum permissible level accepted for drinking waters. Increased values of radon volume activity in the mud volcanoes (especially in the gases released from the griffins) have been also revealed. On the basis of complex processing of obtained data it's concluded that in the part of the living quarters elevated values of radon volumetric activity has the natural character.

VARIABILITY OF INDOOR RADON LEVEL ACCUMULATION: A STUDY IN PORTUGUESE THERMAL SPAS

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Exposure to ionizing radiation of natural origin contributes with 81% to the annual dose received by the population, and, in the case of Portugal, most of the average annual dose to which the population is exposed by natural sources, is due to radon (57%) and terrestrial gamma radiation (18%).

Portugal is a country with some risk in what concerns to natural radiation, due to the geological settings which mostly comprise granite rocks with uranium mineralizations.

In the European Directive 96/29/EURATOM, hydrotherapy was identified as a professional activity during which workers are exposed to radiation from natural sources. The exposure is in large part due to inhalation of radon released to air upon usage of thermal water. Therefore, the assessment of the indoor radon levels is important from the point of view of radiological protection and public health.

The aim of this work was to measure the concentration of the indoor radon in 16 Portuguese thermal spas (38% of the thermal spas in Portugal) and assess its variability within each establishment as well as its contribution to the effective dose. The measurements were performed with CR-39 passive detectors placed at different workplaces within each thermal spa, for an average period of 42 days, in different seasons of the year.

The indoor radon concentrations ranged from 68 to 4335 Bq/m^3 with a geometric mean of 437 Bq/m^3 and an arithmetic mean of 702 Bq/m^3. Geological factors that can lead to such behaviour are discussed.

The results showed that the EU reference level of 300 Bq/m^3 (Directive 2013/59/EURATOM) was exceeded in several cases. No significant differences were observed among measurements taken during different seasons of the year, however, large differences of radon concentrations in different rooms of the same thermal establishment were noted as well as significant difference when comparing to others thermal establishments. The existence of such excesses indicates that in, these cases, indoor radon has to be monitored for a longer period of time of at least one year.

The effective dose resulting from the inhalation of radon ranged between 2 and 32 mSv/y. In 43% of the thermal spas, the effective dose is likely to be higher than 6 mSv/year which means that the exposure should be managed as a “planned exposure situation” according to the European Directive 2013/59/EURATOM. Also, in 19% of the cases, the annual effective dose exceeds 20 mSv/y, and in these cases, monitoring and radiological protection is required as laid down in the European Directive 2013/59/EURATOM.

MONITORING AND CONTROL OF RADON IN WATERS OF MOLDOVA IN ORDER TO PREVENT PUBLIC EXPOSURE TO IONIZING RADIATION

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Background. Radon (^{222}Rn) is a colorless and odorless radioactive gas that is produced by decay of uranium (^{238}U) and thorium (^{234}th), present in all rocks and soils in small amounts. All rocky regions, mountainous areas and soil rich in phosphates and water around the world, tend to contain varying amounts of ^{222}Rn. There are several isotopes of ^{222}Rn, of which the most important are ^{222}Rn (produced from ^{238}U) and ^{220}Rn (produced from ^{234}th), emitting alpha ionizing radiation extremely harmful for people when they are ingested.

Aim of the study. Monitoring and control of radon in waters Moldova in order to prevent public exposure to ionizing radiation. In the period of 2012-2015 a total of 31 water samples were taken and analyzed for their content of ^{222}Rn.

Methods. Measurements of the ^{222}Rn concentrations in water samples collected from different sources (spring waters, wells, artesian wells, aqueduct) have been determined on the basis of a simple method using 1688-2 RTM radiometer and special facility for determining ^{222}Rn and ^{220}Rn in water samples.

Results. Our study show that in the waters of artesian wells radon concentrations ranged within 1.977 to 4.072 Bq/m^3;in the aqueduct water from 0.106 to 0.431 Bq/m^3; in the spring waters from 4.857 to 7.729 Bq/m^3; in wells, from 0.447 to 5.590 Bq/m^3 and in the surface water — about 1 Bq/m^3. It was stated that ^{222}Rn concentrations in the surveyed waters did not exceed the permissible values according to national rules and Directive 2013/59/Euratom.

Conclusions. ^{222}Rn concentrations measured in all localities taken in this study were found to be lower than the minimum standard set by WHO. The highest concentration of ^{222}Rn was recorded in spring water and wells, and the lowest concentration – in the surface water, due to direct passing of ^{222}Rn in the air.

