INTERNATIONAL CONFERENCE ON RADIATION APPLICATIONS

In Physics, Chemistry, Biology, Medical Sciences, Engineering and Environmental Sciences

virtual online conference

September 6-8, 2021

www.rap-conference.org

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INVITED TALK

CONFERENCE ABSTRACTS

Biomarkers for radiation injury and medical countermeasure efficacy

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Several candidate drugs for Acute Radiation Syndrome (ARS) have been identified which have low toxicity and significant radioprotective and radiomitigative efficacy. Since exposing healthy human volunteers to injurious levels of radiation is unethical, the development and approval of new radiation countermeasures for ARS are, therefore, presently based on animal studies and Phase I safety studies in healthy volunteers. The Animal Rule that underlies the Food and Drug Administration (FDA) approval pathway requires a sound understanding of the mechanisms of injury, drug efficacy, and efficacy biomarkers. In this context, it is important to identify biomarkers for radiation injury and drug efficacy that can extrapolate animal efficacy results, and that can be used to convert drug doses deduced from animal studies to those that can be efficacious when used in humans.

We have conducted studies using various omic platforms; metabolomics, proteomics, transcriptomics, and miRNA have been used to identify biomarkers for radiation injury and countermeasure efficacy. Specifically, we have used two promising radiation countermeasures under advanced development, gamma-tocotrienol and BIO 300, to identify and validate biomarkers using the nonhuman primate model and various omics platforms. In addition, we have used amifostine, a radiation countermeasure approved by the FDA for limited indications. We have identified several biomarkers which may be used for radiation injury assessment, dose reconstruction, and countermeasure efficacy. Some of these biomarkers can be used for dose conversion of countermeasures from animal to human. In addition to metabolomes, lipidomes, and proteomes, we have identified a few miRNA which can be used as radiation injury markers (mir-126, mir-150, mir-375, mir-133a, mir-133b, mir-215, and mir-30a) and to determine the efficacy of gamma tocotrienol (miR-30a, miR-126, and miR-375).

Age-specific computational phantoms for bone-seeking ^{89,90}Sr bone marrow dosimetry

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The radioactive contamination of the Techa River and adjacent territories occurred as a result of industrial activities at the "Mayak" PA in 1950s. An increase of leukemia risk associated with dose to active bone marrow (AM) was revealed in epidemiological studies of the Techa river residents. Bone-seeking ^{89,90}Sr were the most significant radionuclides, in terms of bone marrow dose, for the exposed residents. In this context, dosimetric modeling to calculate dose factors (DFs) is an important task. DFs allows converting ^{89,90}Sr specific activity in trabecular and cortical bone (source-tissues) into dose rate in the AM (target-tissue).

The aim of the study is to present family of computational voxel phantoms describing geometry and microstructure of main hematopoietic bone sites of the human skeleton: newborn, 1-year-old, 5-year-old, 10-year-old, 15-year-old male, 15-year-old female, adult male and adult female.

The new computational phantoms modeling method which takes into account the individual variability of the macro- and microstructure of bone tissue was elaborated. Main hematopoietic sites of the skeleton were selected according to literature data on AM distribution within the skeleton of different ages. Hematopoietic bone sites were divided into small segments that could be described by simple geometric shapes. Parameters of each bone segment and its variability are based on literature derived bone histomorphometry measurements including: bone linear sizes, cortical bone thickness and microparameters of trabecular bone (bone volume fraction, trabecular thickness, trabecular separation). Trabecular bone was modeled as an isotropic three-dimensional grid of rod-like trabeculae that "run through" the AM, using original "Trabecula" software. To simulate variability of bone microstructure a multiple deformation of rod-like structures was performed. MCNP 6.2 was used for electron-photon transport simulation in bone media.

The number of hematopoietic sites varied with age in the range of 14 for newborn to 12 for adult male and female. Total 247 phantoms of bone segments were generated for all age groups. Skeletal growth leads to increase of the bone segments sizes and multidirectional changes in parameters of bone phantoms. For each age group skeletal-average DFs for ^{89,90}Sr were calculated. Skeletal -average DFs for ^{90}Sr of computational phantoms of different age are in the range of 5.42×10^{-11}-3.98×10^{-11} (Gy/s) per (Bq/g) for beta emission within the trabecular bone and 1.05×10^{-11}-2.39×10^{-11} (Gy/s) per (Bq/g) for the cortical bone.

Acknowledgments: This work was funded by the U.S. Department of Energy and the Federal Medical and Biological Agency of Russia.

Development of a novel setup for the on-line monitoring of proton therapy – status report of the SiFi-CC project

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Since it was first proposed in 1946 proton therapy has risen to the rank of one of the most important radiotherapy modalities with increasing number of new therapeutic facilities and treated patients. Due to the favorable energy deposition pattern of charged particles, proton therapy allows to precisely irradiate a tumor and spare surrounding healthy tissues. However, quality of proton therapy could be further improved if safety margins applied during the treatment were reduced. To achieve that method of treatment monitoring in real time is required. Intensive research conducted in the field resulted in proposals of various real time monitoring methods based on detection of secondary particles emitted during patient's irradiation.

In my presentation, I will introduce the SiFi-CC project which is a joint effort of scientists from the Jagiellonian University, the RWTH Aachen University and the University of Lübeck. The aim of the project is development of a method for real time monitoring of the dose distribution delivered during proton therapy via detection of prompt gamma radiation. To achieve this goal, a dedicated, novel detection system based on heavy inorganic scintillating fibers and silicon photomultipliers is under development. The detection setup will be operating in two modalities: as a Compton camera and as a coded mask. In order to find the optimal scintillator for the active part of the detector, extensive laboratory tests with different materials were conducted, to ensure the best possible detection efficiency, large light output, good energy resolution and timing properties. The geometry of the detection setup was optimized by the means of Monte Carlo simulations. High granularity of the detector along with the fast electronics will reduce background and enable high rate capability. The data acquisition system will be based on FPGA boards and will feature data preprocessing and data reduction stage, which will result in high throughput and flexibility needed for both designed detection modalities. Classification of Compton events recorded by the detector will be performed using an algorithm based on neural networks. Output of that will be subsequently fed to the LM-MLEM algorithm in order to carry out image reconstruction. Computer simulations showed that estimated imaging sensitivity of a proposed detector configuration will be of the order of 10^{-5}.

Currently a small prototype of the proposed detection setup is studied. The prototype consists of 64 LYSO:Ce fibers wrapped in Al foil and organized in four independent layers, which can be rotated relative to each other. The small prototype allows to verify results obtained in simulations, test software and algorithms developed so far, tune electronics and test different technological solutions necessary for construction of the final detection setup.

Comparison of FOTELP and MCNP with voxelised geometry in radiotherapy

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For the first time, a comparison of two leading programs, the European, Serbian program FOTELP and the American program MNCP, is presented in this research. Increasing application Monte Carlo's technique in medicine relies on voxelized geometric shapes that are obtained by voxelization or from CT data. These programs could be used as general-purpose software packages in dosimetry and radiology. Domestic program FOTELP (R. Ilić) and derived versions from it, including the package for brachytherapy, which is already being applied at the Institute for Nuclear Research, Russian Academy of Sciences, Laboratory for Medical Physics. Both programs are based on the Monte Carlo method, whose most important feature is the ability to simulate all individual particle interactions in three dimensions and to set up different numerical experiments. The properties of these two programs are compared for the same particle types, for identical particle source configurations with special reference to their application to external and internal sources.

First, a comparison of the set numerical experiment with concentric spheres of filled waters and a selected electron source of 5 MeV in the center of the sphere was performed. The deposited energy in concentric spheres was determined, with the radius of the first 1 cm and the last 15 cm. The deposited energy was determined according to one current practice, with the discrepancy between these two programs ranging from 2 to 25%, which is probably a result of the use of different libraries and insufficient statistics.

In radiotherapy, CT images are obtained, which can be converted into a voxel model. Voxelization of CT images can be used to calculate the absorbed dose in melanoma of the eye tumor. The dimensions and number of voxels, together with Hounsfield numbers, are the basis for the preparation of simulation data.

Further work can show that the developed and tested packages FOTELP-VOX and SRNA – VOX (R. Ilić) can already services for the development of systems for planning radiotherapy with electrons, ie protons. This announcement can give readers recommendations on possible numerical experiments in radiotherapy.

On muon energy group structure based on deflection angle for application in muon scattering tomography: A Monte Carlo study through GEANT4 simulations

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The average deflection angle of the tracked muons in the muon scattering tomography exponentially declines in function of the initial kinetic energy, the angular dependence of which provides an opportunity to set out a binary relation between the initial kinetic energy and the average deflection angle, thereby leading to a coarse energy prediction founded on the mean deflection angle in the case of experimental incapabilities or limitations. Nevertheless, in addition to the disadvantageous exponential trend, the standard deviations observed in the deflection angles restrict the number of energy groups by yielding a significant number of coincided angular outcomes even at the fairly distinct energy values. In this study, we address the problem of the muon energy classification for a tomographic system consisting of 0.4-cm plastic scintillators manufactured from polyvinyl toluene and we explore a four-group structure besides a ternary partitioning between 0.25 and 8 GeV. In the first instance, we determine the deflection angles by tracking the hit locations in the detector layers on the sub-divided uniform energy intervals through the GEANT4 simulations. In the latter step, we express two misclassification probabilities where the first approach assumes a symmetrical linear propagation bounded by one standard deviation in one dimension, whereas the second procedure employs a positively defined modified Gaussian distribution that governs the overlapping area in two dimensions. In the final stage, we compare qualitatively and quantitatively the adjacent energy groups by using the computed misclassification probabilities. In the absence of any further data manipulation, we explicitly show that the misclassification probabilities increase when the number of energy groups augments.

Furthermore, we also conclude that it is feasible to benefit from the mean deflection angle to roughly estimate the muon energies up to four energy groups by taking the misclassification probabilities into consideration, while the classification viability significantly diminishes when the partition number exceeds four on the basis of standard deviation.

Keywords: Muon tomography, deflection angle, muon energy, energy groups; Monte Carlo simulations, GEANT4

Investigation of polymer concentration on physical and morphological properties of PLLA based fibrous structures

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The selection of the raw materials is one of the most important factors for tissue scaffolds to function as a native tissue. In this regard, the usage of the biopolymers is crucial because these polymers are biocompatible, biodegradable and non-toxic; moreover, different constructions can be easily obtained by using physical and chemical modifications. PLLA has a high biocompatibility that promotes cell attachment and proliferation, also it has suitable biodegradation time to allow cells to generate their own extracellular matrix (ECM) without creating any toxicity. In this study, PLLA-based fibrous structures are produced by electrospinning. Different concentrations of PLLA (10%, 14%, %18 and %22 wt.) are solved in 8/1/1 Chloroform/Ethanol/Acetic Acid. The physical and morphological analyses are accomplished to determine the effect of concentration on the web structure.

Using effective detective quantum efficiency (eDQE) to assess and compare imaging systems in digital mammography

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Evaluation of image quality in mammography still often relies on subjective methods, such as visual assessment of phantom images. Digital detector technology opens the possibility of implementing mathematical methods in assessing and comparing these systems. Optimal assessment of imaging systems requires quantitative image analysis. While Detective Quantum Efficiency (DQE) can be used for a quantitative description of the image detector performance, Effective Detective Quantum Efficiency (eDQE) measures performance of the detector within a whole mammographic system in clinical conditions, including the presence of scattered radiation and an anti-scatter grid.

In this work, we determined effective detective quantum efficiency (eDQE) for four mammography systems from three different manufacturers. Each manufacturer uses different image detector and different target/filter (T/F) combinations:

- two Siemens Mammomat Inspiration units with amorphous selenium detectors (pixel size 85 μm), W/Rh combination used clinically;
- one Hologic Selenia unit with amorphous selenium detector (pixel size 70 μm), Mo/Mo and Mo/Rh;
- one GE Pristina Senographe unit with CsI scintillator detector (pixel size 100 μm), Mo/Mo and Rh/Ag.

The eDQE was measured for poly(methyl methacrylate) (PMMA) thicknesses of 20, 30, 40, 45, and 70 mm, with an anti-scatter grid and for a selection of clinically relevant T/F combinations. Air kerma was measured using a calibrated radiation meter (Piranha Black 457, RTI Electronics AB, Sweden). All calculation procedures were performed on user-friendly, Python-based software developed by NCNR.

At 1 mm^{-1} eDQE ranged between 0.21 – 0.35 (for the two Siemens systems), 0.20 – 0.26 (for the Hologic system) and from 0.25 to 0.34 (for the GE system). In all cases, values of eDQE in two perpendicular directions were similar. For the Siemens units, the highest values of eDQE were observed for the thinnest phantoms. In contrast, the highest values observed for the GE occurred with the thicker phantoms (45 mm and 70 mm). This may reflect dependence of eDQE on the T/F combination. While the Siemens units used a single T/F combination is independent of the object's thickness, the GE unit uses a different combination for thick object (Rh/Ag) than for thin objects (Mo/Mo).

Successful application of eDQE methodology in different types of mammography systems provides valuable information on the performance of digital detectors in clinical situation. The information may potentially be used during optimization of imaging parameters, especially regarding choice of T/F combination.

The effect of an anti-scatter grid on performance of digital mammography systems – an eDQE study

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Optimization of exposure parameter settings and patient dose is an important task in digital mammography. An anti-scatter grid is commonly used to improve image quality, but its usage is associated with significant dosage increase. In our work, we compared the effective detective quantum efficiency (eDQE) obtained with and without anti-scatter grid to determine if the additional radiation dose associated with grid usage is necessary in some patients. The results were correlated with the mean glandular doses (MGD) calculated for the exposure conditions studied.

eDQE describes the performance of an imaging system in a spatial frequency domain; eDQE calculations are based on measurements of effective Modulation Transfer Function (eMTF), effective Normalized Noise Power Spectrum (eNNPS) and scatter fraction (SF). The study was performed on three mammography systems in use at MSCNRIO in Warsaw:

- Siemens Mammomat Inspiration with amorphous selenium detector (pixel size 85 μm), W/Rh target/filter combination;
- Hologic Selenia with amorphous selenium detector (pixel size 70 μm), Mo/Mo and Mo/Rh;
- GE Pristina Senographe with cesium iodide scintillator and an amorphous silicon photodiode array (pixel size 100 μm), Mo/Mo and Rh/Ag.

Measurements were performed in fully automatic AEC mode under clinical exposure conditions for three PMMA thicknesses: 20, 40 and 70 mm. For eMTF evaluation using the "free-air" method, we employed an edge test device designed and manufactured at the NCNR. For SF measurements a modified beam-stop method was used, employing 6 Pb disks also manufactured at the NCNR. Preliminary calculations (SF, TF) were performed using a free DICOM file viewer and spreadsheets. Calculation of eDQE was performed using self-made, Python based software.

MGD was calculated based on the 4th edition of the European guidelines for quality assurance in breast cancer screening and diagnosis.

eDQE values calculated with the 20 and 40mm PMMA phantoms were very similar for all three systems using either the grid-in and grid-out options. eDQE for the 70mm PMMA in all three systems was significantly higher with the grid in place. These results suggest that image acquisition for thinner PMMA phantoms (i.e. smaller breasts) without grid can reduce MGD by 35, 42 and 52% (for Siemens, Hologic and GE systems respectively) while maintaining the same level of system performance.

An atmospheric nuclear explosion source term module for the Lagrangian Transport and Dispersion Model FLEXPART

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Different nuclear fallout prediction codes (like the *Hazard Prediction and Assessment Capability* HPAC or the *Defense Land Fallout Interpretive Code* DELFIC) have been used in the past to predict the fallout after atmospheric nuclear explosions. These models may be fast, but hardly allow for the ingestion of gridded, multi-variable meteorological fields, which can lead to poorly forecasted plumes. Atmospheric transport and dispersion codes allowing for the ingestion of comprehensive meteorological data, but not developed specifically for nuclear fallout prediction - with the exception of the *Hybrid Single-Particle Lagrangian Integrated Trajectory model* HYSPLIT - have hardly been used to this aim. The presentation will demonstrate the first use of a source term module based on empirical relations describing the geometry of and activity distribution within the stabilized nuclear explosion cloud in combination with the widely used Lagrangian *FLEXible PARTicle dispersion model* FLEXPART. The plume parameterization most importantly comprises nine different particle bins (ranging from mean radii of 2.2 to 173 μm) and one bin for a generic noble gas as well as a bimodal lognormal particle activity-size distribution. Ground touching and merely atmospheric nuclear explosions are treated differently. The recently available ECMWF re-analysis fields ERA5 going back to 1950 will serve as unique meteorological input (~0.25° horizontal and hourly temporal resolution) to model ambient dose rates and arrival times with FLEXPART for six historic US tests performed in the 1950s. Evaluation results against historic measurements based on different metrics will be shown.

Empowering Underground Laboratories Usage Network (EUL) project

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The Underground Laboratories (ULs) can provide a unique environment not only for scientific research. The main goal of the Empowering Underground Laboratories Usage Network (EUL) project is to develop the capability of underground laboratories, located in the Baltic Sea Region, to offer technology transfer for business development and innovation. One of the project tasks is a characterization of natural radiation background in EUL ULs. In the presentation, the main project goals and achievements will be presented, together with the selected results of natural radioactivity measurements.

Characteristics of natural background radiation at BSUIN and EUL Underground Laboratories

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The measurements of the natural radiation background (NRB) performed with BSUIN (Baltic Sea Underground Innovation Network), and EUL (Empowering Underground Laboratories Network Usage) projects will be presented. The NRB was estimated in Callio Lab (Finland) at a depth of 4100 m w.e., and in Reiche Zeche mine (Germany) at a depth of 410 m w.e. The in-situ measurements consisted of gamma spectrometry and radon concentration in air. The water and rock samples were measured in the laboratory using α, β, and γ spectrometry.

Safecast dose rate monitoring – a Citizen Science project

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Safecast [https://safecast.org/] was founded in 2011 after the Fukushima accident. Its motivation was distrust in the perceived unreliable and incomplete information by Japanese authorities and the NPP operator (TEPCO) about the radiation situation. Measurements performed by citizen were supposed to verify and to complement official data. A standard instrument was designed for the purpose, called *bGeigie Nano* [https://safecast.org/devices/bgeigie-nano/], based on a pancake-type G-M detector with thin window. An on-board GPS receiver records geographical position and every 5 seconds writes it into a log file together with date/time and the dose rate reading. The log file is stored on a SD card. It can be submitted to Safecast in order to be added to the on-line Safecast map [https://map.safecast.org/] or to be processed with GIS software, such as QGIS, utilising plug-in provided by SÚRO Prague [https://www.suro.cz/aplikace/ramesis-wiki/index.php/V%C3%ADtejte_na_informa%C4%8Dn%C3%ADm_port%C3%A1lu_projektu_RAMESIS]. All data are publicly accessible for viewing and download.

Safecast soon expanded internationally. Today (spring 2021) it includes about 160 million measurements world wide acquired with about 5000 detectors [https://safecast.org/]. However measurement density is very variable, with high densities mostly in Japan, some European countries and the U.S.

The benefits of Citizen Science are multiple. Involving citizens who are not trained scientists, in general, adds to science education - in this case to better understanding of radiation protection altogether, the nature of natural radiation, ambient dose rate and its geographical variability, and of what measurement means, including the importance of observation protocol and uncertainty. Additionally, it helps in communication with professional radioprotection institutions and in adopting their knowledge.

An advantage of Citizen Science-based over institutional monitoring surveying is that it can acquire amounts of data which the latter can hardly do. Thus it can detect phenomena and geographical patterns of ambient radiation which may have elapsed institutional attention, and help in effective utilizing of capacities of professional monitoring teams. On the other hand, since citizens are usually not familiar with quality assured metrology, their results are affected by uncertainty due to deviations from standard measurement protocols. These are difficult to quantify and may impair the reliability of results, but analysis of large amount of data generated by citizens can help in understanding and even quantifying these uncertainties.

In this presentation, we introduce Safecast and show radiation maps on different geographical scales. We further discuss issues related to the bGeigie Nano and address matters of quality assurance.

Long-term record of tritium in precipitation – can we deduce influence of solar activity cycles on tritium production?

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Tritium (^{3}H) is a natural cosmogenic isotope of hydrogen with the half-life of 12.32 years. It is formed in the upper atmosphere through reactions of thermal neutrons with ^{14}N and oxidizes to tritiated water, $H^{3}HO$, and thus as a part of water molecule enters the natural water cycle. Tritium is also an anthropogenically produced isotope, either "bomb-produced" or of technogenic source. Massive injections of ^{3}H from weapons tests in the 1950s and 1960s, mostly in the Northern Hemisphere, caused an almost 100-fold increase in the tritium activity concentration in precipitation, known as the bomb peak that had its maximum during 1963. After the cessation of atmospheric nuclear weapons tests, a gradual decrease in ^{3}H activity concentration in precipitation was observed worldwide approaching presently the natural pre-bomb level. The value of tritium for studying hydrologic processes was quickly recognized, and for the past five decades tritium has been widely used to obtain time scales for physical mixing processes in oceanographic and hydrologic systems, i.e., for dating of modern waters. However, the scientific value of tritium in precipitation for hydrological applications is no more as high as in the second half of the 20th century.

Monitoring of tritium activity concentration, *A*, in monthly precipitation at a station in Zagreb (Croatia) has been performed since 1976. Long-term record exhibited a pattern typical of continental stations of the Northern Hemisphere. Seasonal variations were superposed on the basic decreasing trend of mean annual values until approximately 1996. The decrease in mean annual tritium activity concentration values continued after 1996, but to a much lesser extent. Data recorded between 1996 and 2019 resulted in a mean value of 8.5 ± 1.2 TU (1 TU represents one tritium atom per 10^{18} atoms of hydrogen, equivalent to 0.118 Bq l^{-1}). Seasonal variations remained observable, with winter activities close to the natural pre-bomb ^{3}H activity concentrations (<5 TU) and summer values up to 21 TU.

The relation between the solar activity and production of some cosmogenic isotopes has already been proven. However, bomb-produced tritium in precipitation until about 1995 prevented studies on whether the natural production of tritium was influenced by variations in solar activities. The modulation of cosmogenic tritium production by an 11-year solar cycle has been recently shown in precipitation at several stations worldwide [Palcu et al., *Sci. Rep.* 2018, 8, 12813]: local maxima in the tritium activity concentration in precipitation were observed simultaneously with maxima in neutron flux (minima in sunspot numbers). Our long-term data will be evaluated by applying frequency analysis cross correlation analysis. The preliminary analysis has shown local maxima in mean annual values and larger variability in 1996, 2007, and 2018, when also neutron flux maxima where observed.

Photoactivation method for ^{59,63}Ni content determination in nuclear power plant structural materials

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Nickel is an essential chemical element in the nuclear power plants' stainless steel structural materials. During the operation of any reactor, long-lived radioactive isotopes ^{59}Ni ($T_{1/2}$ = 7.6×10^4 years) and ^{63}Ni ($T_{1/2}$ = 100 years) are produced in nickel-containing materials by (n, γ)-reactions. These radionuclides decay without gamma radiation emission. Therefore, their registration is a rather tricky task. According to all theoretical estimates, the contribution of the ^{63}Ni activity to the structural materials' total activity after long-time reactor operation should be significant. We developed a photoactivation method for determining the nickel radionuclides' activity relative to the cobalt-60 activity. Cobalt always presents as an impurity in nickel stainless steel. ^{60}Co ($T_{1/2}$ = 5.27 years) is formed simultaneously with nickel radionuclides in the NPP structural materials by (n, γ)-reactions. It decays with the emission of easily detectable gamma quanta. The ^{60}Co and ^{59,63}Ni activities' yields are proportional to the number of atoms, (n, γ)-reactions' cross-sections and neutron flux. Therefore, the ^{60}Co/^{63}Ni activity ratio has only one unknown value. It is the number of Co and Ni atoms. To determine the Co/Ni atoms' ratio, we proposed to use the photoactivation method and the (γ, n)-reaction yields. We irradiated the NPP structural material samples with 36 MeV bremsstrahlung gamma quanta to implement the proposed technique. We determined the ^{59,63}Ni activities for three NPP structural material samples taken from the Chernobyl NPP 2nd power unit core. Obtained data were compared with the ^{59,63}Ni radiochemical release from studied structural materials samples. The results coincide with an accuracy of 10-15%.

Study of the Chernobyl hot particles' destruction by soil micromycetes' influence

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Essential sources of transuranium elements environment release are radiation accidents, nuclear power cycle enterprises, and nuclear weapons testing. The artificial origin, high radiotoxicity, and the very long half-life of transuranic nuclides result in their constant accumulation on a planetary scale. Some soil micromycetes retain a high level of bioactivity in nuclear waste burial sites containing transuranium elements and can change their solubility and bioavailability.

The studies of radionuclides migration on highly contaminated areas of the Chernobyl Nuclear Power Plant 30 km zone demonstrated that at present, the ^{241}Am activity could be traced to the depth of 50-60 cm. According to some assumptions, such intensive fuel fallout destruction in the soils can be influenced by soil micromycetes.

The presented work reports the study of some micromycetes strains' influence on the destruction of hot particles containing the plutonium isotopes, ^{241}Am and ^{137}Cs. Studies of the interaction "micromycete and hot particle" were carried out in model experiments. Two strains of *Cladosporium Cladosporioides* were cultivated together with Chernobyl origin hot particles in a liquid medium under oligotrophic conditions for 60 days. After all, the model system components were separated: hot particles, culture liquid, mycelium. Each component's specific activity was determined using alpha, beta, and gamma spectroscopic methods. The plutonium isotopes and ^{241}Am direct accumulation of micromycetes' mycelium were detected for the first time.

Acknowledgments: The reported study was funded by RFBR, project number 19-05-50095.

Open problems in radon research

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Environmental radon (Rn) has been given increasing attention in Europe, primarily due to its radiological significance, but also its potential as tracer of ecological processes. The former motivated regulation, latest the European Basic Safety Standards (BSS) Directive, 2013. Among other, it requires EU Member States to establish National Radon Action Plans whose objective is reduction of Rn exposure. Also some non-EU countries have adopted it or the similar IAEA-BSS.

During BSS implementation certain challenges emerged. Fulfilling the action plan means deciding about action aimed to establish or verify compliance with law. A decision must be quality assured (QAed) in the sense of reliability. Hence the steps leading to a decision must be QAed. For Rn, this concerns QA of measurement and of models which underlie e.g. estimation of Rn priority areas or of doses.

Some challenges were addressed in the Empir project Metro Radon (2017-20). Among topics were precise determination of low indoor Rn concentration, influence of thoron on Rn measurement and estimation of Rn priority areas. However, issues remained open because of the limited capacity of that project. Some are addressed here as an incentive for further research.

- Temporal variability of indoor Rn concentration with consequences for testing compliance with a reference level defined for long-term concentration, by measuring over a limited period. Related, the stability of estimated Rn priority areas under secular changes of Rn concentrations and observation density.

- Measurement QA of Rn and thoron progeny, relevant for exposure and dose estimation. Related, variability of model parameters, e.g. activity size distribution of aerosols.

- Calibration and performance of instruments under fluctuating Rn concentration, which more realistic than in usual laboratory tests. Active monitors which are nowadays quite cheap, should be subjected to QA more thoroughly, as they will play an increasingly important role in Rn surveying.

- The BSS concern workplaces more than dwellings, while most Rn data are on dwellings. Rn characteristics of workplaces are different, so that a decision valid for one type may not be applicable to another. In particular, this concerns “big” buildings, which may have especial Rn characteristics. Protocols for Rn assessment on workplaces should be developed.

- Conclusions about a local Rn situation are often drawn from geogenic quantities, usually taken from databases supposing natural conditions, e.g. from base rock maps; little is known on the effect of urbanisation on this assumption.

- Regional log-normality of Rn concentration implies occurrence of cases with very high concentration. They must be given attention for radioprotection reasons. Identification and modelling of rare events is a challenge, as is the question how to deal with them in the framework of the priority concept of the BSS.

- Rn mapping is advanced in Europe, but issues remain, viz. mathematical modelling, inclusion of covariates, new techniques (e.g. machine learning).

- Low public radon awareness: Strategies for communication and education will remain on the agenda. Also the potential of Citizen Science shall be explored.

As one of the potentials of Rn to serve as environmental tracer, we address time series of Rn concentration in soil or groundwater. These react to geogenic processes and Rn signals may serve as their indicators. However, analysis is demanding and theoretical and experimental issues remain to be solved.