HEALTH RISK ASSESSMENT RESULTING FROM EXPOSURE TO IONIZING RADIATION

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Background: Radon (^{222}Rn) is a radioactive gas that is accumulated in the indoor air of different types of housing. Inhalation of ^{222}Rn cause serious damage to the human organisms such as lung cancer. Lung cancer is among the top causes of cancer death in Moldova, with 858 (about 1.0 % from the total number of population) of new cases diagnosed in 2014. The national "Fundamental Radiological Protection Norms (NFRP-2000)" in the Republic of Moldova establishes maximal admitted concentration of ^{222}Rn gas in the indoor air for permanent habitation of humans, should not exceed 100 Bq/m^3 in designed, constructed or rebuilt spaces and 150 Bq/m^3 in earlier (before 2000) constructed buildings.

Aim of the study: Investigation of ^{222}Rn concentrations and its progeny in the indoor air in different location in rural and urban areas in different zones of the Republic of Moldova and determination of correlation coefficient between ^{222}Rn concentrations and the incidence of lung cancer.

Methods: The measurements of ^{222}Rn concentration were carried out by the National Centre of Public Health, Scientific Laboratory Radiation Hygiene and Radiation Biology with the objectives of studying the distribution of ^{222}Rn in homes and workplaces. The measurements in the houses were made using both active measurement methods through Radonometer RTM 1688-2 and the passive methods – RAMARN detectors, in the bedroom and kitchen.

Results: Based on measurement results, it was concluded that in the Republic of Moldova in many districts, values of ^{222}Rn concentration was above the authority recommended limits: 100-150 Bq/m^3 and that require the development of indoor ^{222}Rn concentration monitoring program. It was found that the numerical value of the correlation coefficient between cases of cancer disease and ^{222}Rn concentrations was r=0.571. This indicates to a middle correlation, which demonstrates that ionizing radiation is responsible for the developing of this type of cancers.

Conclusion: The correlation analysis detected that the increased number of lung cancer cases was correlated with high values of ^{222}Rn concentration.

MERITS AND DEMERITS OF DIFFERENT METHODS FOR RADON EXHALATION MEASUREMENTS

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With an increase in the awareness of the need to save energy, residents tend to live in dwellings with increasingly tight windows and doors, thus reducing the ventilation rate of indoor air which leads to an increased accumulation of radon indoors. Having in mind that an exposure to inhaled radon and its progenies can be higher than a dose received from radium in building materials, it is suggested that radon exhalation measurements should receive due attention. In this contribution, the authors compare results gathered using a few methods for radon exhalation measurement and discuss its merits and demerits.

RADON POTENTIAL MAPPING IN THE SOUTHERN CITIES OF CHINA

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Mapping the radon potential in China is a research project supported by National Natural Science Foundation of China. Zhongshan City (ZC) was chosen as one of the test areas. ZC is located in the southern part of China and bordered with Zhuhai City, a city with high radiation background. A preliminary radon survey is ZC was conducted using a portable semiconductor radon monitor RAD-7 and soil permeability instrument Radon-jok, covered a total area of 1800 km^2 with a grid of 10 * 10 km. The sampling depth for soil gas radon measurement in the field was at depth of 80 cm below the ground.

^{222}Rn concentrations varied between 0.74 and 158 kBq/m^3, and ^{220}Rn between 0.02 and 235 kBq/m^3 The average value of ^{222}Rn and ^{220}Rn was 67.6 and 74.8k Bq/m^3, respectively. ^{222s}Rn mean value is one of the highest values in soil in the world. Our preliminary radon investigations show that: (1) The characteristics and distribution of ^{222}Rn and ^{220}Rn concentration from soil gas in ZC are obviously related with lithology (the Middle and the Late Jurassic and the Crelaceous biotitic- granite) and geological formation. High ^{222}Rn and ^{220}Rn concentrations were observed in the outcrops of weathered granite or fill back granite sands. (2) The distribution model of ^{220}Rn is as same as that of ^{222}Rn. The radon potential map of ZC was made based on the radon concentration in ill gas and soil air permeability, combined with GIS technology. The Wuguishan Mountain areas and in the south-east areas of ZC, covered with granite rocks, are high radon districts; the central zones are low radon potential areas and part of the northern districts are medium radon potential areas.

The investigation suggests that we should pay attention to ^{220} Rn contributing in radon mapping in ZC because high ^{220}Rn would have a greater contribution to the inhalation dose to human beings.