Development of techniques for clearance of spent sealed nuclear medicine calibration sources

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The present work concerns the development of techniques that can be used to verify clearance of Ge-68/Ga-68 and Co-57 sealed radioactive sources. These sources are used for the calibration of various nuclear medicine systems like Gamma camera and PET imaging. There are several types of such sources of different characteristics and geometry i.e. linear, area, volume, while after their useful life these sealed sources need to be kept in control for decay till meeting the clearance criteria.

The techniques aim to determine the activity of the sources after storage for an appropriate time span until the clearance criteria are met and are based on Monte Carlo simulation using the MCNPX code for evaluation of the 3x3 NaI (Tl) scintillator detector efficiency.

A preliminary work [HNPS2018 Vol. 26 (2018) 194-197] was done for two types of sealed radioactive sources: i) a line source containing Ge-68/Ga-68, ii) a flood source containing Co-57. However, the determined activities were underestimated by 13.6% for Co-57 flood source and 26.9% for Ge-68 line source, compared to the source's nominal activities. In the present study, the accuracy of the previously developed techniques has been improved by detailed detector characterization. Furthermore, additional source geometries have been studied. The MCNPX models have been validated by measurements for all the examined types of sealed sources.

Dose rate assessment of ^{137}Cs to pelagic fish using an innovative method combining field measurements, CMEMS data and ERICA Assessment Tool

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Earth Observation satellites and environmental models are able to monitor changes of ecological parameters in the marine environment. Radionuclides cannot be directly measured using satellite remote sensing, because they are not currently detectable by the satellite instruments. Nevertheless, the levels of radionuclides, in the marine environment are known to be associated with physical and biogeochemical parameters of the natural environment. Considering this attribute, we investigate the potential relation between ^{137}Cs activity concentration and sea surface salinity. We select the parameter of salinity, as the element of Cs in the seawater is conservative and contributes to it. Cs-137 activity concentration measurements are issued from the database of the Environmental Radioactivity Laboratory (ERL) of NCSR "D". Salinity corresponds to sea surface salinity (SSS) data issued from Copernicus Marine Environment Monitoring Service (CMEMS) database spanning the period 1993 to 2006. A total of 15 measurements are used for the establishment of a linear regression model for the marine environment of the Island of Lemnos (Greece). The Island of Lemnos is located in the Aegean, southwest of the Dardanelles Strait and its waters are constantly enriched with ^{137}Cs of Black Sea origin.

The resulting linear model (R^2=0.82) is then validated using recent ^{137}Cs measurements spanning November 2018 and July 2019. During two sampling cruises that took place, on 12-15 November 2018 and on 24-28 July 2019, a total of 11 samples were collected and analyzed. The measured concentrations obtained by gamma spectrometry, in terms of activity concentrations (Bq/m^3), are then compared with the estimated ^{137}Cs concentrations obtained by the model. The estimations present a relative error of less than 25%. Finally, in order to conduct the risk assessment in the studied area, the dose rate thematic maps in the marine area of Limnos are calculated with the ERICA Assessment Tool and QGIS for pelagic fish, as the most representative organism and the most important, in terms of commercial value. The doses in pelagic fish are calculated for each pixel within the estimated ^{137}Cs activity concentrations thematic maps for November 2018 and July 2019.

The results show the corresponding dose rate maps for the pelagic fish during November 2018 and July 2019 for the Limnos Island. The dose rates in the thematic maps vary from 0.7 to 1 μGy/year, which are far lower than the intervention levels, indicating low impact due to the ^{137}Cs exposure.

Comparison of the vertical distribution of ^{137}Cs in soil after the elapsed time of about a half of the half-life of caesium

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According to recent studies, environmental contamination is usually accomplished by estimating soil. The findings show that ^{137}Cs is still present in the environment as a result of the Chernobyl disaster and atmospheric weapon tests. Caesium is an artificial radionuclide, a fission product with a half-life of 30.2 years. From the point of view of radiation protection, it is a health hazard, because it causes cancer in humans and accumulates in the bones and muscles. Therefore, there is an increased interest in the research of this radionuclide, especially after the accidents at the nuclear power plants in Chernobyl and Fukushima. Soil samples were collected in Sumadija district in central Serbia twice: first, during the spring - summer of 2001 and during autumn of 2018. The sampling locations were chosen to explore the effects of soil properties on the depth distribution of ^{137}Cs in soil. A HPGe detector and a multi-channel analyzer were used to measure the activity of ^{137}Cs in soil samples. The highest activity of ^{137}Cs is still within 15 cm in the top layer of the soil, 35 years after the Chernobyl accident and more than 50 years after nuclear probes. It can be concluded that ^{137}Cs now diffuses to higher depths. This finding confirms that ^{137}Cs penetration in soil is a slow process, due to a very long half-life.

Investigation of the ^{14}C, ^{137}Cs and $^{238,239,240}Pu$ radionuclide activity concentration distribution in the profiles of lake bottom sediments near Ignalina Nuclear Power Plant

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Lake bottom sediments is a media which layer-by-layer accumulates deposits from the water column and can serve as a natural indicator for assessment of the past contamination of the lake water. RBMK-1500 type graphite moderator reactors were exploited at Ignalina NPP (Lithuania): Unit 1 - 1983-2004; Unit 2 - 1987-2009. During exploitation the nuclear power plant used Lake Drūkšiai as a cooling pond. The activity concentration vertical profiles of important technogenic origin radionuclides ^{14}C, ^{137}Cs and $^{238,239,240}Pu$ were examined in the cores of the lake bottom sediments, sampled in 2014-2019. The ^{14}C activity concentration was determined in two organic fractions: alkali-soluble (AS) and alkali-insoluble (AIS) organics. The activity distribution profile with depth showed contribution of nuclear weapons tests in atmosphere and clear impact of the Ignalina NPP. Observed technogenic origin peaks of the radiocarbon activity concentration above background reached about 90 pMC and 10 pMC in the AS and AIS fractions, correspondingly. The ^{137}Cs activity concentration in sediments showed tree peaks, which corresponded to global fallouts due to nuclear weapons tests, Chernobyl NPP accident and Ignalina NPP exploitation. The INPP caused peak was quite flat and its activity concentration was up to 220 Bq/kg (d.w.). Similarly, the elevated activity of the plutonium isotopes were detected in the top layers of the lake bottom sediments up to 10 cm in depth. The measured maximum activity concentrations were 0.09 Bq/kg (d.w.) and 3.6 Bq/kg (d.w.) for ^{238}Pu and ^{239}Pu, correspondingly. The examination of the accumulated radionuclides in the lake bottom sediments is informative and can be used as a tool for retrospective assessment of contamination, released from the nuclear power plants.

Acknowledgments: This research was funded by a grant (No. S-MIP-19-16) from the Research Council of Lithuania.

Determination of Ra-226 and Rn-222 in natural drinking water in the province of Granada (Spain)

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^{226}Ra is a natural radioactive isotope (alpha emitter, Eα = 4.784 MeV, $t_{1/2}$ = 1600 years) belonging to the natural radioactive family of ^{238}U (abundance 99.27%; $t_{1/2}$ = 4.49x10^9 years). Its radioactive decay causes the emanation of a radioactive gas, ^{222}Rn (emitter alpha, Eα = 5,489 MeV, $t_{1/2}$ = 3.8 days). Both isotopes are widely distributed in a natural and heterogeneous way in the earth's crust, so their presence in groundwater has a natural origin where their accumulation or concentration depends on several factors such as: chemical nature of the rocks that surround the aquifer, geological characteristics of the land, the physicochemical processes that occur in the aquifer, among others, as well as an anthropogenic origin (due to mining activities or the use of fertilizers). Their determination in drinking water is important because they are a source of internal contamination with a high radiological health risk, so are the short-term high-energy alpha emitters Radon decay products.

The purpose of this work is to determine the activity concentration of ^{226}Ra and its daughter ^{222}Rn in non treated drinking water from sources distributed along the coast and Alpujarra of Granada to know their environmental implications, to determine their natural or anthropogenic origin, as well as to know if they comply the limits established by regulatory bodies (Directive 2013/51 / EURATOM and RD 314/2016) for its consumption. On the other hand, Total Indicative Dose for ingestion has also been estimated.

The Radiometric Techniques used to monitor both radionuclides have been Gamma Spectrometry with High Purity Intrinsic Germanium Detector (HPGe), and Liquid Scintillation Counter (TRI-CARB 1500). ^{222}Rn measurement has been carried out directly, 3 hours after sampling, both by Gamma Spectrometry (from the emission photopeaks of ^{214}Bi and ^{214}Pb) and Liquid Scintillation (based on the quantification of the alpha radiation emitted when the secular equilibrium between Radon and its descendants, ^{218}Po and ^{214}Po, is established). For the measurement of ^{226}Ra with both techniques, the samples have been stored, properly sealed and refrigerated for 30 days, to achieve the secular equilibrium (99.5%) between Radium, Radon and their descendants.

Chronic low and moderate dose rate irradiation is as potent as acute exposure in inducing a pro-inflammatory and senescent phenotype in primary human endothelial cells

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Recent epidemiological studies strongly suggest that exposure to ionizing radiation may lead to increased risk of cardiovascular disease. Moreover, data on occupationally exposed personnel cast doubt on the common notion that low dose rate irradiation is associated with a large sparing effect compared to acute exposures, as such cohorts show cardiovascular risk comparable to that estimated for A-bomb survivors.

It is reasonable to assume that the endothelial lining of blood vessels is the main target for radiation in the vasculature. Therefore, by taking advantage of our chronic radiation facility and a high-throughput imaging system, we aimed to elucidate the response of primary human endothelial cells to protracted radiation exposures at low and moderate dose rates (from 100mGy/d to 1Gy/day over a 4-day period), and compare it to acute irradiation at doses from 0.4Gy to 4Gy. We have focused on markers of DNA damage and repair, chronic inflammation and senescence. In comparison to other cell types, such as fibroblasts, endothelial cells showed a remarkable radiosensitivity, characterized by increase in senescence, starting from the lowest experimental dose and dose rate. The growth arrest and acquisition of a senescence morphology were accompanied by a robust Senescence Associated Secretory Phenotype (SASP) and a significantly altered inflammatory status and affinity to interacting with immune cells. Notably, no significant dose rate effect was observed, indicating that chronic low and moderate rate radiation exposure is as potent as acute irradiation in inducing senescence-associated endothelial dysfunction.

Here we will report the main results of the study and also discuss briefly some mechanistic insights from experiments with inhibition or siRNA knockdown of inflammatory or senescence pathways. We believe that this study sheds some light on the dose and dose rate dependencies of radiation-induced endothelial dysfunction, and may be useful in future efforts to advance the estimation of radiation-induced cardiovascular risk.

Effects of dose, dose rate and repair capacity on the formation and resolution of DNA damage foci under conditions of chronic irradiation

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DNA Double Strand Breaks (DSBs) are deeply implicated in radiation-induced biological effects and are a logical starting point for deliberations on radiation-associated risk to human health. The most common technique used in studies of radiation-induced DSBs is the microscopic detection of DNA damage foci by immunolabeling of repair proteins such as 53BP1. A massive body of research has been compiled to date on Radiation-induced foci (RIF). However, studies on prolonged exposures at low and moderate radiation dose rates remain scarce, and there exists a single report in the literature showing that at dose rates up to 0.35 mGy/min, RIF levels are proportionate to the dose rate but do not increase with total dose. Nevertheless, formal dose-response relationships for RIF under chronic radiation have not been reported.

Here, we have utilized a high-throughput imaging system to analyze DNA repair foci in a very large number of cells providing sufficient statistical power at low dose rates and doses. Repair-proficient and repair-deficient human and mouse primary fibroblasts were exposed to chronic radiation at dose rates of 0.1, 0.2 and 0.3 mGy/min for time intervals between 3 and 120 hours, corresponding to total doses between 0.018 and 2.25 Gy. Our data demonstrate that in repair-proficient cells RIF accumulate during the early hours of chronic radiation exposure and then maintain a constant level, most likely reflecting an equilibrium between formation of new RIF and their resolution by repair. In contrast, repair-deficient cells accumulate DNA damage under chronic radiation at a rate inversely proportionate to their repair constants.

In order to formally describe the results of the study, we are introducing here a growth/decay mathematical model for dose-response curves under low and moderate dose rates. The RIF induction and repair constants obtained from the model reflect the radiation dose rate and repair capacity of the cell models respectively, and therefore allow us to gain some mechanistic insights into the underlying processes, which we will briefly discuss here, together with some probable implications of out observations for radiation risk assessment.

Small cell neuroendocrine carcinoma of the cervix: A case report

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Introduction. Worldwide, cervical cancer is the most prevalent human papillomavirus (HPV)-related cancer, the fourth most common cancer in women, and the second most common cancer among women ages 15 to 44 years. Radiotherapy is effective for patients with locoregional cervical cancer of any stage, especially if they are not candidates for surgery. Treatment usually consists of a combination of external-beam radiotherapy (EBRT) with concurrent chemotherapy and brachytherapy.

80% to 90% of cervical cancers are squamous cell lesions. Small cell carcinoma of the cervix is a very rare histological type which is a neuroendocrine cancer. About 3% of cervical cancers are of this histological origin. The early and frequent lymphatic and distant spread is quite common. And the prognosis is poor. It is safe to say that traditional therapy for cervical cancer SCC are not effective in patients with neuroendocrine small cell carcinoma. Histologically it is indistinguishable from small cell carcinoma in lung, gastrointestinal tract and other sites. In this report we present a case diagnosed with cervix small cell carcinoma.

Case. A 53 year old woman was inspected with 6 months of vaginal bleeding. Gynecological examination and transvaginal ultrasonography revealed an ulcerative mass of 23 mm on the posterior wall of cervix. The histological examination of cervical biopsy was reported as high grade neuroendocrine carcinoma, small cell type. On immunohistochemical analysis, the neoplastic cells expressed synaptophysin, pankeratin, chromogranin but were negative for s-100, p63 and p40. PET-CT reported a cervical mass extending to 1/3 proximal vagina and pelvic lymph node metastasis to both right and left internal and external lymph nodes. The patient was staged as FIGO stage III C1. Primary treatment was planned as concomitant chemoradiotherapy and brachytherapy. Radiotherapy doses were 50.4 Gy (180 cGy /fr- 28 fractions) to pelvic lymph nodes and primary lesion, 45 Gy (180 cGy /fr- 25 fractions) to paraaortic region and 54 Gy to involved lymph nodes, and concomitant chemotherapy protocol was 40 mg/m2 cisplatin (70 mg weekly). Following concomitant therapy patient immediately started brachytherapy and 24 Gy in four fractions were given. PET-CT obtained 3 months after completion of concomitant external beam radiotherapy and chemotherapy and brachytherapy showed complete response of primary tumor and pelvic lymph node metastases but revealed new metastatic lesions of lung parenchyma and mediastinum. The patient was referred to medical oncology for chemotherapy. After 6 cycles of chemotherapy (cisplatin and etoposide) PET-CT revealed partial regression but the diagnostic images after 2 months showed progression of the disease in lungs and the patient were given 3 cycles of irinotecan. The diagnostic images taken following chemotherapy showed progressive lung lesions and new skeletal and left adrenal gland metastasis.The patient succumbed to the disease after 17 months following diagnosis.

Conclusion. Because small cell neuroendocrine carcinoma of cervix is a very rare tumor, it is difficult to design prospective randomized trials to evaluate the impact of various treatments on outcome. Small cell carcinoma of cervix has an aggressive clinical course and it is possible that the inclusion of intensive sequential chemotherapy regimens following concomitant chemoradiotherapy may improve survival results.

Modulated electrohyperthermia (mEHT) enhances tumor cell apoptosis during radiotherapy in cervical cancer patients

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Objectives. Cervical cancer patients with deep tumor invasion to pelvic tissues still have a very poor prognosis because of frequent incomplete local response to chemoradiation (CHRT) and contraindications to concomitant chemotherapy. Modulated electrohyperthermia (oncothermia), based on alternating high-frequency electric field (13.56 MHz), modulated by fractal harmonic oscillations 0-5 KHz, performed by capacitive coupling of asymmetric electrodes, seems to be an effective radiosensitizer in different tumor types and sites, with unclear molecular mechanism of biological effects.

Aim. To assess mEHT effects on tumor apoptosis in IIb-IVa cervical cancer patients.

Methods. 155 pts, T2b–T4aN0-1 cervical cancer, were randomised in 2 groups. Conformal EBRT (3D–CRT, IMRT) in 2Gy, 46–48Gy for pelvic or extended paraaortic fields was performed in all pts; concomittant Cisplatin 40mg\m2 or Carboplatinum AUC2 weekly – in 101 pts (51pts in research branch A (mEHT+EBRT+chemo), 50 pts – in control C branch (EBRT+chemo); mEHT (EHY-2000), 60-90' 3 t/, 90-120Wt6 before irradiation, 3 times a week, 10–13 per course –in 105 pts, research A and B (mEHT+EBRT) branches, 969 mEHT sessions in total. We use 20-genes panel for dynamic tumor apoptosis assessment in 4-point tumor samples before treatment, at 25-30Gy and after the last EBRT session.

Results. Tumor apoptosis was expressed in all tumor samples, significantly higher in A vs B and C ($p<0.05$), B branch vs C ($p<0.05$) for intergroup comparison. BCL2, p16INK4a and BAG1 expression level after the treatment had a predictive value for complete local response.

Conclusion. mEHT enhances radiotherapeutic effects on tumor cell apoptosis in cervical cancer patients.

Comparison of tangent-based volumetric modulated arc therapy and 3-D conformal radiotherapy with deep inspiration breath-hold technique for left breast cancer patients

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Aim. This study compared the dosimetric characteristics of tangent-based volumetric modulated arc therapy (t-VMAT) and 3-D conformal radiotherapy for left breast cancer patients during deep inspiration breath-hold (DIBH).

Methods. Two patients with left breast cancer after breast-conserving surgery were included. Two different treatment planning techniques were generated for each patient on the Eclipse treatment planning system. For planning target volumes (PTVs), conformity index homogeneity index and integral doses were reported. For the organs at risk, the analysis included the mean dose and VXGy, depending on the organs (lungs, heart, right breast).

Results. We have summarized the dosimetric results of PTV and OAR's in table-1 and CI, HI and Integral body doses in table-2. In patients after breast-conserving surgery, 3-D conformal radiotherapy (CRT) can effectively reduce mean, %2 doses, V_{10} and V_5 of the affected opposite lung and breast (right breast and lung) doses in clinics.In contrast, heart volume at high doses (mean and V_{30}) and left lung (%2 and V_{20}) were lower for t-VMAT technique. Moreover, the t-VMAT plans showed superior to PTV dose coverage, conformity index (CI), homogeneity index (HI).Integral doses was significantly lower in 3-D conformal radiotherapy technique in two patients (8.878 and 5.917).

Conclusions. Among the deep inspiration breath- hold radiotherapy treatment plans, the t-VMAT achieved better PTV dose coverage CI, HI index with sparing of left lung and heart.

On the microscopic description of irradiation dynamics

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We discuss microscopic mechanisms of irradiation in clusters and molecules. We consider the case of isolated molecules/clusters [Phys. Reports 337 (2000) 493] and/or in contact with an environment [Phys. Reports 485 (2009) 43]. Examples are taken from free metal clusters, from fullerenes, from molecules of biological interest and from clusters deposited on a surface or embedded in a matrix. We analyse in particular the properties of emitted electrons (photo electron spectra, angular distributions…) which constitute a key tool of analysis of the properties of irradiated clusters and molecules [Phys. Rep. 562 (2015) 1].

The microscopic real time description of irradiation processes requires an explicit dynamical account of electronic degrees of freedom. But it is necessary to treat electrons in a non-adiabatic way and to allow for ionization and/or electron transport. Basis of the description is Time Dependent Density Functional Theory (TDDFT, for electrons) coupled to Molecular Dynamics (for ions). Widely used TDDFT approaches such as Local Density Approximation (LDA) however lack crucial dynamical correlations responsible for energy redistribution and thermalization after irradiation.

We thus propose a quantum Relaxation Time Ansatz (RTA) providing an approximate quantum kinetic treatment [Ann. Phys (NY) 354 (2015) 183]. The RTA has allowed us to access realistic irradiation scenarios and study the impact of dissipation on electron emission in moderate size systems. RTA has recently been included in an open source software package entitled QDD (Quantum Dissipative Dynamics) which allows to study moderate to large systems such as fullerenes. We shall briefly outline the capabilities of this new open source software [https://www.irsamc.ups-tlse.fr/qdd/].

RayActive: A new optimized and automated methodology to assess the neutron induced activation

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Neutron production in nuclear facilities can be at the origin of a SDDR (Shutdown Dose Rate). This SDDR could be dangerous even years after neutron source extinction. Several methods exist to simulate the SDDR of neutron irradiated materials. A method mainly used is the R2S (Rigorous-Two-Steps) method. The R2S method consists in computing the neutron flux in the modeled geometry with a Monte-Carlo transport method [http://inis.iaea.org/Search/search.aspx?orig_q=RN:34020451] [http://inis.iaea.org/Search/search.aspx?orig_q=RN:35106312]. The neutron flux is calculated on a user-defined mesh in order to take into account the neutron flux gradients. Then, an inventory code is used to compute the inventory for each voxel of the mesh. Finally, the decay sources from the produced radioactive isotopes are transported by a Monte-Carlo method to obtain a map of the SDDR.

RayActive is a new methodology that allows to compute the SDDR. It is based on a R2S method with an almost exact identification of the volumes of materials encompassed in each voxel of the superimposed mesh. The identification of materials enclosed in voxels is made possible by the use of CAD (Computer-Aided Design) based geometry definition. Moreover, RayActive is conceived to be as automated as possible. The method is designed so that each part of the computation has been optimized to minimize the computational time. A verification of the method has been done on shutdown dose rate benchmarks made with FLUKA code [doi: 10.3389/fonc.2016.00116]. Good agreement was found for these benchmarks. Finally, new features to make the method even more optimized and easy to use are under construction.

Application of neutron activation analysis in environmental and material science

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Neutron activation analysis is a high sensitive analytical technique used in the environmental studies for the determination elements in a wide range of concentrations. The principle of instrumental neutron activation analysis is discussed and the advantages of this technique in analysis of environmental objects are shown. Examples of research performed on the radioanalytical complex REGATA at the IBR-2 reactor (Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna) will be presented. The presentation will be focused on application of neutron activation analysis in assessment of trace elements deposition using moss as biomonitors, wastewater treatment, assessment of soil and water pollution, evaluation of elemental composition of nanomaterials and archeological objects.

An extraction-chromogenic system for vanadium(V) based on 4-(2-thiazolylazo)orcinol and benzalkonium chloride

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A water–chloroform extraction–chromogenic system for vanadium(V), based on the azo dye 4-(2-thiazolylazo)orcinol (TAO; H_2L) and benzalkonium chloride (BZK), was studied. Under the optimal conditions (c_{TAO} = 2.8×10^{-4} mol dm^{-3}, c_{BZK} = 1.0×10^{-3} mol dm^{-3}, pH 5.2 and extraction time t = 3 min), vanadium(V) is extracted as a ternary dimeric complex which can be represented by the formula $\{(BZK^+)[VO_2L^{2-}]\}_2$. The following extraction-spectrophotometric characteristics were determined at the above-mentioned optimal conditions: λ_{max} (549 nm), molar absorptivity (2.7×10^4 dm^3 mol^{-1} cm^{-1}), Sandell's sensitivity (1.88 ng cm^{-2}), Beer's law limits (34–2500 ng cm^{-3}), constant of extraction (Log$K$ = 14.0±0.2), and fraction extracted (96.8 %).

Acknowledgments: This work was supported by the Plovdiv University Scientific Fund (grant No. SP21-004) and by the Medical University of Plovdiv (grant No. DPDP24/2019).

Modification of ^{18}F-fluorodesoxy-glucose (^{18}F-FDG) radiopharmaceutical by oxime conjugation

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The radionuclide 18F is one of the attractive positron emitters and most often the isotope is obtained in the cyclotron by the nuclear reaction 18O (p, n) 18F. Basically, the radionuclide ^{18}F is used for the production of ^{18}F-labeled radiopharmaceuticals applied in positrone-emission tomography (PET). The most widely used among them is ^{18}F-fluorodeoxy-glucose (^{18}F-FDG). ^{18}F-FDG as glucose analog can be used to assess the metabolism in the brain and heart, and also to study malignancies. It plays an important role in the planning of radiation therapy for pathologies such as lung cancer, head and neck cancer, colon cancer. This radiopharmaceutical is produced in the Clinic of Nuclear Medicine at the University Hospital "St. Marina". Apart from being a universal but non-specific PET radiopharmaceutical, 18F-fluorodeoxy-glucose can also be used as a prosthetic group for indirect radiofluorination of biomolecules such as peptides and proteins under relatively mild reaction conditions, which allows the development and synthesis of more specific PET radio tracers. A method has been developed to modify 18F-FDG synthesized in the clinic by forming an oxime chemical bond with a bifunctional compound. The syntheses are carried out by varying the buffer, temperature and catalyst used. The course of the reaction is monitored by radio TLC - chromatography.

Acknowledgments: The authors are grateful for the support provided by the Research Fund at the Ministry of Education and Science (contract № KP-06-N29/4).

VOXES: a new HAPG mosaic crystal based Von Hamos spectrometer for millimetric sources

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Von Hamos spectrometers are widely used in several fields, ranging from pure physics applications to very different types of practical ones. However, these type of Bragg spectrometers are usually implied in high rate – high resolution experiments, where the typical source size can be as low as few tens of microns.

The VOXES collaboration at the INFN Laboratories of Frascati INFN recently developed a VH spectrometer, making use of HAPG mosaic crystals and a X-ray beam optics optimization, which could be used for source sizes up to few mm, (in the Bragg plane), some tens of mm in the sagittal plane and, if gaseous sources are used, of several tens of cm in the X-ray propagation direction. Such kind of a spectrometer could be used, for example, to open a new era in the field of exotic (kaonic) atoms precision measurements, delivering data with unprecedented precision to the (strangeness) nuclear physics community. In order to foreseen the possible capabilities of this apparatus in terms of signal collection efficiency, reliable ray tracing simulations are necessary, whose consistency with experimental data has to be preliminary checked. We present the main results obtained with the VOXES spectrometer, as well as a comparison of ray tracing simulations. For both of resolutions and reflection efficiencies, the simulations and the experimental results are found to be well in agreement within the errors.

Multipurpose J-PET detector for medical imaging and tests of discrete symmetries

Sz. Niedźwiecki
on behalf of the J-PET collaboration

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The Jagiellonian Positron Emission Tomograph (J-PET) is a detector for: 1. medical imaging by combining metabolic information collected by standard PET with structural information obtained from Positronium lifetime in a concept of morphometric image, 2. tests of discrete symmetries, 3. and even test of quantum entanglement of photons originating from the decay of positronium atoms. The novelty of the system is based on usage of plastic scintillators for active detection material and trigger-less data acquisition system. The apparatus consists of 192 plastic scintillators read out from both ends with vacuum tube photomultipliers. Signals produced by photomultipliers are probed at four levels in the amplitude domain and digitized on 8 FPGA based readout boards in trigger-less mode. At J-PET the Time Over Threshold (TOT) response is used as a measure of energy loss instead of charge integration methods. This significantly reduces system dead-time, which is especially crucial since plastic scintillators produce fast light pulses. In the talk a system performance and recent results will be presented and the non-linear correlation between input energy loss and TOT of the signal will be discussed.

Frequency dependent electrical characteristics of Al/SiO_2/SiNWs/n-Si MOS capacitors

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In this work, the frequency dependent electrical characteristics of Al/SiO_2/SiNWs/n-Si MOS capacitors were investigated. The electrical properties of the capacitors were calculated from the capacitance-voltage (C-V) and conductance-voltage (G_m/ω-V) measurements for several frequencies ranging from 50kHz to 1MHz. Our experimental results showed that both frequency and voltage variations had a significant impact on the C-V and G_m/ω-V characteristics. The C-V characteristics were found to decrease with an increase in the applied voltage frequency due to the distribution of the interface states (N_{it}) within the oxide layer. The G_m/ω-V characteristics were also found to have peaks and the peaks increased with an increase in the applied voltage frequency but except for 50kHz and 100kHz. This was caused by the existence of series resistance (R_s) and N_{it}. We have also studied the frequency dependence on the electrical parameters such as R_s, N_{it}, doping concentration (N_D), and barrier height (Φ_B). The values of R_s were found to decrease with increasing frequency, while the values of N_{it}, N_D and (Φ_B) were also found to increase with increasing applied frequency.