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PRELIMINARY INVESTIGATION OF RADON CONCENTRATION IN SURFACE AND DRINKING WATER IN SOME REGIONS OF BEIJING

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A radon survey in surface and drinking water in some regions of Beijing was conducted. The surveyed areas are located in the northern and western suburbs of Beijing. Different measurement systems need to be applied when test radon concentration in various types of water. During the process of measuring surface water bodies such as reservoir water, river and ocean, or measuring municipal water supplies with lower value, we use a professional radon monitor AlphaGUARD PQ2000 PRO, attached with special water measurement device. In the measurement process of groundwater or spring water with higher value, we usually choose a semiconductor continuous radon measurement instrument RAD7 with its accessory device RAD H_2O. The surface water of this research includes reservoir water, water flowing in approach channel, river and water in mountainous areas containing a total of 31 samples. Among that the average radon concentration of water samples in mountainous areas was 0.95 ± 0.07 kBq m^{-3} and the average radon concentration in other types of surface water was 0.07 ± 0.01 kBq m^{-3}. The groundwater samples for drinking were mainly from residents' tap water, namely water using terminal. During this survey 31 groundwater samples were measured. The average radon concentration of the groundwater samples was 15.43 ± 1.34 kBq m^{-3} and the maximum and minimum value were 47.50 ± 5.09 and 1.12 ± 0.29 kBq m^{-3}, respectively. Among the radon concentrations of 18 groundwater samples collected in the research regions are more than 11.10 kBq m^{-3}, exceeding the limit of radon concentration in drinking water stipulated by the national standard of China (GB5749-2006). In combination with surrounding rock lithology analysis we find that higher water radon concentration values exist in igneous rock, volcanic rock and metamorphic rock while the water radon concentration values in sedimentary rock and quaternary sandy gravel are relatively lower. The average radon concentration of groundwater samples in above four types of rocks were 24.20 ± 2.13, 22.33 ± 0.94, 11.88 ±1.15 and 7.57 ±0.72 kBq m^{-3}, respectively. This shows that the groundwater directly contacting with the rock and soil will dissolve certain amount of radioactive elements, so the radon concentration in groundwater will increase significantly. It is advisable to avoid drinking groundwater with high value without any disposal measures. Be on the safe side, it should be placed for period of time after that boiled for drinking.

Key words: Surface water, drinking water, groundwater, radon concentration in water

COLLECTIVE DATA ANALYSIS OF CORRELATION BETWEEN LUNG CANCER INCIDENCES AND RESIDENTIAL RADON CONCENTRATION

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Naturally occurring radioactive gas radon is responsible for approx. half part of an average annual effective dose for humans. This is the reason why its influence on health of people is a subject of many studies worldwide - especially, when one tries to compare its level of concentration with the number of observed lung cancer cases. The question arises is there any correlation between those two values. We performed collective data analysis form 30 case-controlled studies and 2 ecological ones that were published in past years. Original data single analyses were very confusing, suggesting that the lung cancer morbidity and mortality increase or decrease with increasing radon concentration at concentrations up to 200 – 300 Bq/m^3. In all cases the collective data up to 475 Bq/m^3 show, within error bars, neither elevated nor diminished risks, so the overall conclusion is that in this concentration range one sees no radiation effect. In the next step the data analysis was extended to 838 Bq/m^3. Such extension required an assumption on the right limits of the radon concentration when data were reported as measured for radon concentration without maximum value. This time the analysis was carried out in the whole range of radon concentration, and in 3 sub-regions. In all cases both, least-square fitting and Bayesian analysis of a few simplest models were carried out. The general conclusion is that the model of the independence of the radon risk describes the data in the best way. The best conclusion suggests, in light of the data collected so far, that they are insufficient to support the concept of increased risk of lung cancer for considered low concentrations of residential radon.