Keywords: SiNWs, MOS capacitors, Series resistance, Interface states, C-V, G_m/ω-V

Acknowledgments: This work is supported by the Presidency of Turkey, Presidency of Strategy and Budget under Contract Number: 2016K12-2834.

Gamma radiation effects on the electrical and structural properties of the $HfSiO_4$ n-MOS

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Sensors in the form of radiation sensing field effect transistors, also known as pMOS, are used in many fields from spacecraft to medical applications. Sensitive region of the commercial pMOS dosimeters consists of SiO_2, and the response of the device deviates from linearity with increasing dose. It is important to investigate alternative dielectrics in order to obtain sensors that can reach saturation later and which are smaller compared to conventional structures, especially in high radiation exposure. Sensitivity of MOS structures produced with some rare earth oxides such as Er_2O_3, Yb_2O_3 was higher than those with SiO_2, which may result in earlier saturation. On the other hand, while the electrical characteristics of MOS-based devices produced with some dielectrics such as Gd_2O_3 did not shift with the applied dose as expected, the frequency-dependent device response may exhibit different behaviour [J. Mater. Sci. 55 (2020) 7999-8040]. For this reason, it is necessary to determine the structural changes in high-k/Si structures with the applied dose and to examine the effects of these changes on electrical characteristics. The aim of this study is to determine the structural changes of $HfSiO_4$/n-Si structures under gamma radiation using XRD and XPS techniques and to establish a link between the radiation response of the $HfSiO_4$ MOS capacitor and these parameters. Possible contamination on n-type Si (100) wafer was removed by processing the standard RCA cleaning procedure. $HfSiO_4$ films were grown on 6-in. wafers using hafnium silicate granules by EB-PVD system. The front and back metal contacts of $HfSiO_4$/n-Si structures were formed by DC magnetron sputtering. As-deposited structures and MOS capacitors are stored in a nitrogen cabinet. All production stages were carried out in 100 class clean room laboratories in NRDC. The MOS capacitors and high-k/Si structures were irradiated with ^{60}Co radioactive gamma source for 1 kGy, 25 kGy, 50 kGy, and the dose response of the sensors were investigated for 100 kHz and 1 MHz voltage frequencies. No change was observed in the crystal properties of the film with irradiation, and $HfSiO_4$ preserved its amorphous property. The atomic concentration of the Hf decreased continuously with increasing depth from the surface and it got the lowest values at 1 kGy compared to others. At both frequencies, the C-V curves did not continuously shift to the right or left with increasing radiation dose. Similar changes in oxide trap and interface trap charge density made it difficult to establish a link between electrical characteristics and structural properties.

Acknowledgments: This work is supported by the Scientific and Technological Research Council of Turkey under ARDEB1001- Scientific and Technological Research Projects Support Program (Contract Number: 117R054) and also supported in part by the Presidency of Turkey, Presidency of Strategy and Budget under Contract Number: 2016K12-2834.

Study of the consequences of the combined action of prolonged Y-radiation and simulated hypokinesia on the state of erythrocytes

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Relevance. In the course of the study, the functional state of rat erythrocytes to the action of ionizing radiation against the background of hypokinesia was assessed. This is important for aerospace medicine.

Materials and methods. *Ionizing radiation.* Prolonged irradiation of Wistar rats was carried out on a panoramic γ-type device "Experiment" at a dose rate of 5 μGy/min. The animals were irradiated, starting from the first day of the experiment, daily for 4 hours for 4 consecutive days. The total dose of prolonged exposure was 4.8 mGy. *Hypokinesia.* The animals were placed in nylon vests and suspended from a movable carriage of specially designed cages. We used the method of acid erythrograms and determined the activity of catalase and superoxide dismutase.

Results. With the combined action of prolonged g-radiation and hypokinesia on the second and fourth days, the resistance of erythrocytes to acid hemolytic decreases in the same way as when exposed to hypokinesia alone. But in the future, the reaction of the rat organism to the combined effect of hypokinesia and irradiation, tested by the state of erythrocytes, is mainly determined by the radiation factor. On the eighth day of hypokinesia in the irradiated rats, the value of the P index of erythrocytes does not normalize, as it happens in non-irradiated animals, but remains significantly less than the initial one. The main enzymes of the antioxidant system (AOS), four-hour daily-irradiation with an absorbed dose rate of 5 μGy/min against the background of hypokinesia after two sessions of exposure in the AOS simulated the effects caused by the action of hypokinesia. For this period, in the state of the enzymatic link of AOS, not an increase in the activity of superoxide dismutase (SOD) and catalase of erythrocytes, as was the case with isolated hypokinesia, was revealed, but a synchronous decrease. After 4 sessions of radiation exposure over the next 5 days in the dynamics of changes in the activity of these enzymes, a desynchronization of the rate was registered, which manifests in increase catalase and a decrease in SOD activity. The revealed shift in the AOS state correlated with the low total resistance of erythrocytes to acid hemolytic. On the 7th day after the end of hypokinesia, when the P value was restored in the qualitative composition of peripheral blood erythrocytes, a shift towards physiologically old cell forms was revealed. At the same time, in the state of the enzymatic link of AOS, a synchronous and pronounced decrease in the activity of SOD and catalase of erythrocytes was recorded at the indicated time. This indicates that the main pool of peripheral blood erythrocytes is represented by physiologically old cells.

Thus, low-intensity-irradiation of rats against the background of hypokinesia is an aggravating factor that prevents the normalization of the qualitative composition of erythrocytes, altered as a result of stress caused by hypokinesia.

The influence of modulation of intracellular NAD biosynthesis on the efficiency of DNA double-strand break repair in cultivated human cells after ionizing radiation exposure

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Nicotinamide adenine dinucleotide (NAD) is an essential pyridine nucleotide necessary for the main metabolic pathways, including glycolysis and oxidative phosphorylation. In humans, the maintenance of optimal NAD level can be achieved through its biosynthesis from various derivatives of vitamin B3 delivered with the diet. NAD level decreases with aging and the impairments of NAD biosynthetic pathways are associated with progression of age-related diseases. NAD serves as a substrate for a number of regulatory proteins such as protein deacetylases (sirtuins) and Poly(ADP-ribose) polymerases (PARPs) which play an important role in cellular response to genotoxic stress. These proteins cleave NAD to nicotinamide and ADP-ribose. PARP1 is responsible for the production of up to 90% of cellular ADP-ribose in response to DNA breaks and participates in the repair of single (SSB) and double strand (DSB) DNA breaks induced by ionizing radiation. Polymers of ADP-ribose (PAR) modify histones and repair proteins in vicinity of DNA breaks and facilitate DNA repair.

Here, we studied the effect of modulation of NAD biosynthesis on the efficiency of DSB repair, viability and metabolic activity in cultivated human dermal fibroblasts (HDF) after ionizing radiation. Efficiency of DSB repair was studied using immunofluorescence microscopy and antibodies to phosphorylated histone H2AX (gH2AX), which is known as a marker of DSB. NAD level was measured using calorimetric assay and NMR spectroscopy. We have shown that intracellular NAD level can be significantly increased after supplementation of culture medium with NAD precursors - nicotinamide riboside (NR) and nicotinic acid riboside (NAR). No significant decrease of NAD level was observed in irradiated cells at the doses of 1Gy and 5Gy. Moreover, the efficiency of DSB repair was not improved after NR or NAR supplementation. We also used FK866, the inhibitor of nicotinamide phosphoribosyltransferase, an enzyme of the main pathway of NAD biosynthesis, to test if depletion of cellular NAD can influence the DSB repair. Using MTT-assay and flow cytometry, we have shown that the cells are still viable after several days of FK866 treatment. Surprisingly, under these conditions HDF cells were able to repair DSB although less efficiently in comparison with untreated cells. The treatment with FK866 completely eliminated PAR formation in irradiated cells and inhibited the accumulation of activated form of ATM kinase, phospho-ATM (ser1981), which phosphorylates histone H2AX at the sites of DSB. These data indicate that NAD and NAD-dependent regulatory reactions are important but not crucial for the repair of DNA DSB induced by ionizing radiation.

Acknowledgments: This study was supported by the grant from the Russian Science Foundation (grant no. 20-74-00145).

Genotoxic effect of combined treatment with anaesthetic sevoflurane and 2 Gy radiation in mice

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During intraoperative radiotherapy or brachytherapy, general anesthesia is occasionally used not only for the patients ease of pain but also to calm and ease the psychological pain in very anxious or young patients and also to localize as much as possible the target area and lower the possibility of side effects or repeated unnecessary procedure. Given the fact that ionizing radiation (IR) is a known genotoxic and cytotoxic agent, exposure, the dose and number of IR exposures should be kept at a minimum and volatile anesthetics (VA), as the most used type of general anesthesia can be of great help in that mission. Mechanisms of VA action are enhancing inhibitory postsynaptic channel activity, nicotinic acetylcholine, serotonin, and glutamate in the central nervous system. They are considered generally safe for the patients, but there are studies demonstrating different side effects among patients but also among occupationally exposed personnel. Since there is no study comparing the DNA damage effect from the VA exposure combined with the fractionated single IR dose exposure, we wanted to investigate whether there is a difference in DNA damage response of white blood, kidney, brain, and liver cells *in vivo*. After gaining all ethical approvals, we anesthetized Swiss albino male mice (60±5 days old, 20-25g body weight) with 2.4% sevoflurane mixture with oxygen and air (50:50) for 2 hours, exposed a group of the 20 animals to 2 Gy IR (^{60}Co, Theratron Phoenix teletherapy unit, Atomic Energy Ltd, dose rate of 1.88 Gy/min), while the other groups were control (non-treated), exposed to only sevoflurane or exposed to only IR. Sevoflurane was chosen as one of the most used VA. Samples of in total 80 animals were taken after 0, 2, 6, and 24 hours from the exposure (5 animals for each time point), and damage was assessed by the alkaline comet assay and Comet Assay IV software (Instem UK) using parameters of comet tail length, tail intensity and tail moment. On the samples prepared in duplicate per each animal and time point, in total 100 comets were analyzed. The cellular DNA repair index was calculated to quantify the cells' DNA repairing damage efficiency. In white blood cells and the brain, sevoflurane demonstrated a slightly protective effect in combined exposure compared to only IR samples that demonstrated significantly higher damage than control. Kidney and liver demonstrated a delay in initiation of DNA repair processes of 6 hours. The significantly higher values in liver and kidney especially 24 hours from the combined exposure, call for further investigation on the mechanisms of combined VA and IR treatment, with longer time periods of observation than the 24 hours from our study, in order to be sure to what extent the DNA damage remains, and how well the cells can recover from single dose exposure to both agents.

Primary DNA damage in brain of mice exposed to anaesthetic isoflurane and ionizing irradiation in dose of 1 or 2 Gy

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Due to fast sedation and stable patients' conditions during the procedures when general anesthesia is necessary, volatile anesthetics (VA) are widely used, and among them, the most commonly used is isoflurane (ISO). Although considered safe, there are reports about its genotoxicity and mutagenicity *in vitro, in vivo,* and in clinical studies but with no consistent and even contradictory results, mostly considering the toxic and protective effects in brain cells. In the last decade, there is an increase in the number of different interventional and diagnostic radiology procedures requiring relative patient immobility either due to the procedure or due to different patients' conditions. The use of novel irradiation techniques in different radiotherapy type (intraoperative radiotherapy, brachytherapy, fractionated and hypofractionated radiotherapy) demonstrated the possibility of receiving less radiation and fewer side effects, ionizing radiation (IR) is still considered a genotoxic, cytotoxic and mutagenic agent that can cause effects not only in a target area but also side effects in the surrounding healthy tissue (cells). Combined VA-IR effects have not been examined so far, although, according to the scientific literature, there is a possibility of their synergistic effects. ISO due to its influence on different receptors against pain, muscle relaxation, etc. demonstrated the highest impact on the brain cells. Therefore, we decided to test the influence of combined VA and single fractional IR dose exposure on the DNA damage levels in *in vivo* model. After ethical approvals, Swiss albino male mice (60±5 days old, 20-25g body weight), grouped in 6 main groups, with 5 animals each, were exposed to either 2.4 % ISO® isoflurane mixture with oxygen and air (50:50) for 2 hours or to 1 or 2 Gy whole-body γ-radiation exposure (^{60}Co, Theratron Phoenix teletherapy unit, Atomic Energy Ltd, dose rate of 1.88 Gy/min) or their combination or served as a control group. Further subgroups were made according to the protocol established in our previous articles and animals were sacrificed immediately (0h), 2, 6, and 24h from the exposure, and brain cell single suspensions were prepared for DNA damage evaluation using alkaline comet assay, with duplicate samples per each animal, scoring 100 cells per each time point. In non-irradiated ISO samples, primary DNA damage levels, although slightly higher, did not significantly differ from control at all time points. IR only samples had significantly higher damage, with the dose increase. In both combined exposures, after 24 hours, ISO significantly decreased DNA damage levels, compared to IR samples and demonstrated its influence on increased velocity repair of the rest of IR damage. Adaptive response, by activating DNA repair mechanisms and the levels of reactive free oxygen radicals' scavengers are the possible mechanisms of isoflurane protective effect but further research should be focused on determining the exact mechanisms.

Reactions of normal and tumor tissues of rats with sarcoma M-1 to carbon ions irradiation

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Ion therapy demonstrates a substantial advantages over conventional radiotherapy due to high dose conformity to a target coupled with biological efficiency what stimulates constructing new ion therapy centres in the world. Currently, physical, dosimetric and radiobiological studies are carried out at the U-70 synchrotron of Institute for High Energy Physics (IHEP), Protvino, with a perspective to open a center of ion radiation therapy on its base. The results of in vivo studies of the pristine carbon ion beam effectiveness at the IHEP radiobiological facility are presented.

Male rats (150-200 g) with solid tumor sarcoma M-1 implanted in the thigh were used in the studies. A rat, fixed in a dedicated container, was placed in the caisson inside a water phantom and then the tumor on the thigh was locally irradiated with ^{12}C ion beam at the pristine Bragg peak. An aluminum collimator with an aperture diameter of 30 mm was placed in front of the caisson to form a narrow beam. The initial energy of the ^{12}C ions was 454 MeV/u, depth-dose curves were measured with ionizing chambers and EBT3 films. LET spectra and doses were also estimated with the GEANT4. The FWHM of the Bragg peak was »20 mm and nearly corresponded to thickness of tumors used. Dosimetry data showed that the average absorbed dose of carbon ions for the whole tumor volume was 10 Gy, at the centre of the Bragg peak it was 13 Gy. Calculated average LET_d values ranged from 120 to 140 keV/μm. To compare the carbon ion effectiveness with that of reference radiation rats with sarcoma M-1 were also irradiated with ^{60}Co gamma-rays at a dose of 36 Gy (assuming RBE=3 for a planed carbon ion dose of 12 Gy).

The tumor growth dynamic and the skin reaction yield within 25 days after exposure were the criteria of the carbon ions and gamma irradiation effectiveness. RBEs were estimated on the basis of calculated area under the curves of the relative tumor volume change dynamics.

The integrals under the growth curve areas were measured to be 17.03 and 19.72 (in arbitrary units) for carbon ions and gamma-rays, respectively (the ratio was 1.16). The results obtained showed that carbon ions at the pristine Bragg peak had higher antitumor efficacy than it was expected, and the experimentally estimated RBE was 4.2 (the isoeffect equation 10 Gy×RBE(^{12}C)=36 Gy×1.16 gives RBE(^{12}C)=4.2). As for skin reactions, wet epidermitis occurred following a gamma radiation dose of 36 Gy. After the local carbon ions exposure dry epidermitis was observed during the first 15 days that corresponded to a gamma radiation dose not exceeding 32 Gy. Overall, the skin reactions yield after carbon ions irradiation as compared to gamma-rays exposure was 2.3 times lower (the criterion is the area under the curve of the skin reactions manifestation dynamics).

Thus, in vivo studies on rats with a model tumor reveal demonstrated high antitumor efficacy of accelerated carbon ions (RBE higher than 4), with mild skin reactions.

Generational impacts of paternal irradiation in a cricket: Damage, life-history features and hormesis in F1 offspring

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Animals exposed to significant stress express multi-modal responses to buffer negative impacts. Ionizing radiation can inflict considerable damage to molecular, cellular and epigenetic aspects, both directly and via generation of reactive oxygen species. Impacts on germ cells may also transmit transgenerational alterations to F1 offspring. Transgenerational impacts have been mainly studied in maternal lines, and paternal lines have received less attention. Here we assess damage and life history alterations arising from irradiation of juvenile (4^{th} instar) male crickets (Acheta domesticus) and their F1 offspring. Paternal transmission of radiation impacts emerged in multiple life history traits. Irradiated males and F1 offspring expressed hormetic responses in survivorship and life span at mid-range doses (i.e., 7Gy & 10Gy doses extended F0 longevity by 37% and 31%, respectively). F1 offspring of paternal 7Gy and 10Gy sires lived 30% and 79% longer, respectively. Although irradiated F0 males had reduced growth rates, F1 offspring did not. Results indicate that irradiation directly impacted males but also mediated significant alterations in life history features (particularly longevity and survivorship) of F1 offspring.

Application of adsorbents in radionuclide separation for radio chronometry purposes

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Accurate radionuclide separation is necessary for archeological dating or in nuclear forensics to determine the age of unknown 90Sr-containing devices. The most effective method of separating the elements at present time is the adsorption method.

The aim of this work is the application of well-known adsorbents for the separation of 90Sr, 90Y, and 90Zr radionuclides. Three basic types of adsorbents have been studied: Dowex HCR S/S cation exchange resin with active sulfonate groups, Dowex 1x8 anion exchange resin having quaternary amines in its structure, and titanium dioxide with a chemically modified surface. The study was performed using stable isotopes 88Sr, 89Y, 90Zr. Separation on cation exchange resin and titanium dioxide was performed from a 2% HNO_3 medium with HF micro impurities. Separation using an anion exchange resin was performed in a 5% HCl medium. Analysis of the initial ion concentrations in the mixture and the concentrations after separation was conducted using ICP-MS “Element-2” with argon plasma.

It was shown that Dowex HCR S/S resin showed increased selectivity for zirconium cations at an initial concentration of elements in the order of 10 ng/ml. However, at higher concentrations, this adsorbent does not show selectivity for zirconium cations and adsorbs all three elements in approximately equal amounts. In addition, this ion exchanger intensively absorbs yttrium cations. The Dowex 1x8 resin separates strontium and zirconium due to the complete absence of adsorption of strontium cations. However, this resin together with zirconium ions adsorbs a small number of yttrium ions. The effective separation of strontium and zirconium ions by Dowex 1x8 occurs in a 5% HCl medium and for subsequent analysis using ICP-MS a solution of 5% HCl is evaporated for 5 hours, and then the dry residue is dissolved in 2% HNO_3 (Optima). The most effective adsorbent for the separation of strontium, yttrium, and zirconium ions was titanium dioxide with a chemically modified surface. This adsorbent selectively absorbs zirconium cations against the background of excess strontium and yttrium ions from 2% HNO_3 at initial concentrations of the studied cations 10 ng/ml and 100 ng/ml. Described methods could be a basis of the technique of determination of the age of unknown 90Sr/90Y β- -sources.

A short description of an alternative method of determining the 90Zr/90Sr ratio based on a combination of liquid scintillation counting of 90Sr and ICP-MS analysis was made. It was shown, that the proposed combination of liquid scintillation counting of 90Sr and ICP-MS analysis could be used as a method of validation.

Morphology, emission and crystal structure of ZnO nanocrystal films co-doped with Ga and In elements

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The impact of double donor doping on the crystal structure, morphology, composition, and photoluminescence (PL) has been studied in the ZnO:Ga:In nanocrystal films. The films were deposited by ultrasonic spray pyrolysis on silicon substrates heated to 400°C. To the study of double donor doping, two groups of samples were prepared. In the first group the In content was of 1at%, but the Ga contents were varied in the range 0.5-3.0at.%. In the second group the In content was of 2at% and the Ga contents were changed in the range 0.5-2.5at%. To stimulate the film crystallization, all samples were annealed at 400°C for for 4h in a nitrogen flow (5L/min).

The non-monotonous variation of the XRD and EDS parameters, morphology, and emission versus concentrations of donor-like impurities has been detected in the ZnO nanocrystal (NC) films. The high-quality NC films with the wurtzite-type crystal structure, planar morphology, bright near band edge (NBE) emission and the small intensity of defect related PL bands have been obtained. The reasons for parameter varying non monotonically and the optimal concentrations for the Ga/In donor type doping of ZnO NC films have been analyzed and discussed.

Comprehensive studies of organic and inorganic adsorbents

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Purification of aqueous solutions from radionuclide contamination is an extremely problematic topic, which is the subject of many scientific papers. This scientific topic is very relevant for Ukraine. The aim of this work is a detailed study of the main classes of organic and inorganic adsorbents and the possibility of analyzing experimental results using adsorption theories. In this work, we focused on two points: (1) the study of the radiation stability of adsorbents and (2) the analysis of experimental results of equilibrium adsorption of Sr^{2+} ions by the Langmuir, Freundlich, and Dubinin-Radushkevich theories.

The radiation resistance of natural zeolite, cation exchange resin, carbon sorbent, and titanium phosphate was investigated, as well as the ability to adsorb strontium ions after internal adsorbents irradiation. It is shown, that upon irradiation the sorption properties of all these materials are slightly reduced. The only exception is titanium phosphate with a surface modified with NH_4OH. Initial and residual concentration of stable strontium isotopes was measured by direct complexonometric titration. Some experiments were performed with radioactive ^{90}Sr as well. Amount of ^{90}Sr was controlled by liquid scintillation techniques. The values of adsorption of strontium ions by irradiated and non-irradiated samples of amorphous titanium phosphate were determined. The analysis of the experimental results of equilibrium adsorption was carried out using the Dubinin-Radushkevich theory, which is based on the potential theory of adsorption, as well as by the theories of Langmuir and Freundlich.

The analysis of changes of titanium phosphate surface under the action of external irradiation was conducted by the method of low-temperature nitrogen adsorption-desorption isotherms. The proportion of micro and meso-pores, as well as the total surface area of the investigated adsorbent, were estimated. The pore volume and pore radius were calculated by the DFT and BJH methods. A brief comparison of these calculation methods was made.

Dosimetric planning aspects of simultaneous irradiation of two liver metastases with high-dose-rate brachytherapy

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Liver tumour lesions are one of the most common in cancer morbidity and mortality. Only 20% of them are resectable or potentially resectable. The development of palliative, minimally invasive methods remains relevant. Therefore, the high-dose-rate (HDR) brachytherapy is relevant. The main goal of this method is to reduce the risk of local relapse while minimising the radiation exposure to the organs at risk (OARs) due to the precision of dose delivery. Since using this method, the tumour is irradiated with high doses, and correct radiation limits are important for radiation quality assurance.

In November 2020 in the A. Tsyb Medical Radiological Research Centre was the patient who needed simultaneous irradiation of two liver metastases with HDR brachytherapy . He was an 83-year-old man with 2 liver metastatic lesions of colorectal cancers. HHDR brachytherapy was performed in the mode of single-fraction irradiation of 20 Gy. He was an 83-year-old man with 2 liver metastatic lesions of colorectal cancers. HDR brachytherapy was performed in the mode of single-fraction irradiation of 20 Gy. The PTV margin was 8 mm in all directions from the CTV. Dose-volume constraints for target volume and OARs were: V90 ≥ 90% to PTV; to the lungs: Dmax-60 Gy, Dmean-0.4 Gy; the ribs: Dmax ≤ 29 Gy; the skin: Dmax ≤ 20 Gy and to the liver: Dmean ≤ 32 Gy and V5Gy ≤ 67%. The main problem of the dosimetric planning process is to maintain a balance between the target coverage and the radiation exposure to the OARs. This case was unusual due to there were 2 simultaneously irradiated PTV. Therefore, incorrect planning could lead to increased radiation exposure to the liver, which in this case was one of the main OARs. Also, one of the metastases was very close to the ribs. Despite this, the planning and treatment were successful. The parameters of the radiation exposure to the tumour in the III segment were: V90 – 99.7%, V100 - 98%; to another target in the IV segment were: V90 - 81.3%, V100 - 75.9%. As for the OARs, the radiation exposure to the lungs was: Dmax - 8.4 Gy, Dmean - 0.4 Gy; To the ribs: Dmax - 30 Gy, D2cc - 12.6 Gy; to the skin: Dmax - 14.5 Gy, D2cc - 12.2 Gy; and to the liver: Dmean - 16.1 G and V5Gy - 16.1%.

High-dose-rate brachytherapy has almost no restrictions related to the size of the tumour and can be used close enough to large vessels, eliminates errors from the movement of the patient's organs and breathing. This is possible due to the direct introduction of needles to the tumour. This example shows that we have an opportunity to irradiate simultaneously two metastases if they are small and radiation sources are accurately introduced, which can also be considered as a significant advantage of the method.

Effect of ionizing radiation on sprouting and phenology of potatoes infected by fungus *R. Solani*

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Radiation treatment of agricultural products, in particular potatoes, is an effective way both to combat a wide range of fungal, viral, and bacterial diseases and to have a suppressive effect on the germination of agricultural crops during long-term storage. The study was carried out to observe the effect of 1MeV accelerated electrons in doses ranging from 20 Gy to 3000 Gy on the sprouting and phenology of potato tubers of the cultivar Agata naturally infected with the fungus *Rhizoctonia solani Kuhn*.

Seedling development of unirradiated seed potato tubers was recorded on the 15th day after planting. Shoots of irradiated potato tubers came later: at a dose of 20 Gy - 5 days later, at 40 and 150 Gy - 10 days later, and at 100 Gy - 12 days later than in the case of the control tubers. During the growing season, a significant delay in the differentiation of shoots was observed in irradiated potato plants even at the lowest doses. Thus, at doses of 20 and 40 Gy, mass shoots were recorded on the 33rd and 35th days, and full shoots - on the 56th and 40th days from planting, respectively. At the same time, in the control tubers samples, these phenophases occurred on the 17th and 19th days after planting. Mass shoots of potatoes grown from planting tubers irradiated at a dose of 100 Gy were observed on the 52nd day, and the phase of full shoots didn't come. A dose of 150 Gy prevented the potatoes from reaching the phases of mass and full emergence. Exposure to seed tubers at a dose of 200 Gy and more completely inhibited germination of tubers.

The tendency of lagging behind was observed in the development of potato plants and continued in the budding phase of potatoes. The beginning of flowering was recorded on the 72nd and 57th days after planting only in samples irradiated by 20 and 40 Gy, respectively. Moreover, in the control samples, this phenophase occurred on the 43rd day after planting, which is 29 and 14 days earlier than in samples irradiated by 20 and 40 Gy, respectively. Radiation treatment of tubers with doses of 100 and 150 Gy did not allow the plants to bloom. Thus, ionizing radiation in the dose range from 20 to 150 Gy had a negative impact on the growth and development of the potato culture. Doses over 200 Gy resulted in complete inhibition of tuber germination.

A study of new crop potatoes was carried out for the development of Rhizoctonia in pre-planting tubers after irradiation. The prevalence of sclerotia in tubers decreased with an increase in dose compared to non-irradiated control samples. The prevalence of sclerotia on potato tubers after irradiation by the dose of 20 Gy was at the control level. Irradiation of potato seed tubers with the dose of 40 Gy decreased *Rhizoctonia solani* on the surface of tubers of the new crop by half compared with the control samples, while irradiation of potato tubers with 150 Gy completely eliminated *Rhizoctonia solani*.

The lesser amount of sclerotia on the surface of the new crop samples irradiated with the doses of 40-150 Gy in comparison with the control samples can be explained by a long process of plant formation, a shorter period of tuber accumulation, and, consequently, a shorter period of tuber exposure to *R. solani*.

Acknowledgments: This research has been supported by the Interdisciplinary Scientific and Educational School of Moscow University "Photonic and Quantum Technologies. Digital Medicine".

Research of the effects of electron and X-ray radiation on the volatile content of turkey meat

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To solve the problems of ensuring the country's food security, it is necessary to introduce environmentally friendly technologies that enable the growth of production as well as reduce losses during storage and processing.

These requirements are met by radiation technologies used to extend the shelf life and sanitary control of agricultural and food products.

At the same time, the task of increasing the efficiency of radiation processing continues to remain urgent, an optimal irradiation scheme is selected, and the possibilities of using various types of radiation sources are evaluated.

The purpose of the work is to compare the effects of X-rays and accelerated 1 MeV electrons in the same dose rate on the composition and concentration of volatile compounds in chilled turkey meat.