RADON IN A URANIUM BEARING REGION OF PORTUGAL

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Radon (^{222}Rn) mapping in indoor air was performed in Portugal more than 30 years ago using a wide grid, and a clear relationship of high radon concentrations in indoor air and granite regions emerged. In recent years we focused on radon measurements at houses in villages near former uranium mines in order to detect radon exposures that could be of radiological concern. Radon measurements were made using continuous radon monitors based on silicium detectors placed indoors and outdoors in several villages in the uranium region. Radon concentrations in surface outdoor air at short distance of uncapped uranium milling tailings were measured over months and generally fluctuated from 20 to 550 Bq/m^3. The higher average concentrations were measured downwind the tailings but dropped with wind rotation. Generally, radon concentrations were higher close to the tailings. With placement of caps on milling tailings, radon exhalation dropped and radon concentration in local surface air dropped also to an average value of 40 (9-180) Bq/m^3. Radon in indoor atmosphere of buildings in the area fluctuated from 10-400 Bq/m3. Some buildings displayed average concentrations much higher inside, up to 1100 Bq/m^3 and, in extreme cases, up to 12,000 Bq/m^3. These indoor radon concentrations do not relate to the distance to former uranium mines and to milling tailings and radon may, in some cases, result from use of contaminated tailings materials in the construction (in cement or as filling material) or from infiltration of radon from the ground, eventually escaping from minor uranium veins in granite rock fractures into the houses. Radon exposure of members of the public is assessed in the framework of current EU Directive on radiation protection.

RADON CONCENTRATION MEASUREMENTS AT THE IRT-SOFIA RESEARCH REACTOR SITE

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We report on findings from the radon monitoring in selected points of the IRT-Sofia nuclear site which is an important part of surveillance radiation activities during the operation and maintenance of the facilities at the Nuclear Scientific Experimental and Educational Centre (NSEEC) of the Institute for Nuclear Research and Nuclear Energy. The ABPM 201-L and ABPM 203-M monitor units were employed. The ABPM 201-L unit is used for continuous monitoring of the volumetric activities of alpha and beta particulates in ambient air, discharge stacks, ventilation ducts and buildings containing radioactive material. The ABPM 203-M is a mobile monitor for contamination surveillance. It serves to continuously monitor the α and β volumetric activity of airborne particulates in the atmosphere of nuclear installations. The monitor compensates the measurement for naturally occurring radioactivity (Radon) and for externally induced γ fields. Such measurements are in support to operational and radioactive contamination control goals set by the management as well as to meet the environmental legislation and requirements of regulatory bodies. The main conclusions consider outdoor data and indoor measurements carried out in the bottom floors of buildings, which are in direct contact with the ground. The indoor radon, thoron and their decay products are the main contributors of total inhalation dose which has long been recognised as a potential radiological health hazard. The major buildings inspected are the temporarily shut-down nuclear research reactor IRT-Sofia, where in its basement the First Class Radiochemical Laboratory (radiochemical niches, glove boxes etc. for radiopharmaceuticals as well as a technological conveyor line passing through four hot cells for treatment of high specific activity radioactive isotopes) is located and the auxiliary building wherein the laundry facilities and the ^{60}Co gamma irradiator GOU-1 are installed. Ventilation systems managed locally or centrally are used to maintain the radioactivity levels within permitted limits as well as to control the gaseous releases. A dedicated study was done to track the build-up pattern of radon concentration in the closed laundry premises without proper ventilation. Consideration is given as well to the data prior and during the dismantling activities related to the reactor refurbishment project and after their accomplishment. The objectives of the monitoring programme were to determine the distribution of radon levels in the buildings, to disclose areas where the risk of exposure to radon exceeds the established radiation protection safety threshold of 1000 Bq/m^3 for annual average activity concentration of ^{222}Rn in working places and 300 Bq/m^3 for the public, to evaluate possible radon risk to the public and workers, and to evaluate the effectiveness of control measures on radon levels throughout individual rooms and corridors in the IRT-Sofia building.

INDOOR RADON CONCENTRATION IN DRAGAŠ MUNICIPALITY, KOSOVO AND METOHIJA, SERBIA

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Annual indoor radon measurements were carried out in two rooms of 20 mostly ground floor dwellings in the municipality of Dragaš, Kosovo and Metohija. The CR-39 Gammadata detectors were placed in the living rooms and bedrooms, on the furniture shelves or cabinet at a distance of about 30 cm from walls (in order to reduce the thoron contribution to the detector track density) and at a height more than 1.5 m above floor. The mean annual concentration in twenty dwellings was 80.7 Bq m^{-3}. Annual radon concentration in the living rooms range from 26-315 Bq m^{-3} with a mean value of 85.7 Bq m^{-3}, while the same one in bedrooms range from 28 to 448 Bq $m^{-3}$with mean value of 75.6 Bq m^{-3}. The differences between the two measured rooms in each dwelling were investigated. The ratios between radon concentration measured in living rooms and that measured in bedrooms follow the expected lognormal shape; Kruskal-Wallis test confirmed no significant systematic difference appears between radon concentrations in the two room types. The highest value of radon concentration in both rooms was in dwelling built of stone and concrete. The concentrations of radionuclides in the nearby soil, building materials, could be the sources of higher indoor radon; likewise poor ventilation and solid fuel heating could be reasons for radon accumulation in ground dwelling.