As an object of research, samples of turkey were selected that had been stored in a refrigerator at a temperature of 2 ℃ for no more than two days from slaughtering. The irradiation of the samples was carried out on a UELR-1-25-T-001 continuous electron accelerator with an energy of 1 MeV, an average beam power of 25 kW at an average beam current of 600 nA at an ambient temperature of 20 ℃. In the case of X-ray radiation, the samples were irradiated using an X-ray diffractometer with a PUR5 / 50 power source and a BSV-23 X-ray tube with a copper anode. The tube current in all experiments was 25 mA, the voltage was 30 kV, and the operating power of the tube was 0.75 kW. The ambient temperature was 20 ℃. A Frikke dosimeter was used to measure the dose absorbed by the samples during irradiation. A promising method of gas chromatography combined with mass spectrometry (GC-MS) was used to identify volatile compounds in irradiated products.

As a result, the dependences of the concentrations of volatile compounds after irradiation with electron and X-rays were obtained. Based on the results of the study, approximations were constructed and it was noted that the concentration of aldehydes in irradiated samples increases linearly with the increase in the dose, regardless of the type of radiation. With X-ray irradiation, an increase in the concentration of volatile compounds relative to electron irradiation was observed. The slope coefficients in the linear approximation were also large. The concentration of acetone increased linearly with the increasing dose for both types of radiation; for the control (not irradiated) sample, this compound was not detected, which makes it possible to use this ketone as a marker that allows identifying the fact of radiation treatment of meat products.

Acknowledgments: This research has been supported by the Interdisciplinary Scientific and Educational School of Moscow University "Photonic and Quantum Technologies. Digital Medicine".

Monitoring of critical parameters of the radiation sterilization process at an industrial electron accelerator

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The use of ionizing radiation is a safe and effective method for sterilizing medical devices, pharmaceuticals and food products. In accordance with the requirements of international standards, a necessary condition of the process QA is to maintain its critical parameters within the specified limits. Primarily such parameters are the electron energy and absorbed dose. The value of the latter must be controlled in the each unit of the processed product. Traditionally, the disposable chemical dosimeters are used in an off-line mode for these purposes. For on-line monitoring of beam energy and absorbed dose, a method based on measurement of distribution of the charge induced by irradiation in a wide-aperture stack monitor positioned behind an irradiated object was developed and implemented. In the report, a brief overview of a control system developed on the basis of an EPICS package for continuous monitoring of the processing parameters at a LU-10 industrial electron Linac of NSC KIPT with beam energy of 8-10 MeV is presented. The operation principle of the system is described, as well as the procedure and results of calibration of electron energy and absorbed dose measuring channels.

Evaluation of the environmental neutron dose at ground level

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The study and knowledge of the variability of the neutron fluence of cosmic origin at ground level is important for evaluating the environmental neutron dose measurements carried out in many industrial applications, such as in the study of the neutron radiation effects on the functioning of the most common electronic systems. In fact, the primary source of neutrons is identifiable in the interaction between the cosmic rays of solar origin and the various layers of the atmosphere. Therefore, the neutron field is not constant but strongly depends on the solar activity cycles.

This work presents the results of two cycles of neutron dose rate measurements using an ALNOR 2202 D Neutron Dose Rate Meter whose time response is acquired and analyzed using a controlled ORTEC MCS-32 acquisition card in Windows environment.

The data obtained have been compared with previous experimental survey values and with the solar data provided by the worldwide main observatories. The comparison allows to obtain a corrective factor to take into account the fluctuations in the cosmic rays flux during a solar cycle. In this way, it can be evaluated. a value of the “dose rate” and neutron fluence rate averaged over a solar cycle which can be used as a reference for any neutron dose measurement.

Surveillance of medical exposures performed in Romanian hospitals in 2018

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The Romanian national legal framework harmonized with the Community provisions stipulate the obligation and responsibility of the public health network to ensure the radiological protection of the patient during the medical exposures to ionizing radiation.

The monitoring of medical exposures to ionizing radiation is based on data collected from Romanian hospitals, the results obtained at national level being useful in the process of optimization of radiological procedures for diagnostic and also for establisment and review of DRLs.

In 2018, a number of 6,111,694 radiological procedures were reported: 3.634.678 plain x-rays, 210.432 mammographies, 213.347 fluoroscopies, 900.882 CT exams, 35.628 interventional radiology procedures, 126.270 osteodensitometry exams and 990.457 dental X-rays. At the same time, 17.616 nuclear medicine procedures were reported. These were performed using 2361 equipment for diagnostic and interventional radiology, representing 73.5% of the total radiology equipment in use, respectively 24 equipment for nuclear medicine, representing 77.4% of the total nuclear medicine equipment in use.

At the national level, chest radiography is the most frequent examination (30.7% of all conventional radiological examinations), followed by radiography of the limbs and joints (24.0%), lumbar spine and cervical spine, mammography, pelvis radiography, skull radiography and thoracic fluoroscopy, with different percentages in interval 4-8%. The highest frequency of CT exams is for head region (36%), followed by examinations with contrast substance of the chest, abdomen, pelvis, head, abdomen-pelvis region and trunk and also chest without contrast.

The most significant contribution to the estimated collective effective dose for diagnostic and interventional radiology procedures is recorded by CT examinations, with a percentage of 81.8%, followed by the cardiological and non-cardiological interventional radiology procedures (11.6%) and conventional radiology (6.3%).

The structure of the contributions to the estimated collective effective dose for nuclear medicine procedures highlights an important percentage (65.6%) given by the PET-CT hybrid procedures, followed by the bone scintigraphy, SPECT-CT and cardiovascular scintigraphy.

Based on the results obtained for the values of dose-area product (DAP), dose-length product (DLP), mean glandular dose (MGD) and activity levels of radiopharmaceuticals, 32 DRLs for the most frequent radiological and nuclear medicine procedures were proposed to the Ministry of Health.

Passive etched solid state nuclear track detectors for outdoor radon monitoring

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Radon gas represents the largest source of exposure for the public due to natural radioactivity, and, for this reason, efforts are made continuously by scientific communities and authorities in order to increase the metrological capacity in the field of measuring very low atmospheric radon activity concentrations [Röttger, A., 2021. - Project Details - EURAMET]. For this purpose, the traceRadon project works towards this goal, which will help EU member states to comply with the Council Directive 2013/59/Euratom.

One of the techniques to measure radon is using solid state nuclear track detectors method (SSNTD). The SSNTD works based on the principle that ionising particles are creating microscopic defects (tracks) in the detection material that can be revealed by etching treatment with chemicals. Subsequently, these tracks are automatically counted through an optical microscope connected to a PC using an automatic image analysis system. The system used in this case is Clifton Digital Bath and a Tasl*Image* scanning and readout system which is using a TASTRAK™ plastic - (PADC) detectors.

In this study the aim was to observe the integral radon exposure at an Atmospheric Monitoring Network Station (AMNS) while comparing data obtained with the integral value of active monitoring device data. A wide range of environmental effects on PADC radon (222Rn) detection sensitivity are generally known and acknowledged [Radiat. Prot. Dosim. 20, 71–75]. However, in operational services the sensitivity and accuracy of the readings are key factors and must be properly estimated to provide correct exposure from radon. Moreover, knowledge of such effects can offer a solid background in providing even more accurate results. This can be even more challenging in the outdoor environment.

In conclusion, this exercise will prove consistency of the conventional true value obtained by the active and passive methods measurements of radon in a long time period, as this kind of techniques are used for the annual average concentration measurement of the radon.

Acknowledgments: The results presented in this work are developed in the framework of the 19ENV01 traceRadon "Implementation of radon metrology for the analysis of the atmospheric budget of greenhouse gases and radiation protection in the environment" project. This project, 19ENV01, has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19ENV01 traceRadon denotes the EMPIR Joint Network Project reference.

Patient dose estimation using CT-Expo software in a hospital in the South of Brazil

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Introduction. The Report Dose Structured Radiation Dose Report (RDSR) was introduced in CT scans in 2007 and since then allows incorporating most of the information, including CT Dose Index (CTDI) and Dose Length Product (DLP), needed to estimate radiation dose. However, the number of CT scanners that do not provide the RDSR is still significant in Brazil and other parts of the world. In these cases, the information required to estimate the doses received by patients is obtained from the DICOM header by means of detailed technical parameters that, together with geometric information (e.g. scan length), can be used for reasonable estimation of these doses. Tools such as CT Expo software, which is based on Monte Carlo modeling, have been used to estimate the effective doses from these exposures using input data extracted from the DICOM header of CT scans. Thus, the objective of this study was to estimate the doses received by patients who underwent CT scans in a public reference hospital located in the State of Santa Catarina in South Brazil, using the CT Expo V. 2.7 software.

Methods. A cross-sectional study was carried out and data were selected from 50 abdomen exams, of patients aged 30 to 60 years, from a Toshiba Aquilion Prime 84 -slice CT scanner, performed in the month of september 2020 in a public hospital located in the south region of Brazil. The following data were extracted from the DICOM header of the selected exams: Age Group, Gender, Scan Range, Scanner Model, Body Mode, kV, mA, Acquisition Time, mAs, Total Collimation, Table Feed Per Rotation, Reconstructed Slice Thickness, Pitch and Number of Scan Series. These datas were inserted in the “Calculate” tab of the CT Expo software. The values of CTDIvol, DLP and effective dose obtained were used to estimate the dose delivered.

Results. The CTDIvol at the 75th percentile for the 50 abdominal CT scans was 17.73 mGy with a mean of 7.44 mGy. The DLP at the 75th percentile was 1,494.5 mGy.cm with a mean value of 1,199.22 mGy.cm. Finally, the 75th percentile for the calculated effective dose in CT Expo was 22.90 mSv, as a mean value of 17.73 mSv. A comparison between the 75th percentile for DLP (1,494.5 mGy.cm) and the DLP used as Reference Levels (DRLs) used in other countries for the same study such as USA and Switzerland (755 and 670 mGy.cm, respectively) showed that the 75th percentile of the DLP found in the examinations performed is almost double the values practiced in countries with well established DRLs.

Conclusion. Although older CT scanners do not have RDSR, software such as CT Expo can help to estimate the effective dose received by patients through information extracted from the DICOM header. As there are few studies in Brazil on this, the methodology presented can be a good tool to retrospectively estimate doses in CT services in Brazil.

Estimation of diagnostic reference levels for complete myocardial scintigraphy protocol in South of Brazil

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Nuclear Medicine (NM) is a medical specialty divided into diagnostic and therapeutic applications. The doses resulting from procedures in this practice come from activities administered to patients and contribute to the exposure of the population to ionizing radiation. Therefore, the optimization of radiological protection aims to ensure a balance between the quality of medical images and the amount of radiation received by the patient and should be optimized to the minimum value necessary to ensure the achievement of the radiological objective. The International Commission on Radiological Protection (ICRP) provides guidance on the establishment of reference levels for procedures in various modalities. In MN, reference levels are based on the activities administered to patients and are known as diagnostic reference levels (DRLs), serving as an important tool for optimizing procedures. The objective of the present study was to estimate the DRLs resulting from Nuclear Medicine procedures performed in a private service located in the South region of Brazil. The applied methodology consisted of using secondary data and of retrospective nature, collected from the registration systems of the procedures in the participating nuclear medicine service performed in the year 2020. The data collected were: types of procedures, radionuclide used, date the exam was performed, activity administered, weight, height, age, and gender of the patients, as well as the imaging equipment used by the service. The data were used to calculate the specific activity for myocardial scintigraphy procedures (in MBq.kg-1) by means of the NIREA software, developed by Brazilian researchers and in the implantation phase. Through the software output information, the DRLs of the service in question was estimated. The result obtained was average height: 1.67 m; standard deviation: 0.12; average age: 64.17 y; standard deviation 10.62; age_{max}. 93 y and age_{min}. 32 y; average weight: 79.43 kg; standard deviation: 13.95. The local DRL, based on the 75th percentile of the administered activity (MBq) of Tc-99m on myocardial scintigraphy in the stress phase was: 1332 MBq; and in the resting phase, it was 444 MBq. The effective dose (E) was also calculated and reported for the procedures performed. Through studies like this one, we hope to contribute to the estimation of DRLs in NM in Brazil and to stimulate the creation of a culture of recording doses and activities; to help optimize the activities administered and the practices involved; as well as to contribute with the provision of data for the estimation of collective effective dose from NM examinations.

Drugs for increasing the survival and proliferative activity of hematopoietic stem cells based on rhAFP and rhG-CSF after radiation exposure

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The aim of this study was to estimate the intravenous administration effect of recombinant human alpha-fetoprotein (rhAFP), recombinant human granulocyte colony-stimulating factor (rhG-CSF), rhAFP liposomal preparation, rhG-CSF liposomal preparation, and rhAFP and rhG-CSF combined liposomal preparation on the survival and proliferative activity of multipotent hemopoietic stem cells after acute external gamma radiation in mice. The object of the study was white outbred male mice of CD1 stock and male mice of the C57Bl/6 line. The effect of individual components (liposomes, rhAFP, rhG-CSF) and their combinations on the survival and proliferative activity of hematopoietic bone marrow cells in mice was evaluated by the number of endogenous spleen colony-forming units (CFUs) using the endotest (Pereverzev, 1986). Outbred white mice of CD1 stock were injected intravenously after 15 minutes after irradiation and then after 1, 3, 5, 7 days after irradiation - only 5 introductions. C57Bl/6 mice were given intravenously once every 10-15 minutes after external total gamma radiation at a dose of 5.5 Gy, 0.2 ml per animal. In the experiments, the studied components were used in the following concentrations: liposomes from phospholipids 10 mg/ml; rhAFP - 1 mg/ml; rhG-CSF 0.02 mg/ml. Mice from the irradiated control group were injected intravenously with 0.2 ml water for injection according to the same schemes. Experimental groups of 10 animals were formed, which, after general external gamma radiation, were administered the following drugs: water for injection (irradiated control group); empty liposomes; rhAFP; rhAFP liposome preparation; rhG-CSF; rhG-CSF liposome preparation, rhAFP and rhG-CSF liposome preparation. In mice, on the 9th day after irradiation, the spleen mass was analyzed and the number of splenic colonies was counted. The experiments performed allow us to conclude: rhAFP protein has biological activity comparable to rhG-CSF in terms of survival and proliferative activity of hematopoietic stem cells in the endotest; the rhAFP liposomal preparation significantly exceeds in biological activity the effect of rhAFP alone in terms of endotest; the liposomal form of rhG-CSF does not change the biological effectiveness of the protein in terms of endotest; the liposome combined preparation rhAFP and rhG-CSF has the most pronounced effect among the analyzed drugs, which indicates a synergistic positive interaction of its components aimed at increasing the survival and proliferative activity of hematopoietic stem cells after gamma irradiation; liposomal rhAFP and the liposomal combined preparation rhAFP and rhG-CSF can be effectively used to treat the bone marrow form of acute radiation syndrome when applied after radiation exposure.