PRELIMINARY RESULTS OF SOIL GAS RADON LEVELS AROUND MANİ SA FAULT

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In this study, soil gas radon concentration variations were monitored for the first time in terms of its relation with tectonic activities of Manisa Fault. It is an active fault lines that is about 50 km long from Manisa in the northwest to the Gediz Graben. Soil gas radon measurements around the fault were performed by LR-115 Type solid state nuclear track detectors. Two type of measurements were done: Parallel to the fault and Perpendicular to the fault. The behavior of radon levels was analyzed from obtained data.

Key words: Radon concentration, Manisa Fault, LR-115

THE EFFECT OF AIR FILTRATION ON THE FRACTION OF UNATTACHED RADON PRODUCTS

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In a room (size 4 m × 4 m × 2.7 m) of elevated radon activity concentration (weekly average 2500 Bq m^{-3}) an air filtration device was installed and the following parameters have been monitored prior to and during filtration: a) activity concentrations of ^{222}Rn and its short-lived products (RnP: ^{218}Po, ^{214}Pb and ^{214}Bi), degree of secular equilibrium between Rn and RnP, and fraction of unattached RnP (f_{un}), using an EQF3020-2 device (Equilibrium Factor Monitor, Sarad, Germany) and b) number concentration and size distribution of aerosol particles in the 10–1100 nm size range, using an SMPS+C instrument (Scanning Mobility Particle Sizer + Counter), Series 5.400, with the long DMA (Differential Mobility Analyser) unit (Grimm, Germany). In addition, meteorological parameters have been recorded.

In one of the several experiments performed, the number concentration of particles (C_p) was prior to filtration about 7.2 mm^{-3} (particles in 1 mm^{-3}) and geometric mean of particle diameter (d_{GM}), about 70 nm, with a broad maximum in size distribution between 10 nm and 300 nm, peaking at about 100 nm. While activity concentrations of attached ^{218}Po, ^{214}Pb and ^{214}Bi were about 1000 Bq m^{-3}, concentration of unattached ^{218}Po was about 200 Bq m^{-3}, and those of both ^{214}Pb and ^{214}Bi, negligible. The resulted f_{un} value was 0.04. After the filtration was turned on, C_p started to decrease and so did d_{GM}, to reach in about 5 h their minimum values of 1.1 mm^{-3} and 17 nm, respectively. While fraction of particles smaller than 10 nm (to which unattached fraction is associated) was negligible before filtration, it raised up to 0.30 at minimum C_p. At this point, broad peak almost disappeared in the size distribution, and only a smaller amount of particles remained in the region from about 10 nm to 100 nm. These changes in aerosol characteristics dramatically changed distribution of RnP between attached and unattached forms. While concentrations of unattached ^{214}Pb and ^{214}Bi remained low, concentrations of unattached ^{218}Po increased to over 600 Bq m^{-3}. On the other hand, concentrations of all the attached RnP decreased markedly, i. e., ^{218}Po to about 400 Bq m^{-3} and the other two to below 100 Bq m^{-3}. This redistribution of RnP resulted in f_{un} of almost 0.40. When the filtration continued for another 7 h, contribution of particles smaller than 40 nm steadily grew and became prevailing in the size distribution. These particles have been attributed to the release during operation of the filtration device.

Our filtration device effectively removed bigger nano particles. Because the concentration of smaller particles (particularly those smaller than 10 nm, associated to the unattached RnP), remained unchanged (or was even slightly increased), the value of f_{un} was increased. Consequently dose conversion factor, and thus the calculated dose, would be increased.

Other Topics

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THE OPTIMISING FORCE BALANCE EXERCISED IN THE WHEEL – PROFILE CONTACT FORCE DURING THE CURVED PATH. AN EXPERIMENTAL APPROACH OF USING CURVILINEAR PROFILES

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This paper objective is to contribute in the optimization of the problem of guiding forces during the movement of the railway vehicle. The work proposes an innovative solution as compared to classical author suggestions which are limited to a small number of alternatives.

Methodology follows an experimental approach. An experiment with two stages takes place where experimental conditions are modeled after profiles designed following a curved path with 500 m radius (classified as tight curve by definition). In the first experimental stage standard profiles were used, while for the second experimental stage curvilinear profiles were exploited. After experiment conduction data concerning (1) displacement (2) moments of force and (3) guiding forces of wheel-rail contact were analyzed and compared for both stages: standard profiles and curvilinear profiles

After experimental results, major conclusions of the paper are: (1) in the case of curvilinear profiles profile, small movements of vehicle, lead to a change in the size of the wheel displacement smaller than the corresponding change in standard profiles; (2) moments of force are greater in the case of standard profiles compared to curvilinear ones; and (3) curvilinear profiles enable a movement without many contact point with the wheel, friction forces exert their action in longitudinal direction, thus by causing a smaller value of guiding forces.

Key words: Guiding forces, curvilinear profile, moment of forces, wheel displacement

OPTIMIZATION OF WHEEL - RAIL PROFILE COMBINATIONS IN TERMS OF ACCURATE WEAR PREDICTION

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Predicting, calculating and minimizing rail profile – wheel wear is still an important inquiry, although the evolution in its formulation. This paper will contribute in solving the wear prediction problem, frame worked by below guidelines: (a) Wear minimization in terms of different curve radius and (2) Wear minimization in terms of different wheel – rail profile combinations. Paper objectives are: (1) To maximize prediction accuracy of wear index in terms of: (a) Overall wear index, (b) in terms of wheel – rail combinations and (c) in terms of curve radius; (2) To optimize wheel – rail profile combinations in terms of wear indexes for different curve radius scenarios.

In overall, the main contributes of the paper are: (1) this paper significantly contributes in solving one of the most important problems of wheel – rail contact optimization: prediction of wear indexes in tight curved rail tracks; (2) this paper access the predicted value of wear index in different curve radius scenarios, this creates the possibility of adaption in both ways, to adapt the rail profile to wheel type and/ or to adapt the wheel type to rail profile type.

Key words: Wear prediction, rail profile - wheel wear combination, curve, optimization

INVESTIGATION OF ACID-BASE PROPERTIES OF AROMATIC HYDRAZONES IN BASIC MEDIA AT CONSTANT IONIC STRENGTH

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The hydrazones are well-known class of organic compounds with a wide spectrum of application which is a result of having an azometine proton (-NH-N=CH-). These compounds possess diverse biological and pharmacological properties which depend on the ionic forms in which they exist in the solution. Therefore, determination of dissociation constants in defined media is very important. In the literature there are different methods for determination of dissociation constans, but the most suitable method is UV spectroscopy. This method we used in order to determine dissociation constants of some aromatic hydrazones. The acid-base properties of investigated hydrazones were followed in sodium hydroxide media. UV spectrophotometric measurements for investigated hydrazones were performed in the pH region between 7 and 14. The UV spectra were recorded in aqueous solutions containing 3% ethanol (v/v) at constant ionic strength of 0.5 mol/dm^3 adjusted with sodium perchlorate.

Two absorption bands with maximum at around 195 and 330 nm were observed in the UV spectra of investigated hydrazones. For our investigation we followed the changes in the second band. The intensity of this band decreased when the basicity of solution increased. Furthermore, a bathochromic shift of this band was observed in basic media, probably due to dissociation process. The changes in the UV spectra suggested that dissociation process took place in one step for four investigated hydrazones and in two steps for hydrazone with phenol group in its molecule. The first step was due to dissociation of phenolic group which is stronger acid, while the second step was as a result of dissociation of amide group. The observed pH range of first step of dissociation was from 10.8 to 11.6, while for the second step was 11.7-12.1.

The absorbance data from the UV spectra were used for calculation of dissociation constants. The obtained pK_{HA}values were between 2.11 and 2.62. There were no differences in pK_{HA} values of hydrazones with amide group in its molecule. This result suggested that the influence of substituents (-CH_3, -OCH_3, -Cl and -OH) was not significant. The first dissociation constant value of hydrazone which possess amide and phenol group was higher in comparison with other investigated hydrazones. These differences were due to the presence of phenolic group in the molecule of this hydrazone which caused late dissociation of amide group. At the same time, pK_{HA} values were determined graphically from the intercept of the dependence of log$I$ on pH. The dependence of log$I$ vs. pH is linear with coefficient of determination » 1 suggesting satisfactory precision in determination of dissociation constants graphically. There were no important differences between calculated and graphically determined dissociation constant values. This implies that the pK_{HA} values can be successfully determined in both ways.

Key words: Aromatic hydrazones, UV spectroscopy, dissociation, dissociation constants, AM1 semiempirical method

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