Cooking can decrease ^{210}Po and ^{210}Pb amount in *Boletaceae* mushroom meals

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Edible mushrooms can efficiently concentrate some elements in flesh but little is known on highly toxic alpha- and beta emitters. In this study, the absolute values of radioactivity (Bq·kg^{-1} dry biomass) for ^{210}Po were in the range 2.0 ± 2.0 to 308 ± 9 in fresh species and 22.1 ± 1.2 to 142 ± 4 in a ready to eat meals, and for ^{210}Pb were 3.64 ± 0.48 to 51.8 ± 2.9 and 3.03 ± 0.14 to 9.65 ± 0.49, respectively. The studied batches of a corresponding species of mushrooms – raw and cooked - were not equivalent regarding the homogeneity of the composition. However, If expressing data on a dry biomass basis, the raw mushrooms (substrate for any cooking), showed greater radioactivity in relation to stir-fried meals, and what can imply on a partial loss of nuclides. Nevertheless, when expressing data on the whole (wet) weight basis, in a majority of the species radioactivity was similar for both fresh and cooked mushrooms. A daily portion of 100 g of stir-fried mushrooms could provide ^{210}Po and ^{210}Pb resulting provide radiation in the range 0.2 to 2.1 μSv and 0.02 to 0.06 μSv, respectively. Assessed, the cumulative doses of exposure to ^{210}Po were 1.4 to 14 μSv in a week period and 75 to 722 μSv at annual timescale, and of ^{210}Pb amounted at 0.15 to 0.46 μSv and 8.3 to 24 μSv, respectively. The ^{210}Po can be possibly considered as a major source of ionizing radiation activity for heavy fanciers of mushroom meals in SW Asia, while the number of available data is limited.

Gamma-emitting radionuclides in diet supplements of marine origin

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A dietary supplement is a food product to supply a normal diet in vitamins, minerals or other substances exhibiting a nutritional or other physiological effect, single or complex, marketed in a form enabling dosage. Due to popular nutrient deficiencies, especially minerals, in the society, there is an increase in interest in agents supplementing the daily diet with missing ingredients. 72% of Poles admit to taking this type of product, of which 48% use it regularly.

The source for the production of pharmaceuticals may be substances of natural origin, and in the raw materials used in the production process, in addition to the desired ingredients, may also contain small amounts of other, undesirable, chemical substances, such as heavy metals or radionuclides. Previous studies have shown that calcium and magnesium supplements of natural origin, mainly produced from sedimentary rocks, are rich in naturally occurring ^{210}Po, ^{210}Pb, and uranium ^{234}U and ^{235}U.

Popular supplements that are attributed to the properties of “super foods” and referred to as “vitamin bombs” are products of marine origin produced from vegetable raw materials. The aim of the study was to determine the content of natural and artificial radioactive gamma isotopes contained in dietary supplements produced from substances obtained from the seas and oceans. To achieve the intended goal, a number of preparations available on the Polish market were purchased for research, such as: chlorella, spirulina, kelp or diatomite produced from raw materials collected in various regions of the world.

Studies have shown that the analyzed gamma radionuclides were present in the analyzed supplements of marine origin, but their activity levels were low. When analyzing the place of taking raw materials for the production of supplements, no regions of special importance were observed in relation to the calculated effective doses resulting from the breakdown of the analyzed isotopes taken together with the supplements. With respect to gamma emitters marked in supplements, there is no radiological risk associated with taking these isotopes together with the preparations taken.

Gamma-emitting radionuclides in herbal plants from Ukraine

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Herbal or medicinal plant products, in different forms known as herbal teas, have been used for hundreds of years in preventing and treating diseases around the world. Currently, in many cultures, especially in developing countries, it is still the main source of medicaments. Estimated at 70-80% of the world population uses unconventional medicine, and treats it as their primary healthcare. Many studies have found a positive effect of tea consumption on human health, e.g. improved immune defence, cancer prevention and diabetes treatment by lowering blood glucose, and cholesterol levels.

The aim of the study was to determine the content of natural and artificial radioactive gamma isotopes contained in herbal plants collected on Ukraine territory. 40 samples of different popular herbal plants were collected from 2016 to 2018 in Lviv region (Ukraine).

Studies have shown that the analyzed gamma radionuclides were present in the analyzed plants, but their activity levels were low. With respect to gamma emitters marked in supplements, there is no radiological risk associated with taking these isotopes together with the collected herbal plants.

Level of extraction efficiency of ^{210}Po and ^{210}Pb in herbal teas

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Herbal or medicinal plant products, in different forms known as herbal teas, have been used for hundreds of years in preventing and treating diseases around the world. Currently, in many cultures, especially in developing countries, it is still the main source of medicaments. Estimated at 70-80% of the world's population uses unconventional medicine, and treats it as their primary healthcare.

Presented are results of a study on ^{210}Po and ^{210}Pb extraction efficiency in Polish herbal teas and risk to human consumer due to exposure from highly radiotoxic alpha decay particles emitted by ^{210}Po and beta particles emitted by ^{210}Pb. 12 most popular commercially available Polish herbal teas, and their infusions in tap water and filtered water, were analyzed and ^{210}Po and ^{210}Pb activity concentrations were calculated. Analysis of ^{210}Po content in analyzed samples was carried out using an alpha spectrometer, while ^{210}Pb determination method was based on its indirect measurement via its daughter ^{210}Po activity measurement. The chemical analysis efficiency of ^{210}Po and ^{210}Pb determination ranged 95-98%.

The results of ^{210}Po activity determination in dried plants were from 2.11±0.09 for milk thistle to 33.7±0.4 Bq·kg^{-1} dry wt. for cistus what equaled 4.21±0.18 for milk thistle and 43.8±0.5 mBq per one teabag. The extraction efficiencies into tap water ranged from 4.93±0.39 for lime to 27.4±1.4 % for elderberry, while for filtered water were between 7.55±0.47 for lime and 20.3±1.1 % for elderberry.

The highest activity concentration of ^{210}Pb in dried plants was determined in cistus – 35.5 Bq·kg^{-1} dry wt, while the lowest was in milk thistle – 3.25Bq·kg^{-1} dry wt what gives respectively for cistus 46.1±0.7 and 6.50±0.29 mBq for milk thistle per one teabag. The extraction efficiencies in the filtered water oscillated from 5.1±0.5 for milk thistle to 27.3±0.8 % for cistus, while for the tap water they ranged from 7.3±0.6 % for lime to 33.3±2.2 % for white mulberry.

The studies indicated the analyzed herbal teas consumption should not contribute significantly to the annual effective radiation dose in Poland (3.3 mSv) as well as the ICRP international limit given for the public (1 mSv annually). The highest annual effective radiation dose from ^{210}Po ingestion with herbal teas infusions was calculated for white mulberry (3.42±0.09 for tap water and 2.72±0.007 µSv for filtered water). The highest dose from ^{210}Pb would come with white mulberry tea made in tap water (3.15±0.19 µSv), and for cistus in filtered water (3.17±0.08 µSv).

^{241}Am sequential separation in marine sediment samples: Comparison of the most popular radiochemical methods

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Besides naturally occurring polonium and plutonium introduced into the environment as a result of human activities, americium ^{241}Am ($T_{1/2}$ = 432.2 years) is one of the most radiotoxic elements. The development of nuclear energy, conducting experiments and tests with nuclear weapons, caused that the environment became a place of deposition of a large amount of artificial radiation emitters. Plutonium ^{241}Pu, as the main source of ^{241}Am, occurs in the form of sparingly soluble compounds. Therefore, bottom sediments are the main deposition place in the marine environment. Almost all of the plutonium (99 %) is in the bottom sediments. Unlike plutonium, compounds of ^{241}Am are more freely soluble. There is a high risk of migration of this radionuclide from bottom sediments to water. Due to the strong radiotoxicity of ^{241}Am and its probable remobilization from bottom sediments is extremely dangerous. Relatively safe areas can become a serious threat to the health of organisms inhabiting them.

The aim of the study was to compare, verify and adapt known methods of sequential separation and purification of americium ^{241}Am in bottom sediments. This will aid to develop a fast, effective, efficient and cheap method for obtaining pure fractions of americium in geological samples. Three known and widely used radiochemical procedures were verified. They will allow isolation of ^{241}Am using ion exchange chromatography. Radionuclide separation techniques were compared using ion exchange on anion exchangers AG [IAEA Technical Report Series No. 295, IAEA Press, Vienna] and combination with extraction chromatography using TRU resin [Appl. Radiat. Isot., 65(5), 504-511] or DGA resin [Anal. Chim. Acta, 829, 75-80]. These procedures have been adapted to the preliminary method used to divide transuranium element on AG1 resin [Chem. Anal. (Warsaw), 42,107] used in the Laboratory of Toxicology and Radiation Protection.

^{210}Po and ^{210}Pb accumulation and distribution in tropical fruits

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The fruit is an important part of the total diet that encompasses a variety of plant products. It provides many important vitamins and minerals and may be low in calories. Food and atmospheric air are the main sources of chemical elements for the human body. Eating habits and the food origin are very important. That is why it is necessary to know to what extent food products accumulate toxic metals, including radionuclides and whether their consumption is safe. ^{210}Po is considered as one of the most hazardous and carcinogenic radionuclides.

The aim of the study was to recognize the level of ^{210}Po and ^{210}Pb accumulation in tropical fruits as well as their distribution and the results of their activity in selected exotic fruits are presented. Due to specific consumers habits, ^{210}Po and ^{210}Pb distribution in different parts of the fruit were calculated. Research material, as fresh tropical fruit (bananas, lemons, grapefruit, kiwi, mandarins, mangoes and oranges) were purchased in a store in Gdansk. The fruits were washed and divided into parts: flesh (edible part), fruit skin, endocarp (inner layer of the pericarp) with seeds.

The ^{210}Po concentration in the analyzed fruit samples ranged from 0.008 ± 0.001 in banana flesh to 1.51 ± 0.03 mBq/g dry wt. in kiwi peel. In contrast, the concentration of ^{210}Pb was from 0.018 ± 0.0001 also in banana pulp to 2.44 ± 0.01 mBq/g dry wt. in kiwi peel. The research showed the highest amounts of ^{210}Po and ^{210}Pb were accumulated in kiwi peel. The obtained results allowed the estimation of annual effective doses for people who consume one fruit a day. The highest effective dose could come received from mango: 6.15 ± 0.30 μSv from ^{210}Po decay and 3.70 ± 0.27 μSv from ^{210}Pb decay. The obtained research results show that the consumption of the analyzed exotic fruits available in Poland does not significantly affect the effective dose received by the inhabitants of Poland from all sources of ionizing radiation.

The atmospheric fallout impact on ^{210}Po content in herbal plants

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Herbs have been used in medicine for centuries because most of them have healing properties and do not cause serious side effects. However, plant leaves in comparison to other aerial parts such as bark, stalk, fruit or seeds, may contain large amounts of ^{210}Po, ^{210}Bi, and ^{210}Pb, due to the direct deposition of aerosols containing radionuclides as well as by the absorption from the soil.

Because approx. 70-80% of the world's population uses unconventional medicine, it is worth determining whether the consumption of herbal plants is safe for the people from a radiological point of view and whether it increases the effective dose resulting from the decay of ^{210}Po taken with medicinal plants significantly. The subject of the study was to determine the impact of atmospheric fallout on the content of the highly toxic ^{210}Po alpha radiation emitter in commonly used herbs, i.e. lemon balm (*Melissa officinalis*), peppermint (*Mentha piperita*), sage (*Salvia officinalis*), basil (*Ocimum basilicum*), nettle (*Urtica dioica)*, collected from various areas of Poland and pot plants. The additional washing process was conducted on the nettle, and the potential impact of atmospheric precipitation on the content of analyzed isotope was estimated.

The results of ^{210}Po determination in the analyzed herbs showed that the highest value of ^{210}Po activity concentration was found in the sage leaves collected in Lubelskie Voivodeship (33.5 Bq/kg wet weight), while for potted herbs the highest ^{210}Po activity was determined in the sage root (0.52 Bq/kg w.w.). The washing of nettle reduced the activity concentration of ^{210}Po in its root by 12%, stalk – 43%, leaves – 8%, and in the inflorescences by 21%. Based on the calculated concentrations of ^{210}Po activity in studied herbs, effective radiation doses were estimated, which allowed determining the degree of radiotoxicity of the surrounding environment, which is one of the most important tasks in radiological protection of the population.

^{210}Po in medicinal herbs collected in different regions of Poland

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Medicinal plants and various types of herbs are used for hundreds of years to treat diseases. Based on the World Health Organization data, the use of traditional medicine plays an important role in improving overall health in many populations, as an additional way to treat and prevent illnesses. In many developing countries, industrial pollution is a problem and occurs as a side effect of industrialization, which can lead to flora contamination with pesticides, metals, or radionuclides. Therefore, it is very important to determine whether the consumption of herbal preparations is safe from a radiological point of view and whether it contributes to a significant increase in the effective dose resulting from the decay of ^{210}Po taken with medicinal plants.

Polonium ^{210}Po ($T_{1/2}$ = 138.4 days) appears at the end of the decay chain of uranium ^{238}U and is a radio-ecologically interesting natural element to investigate due to its significant radiotoxic characteristics. There are several ways of ^{210}Po permeation to plants: direct isotope deposition on plant surfaces, deposition on surface of the soil, active accumulation of radionuclide from the soil through the root system, and then transferring polonium to the stalk, leaves, flowers, fruit, and seeds.

The studied medicinal plants came from three distant places Gdańsk (northern Poland), Kętrzyn (north-eastern Poland) and Ryki (eastern Poland). The herbal raw material was selected from each plant for the research. During the study, the part of the plant with the highest the concentration of active substances, the most often used in herbalism, were used. Further, appropriate procedures and processes for radiochemical analysis were carried out to isolate and determine the ^{210}Po polonium isotope. Based on the obtained results of the concentrations of radioisotope activity, the annual effective radiation doses were estimated. Referring to the results of the study, potential radiotoxicity to the human body was determined as a result of consuming the analyzed medicinal plants.

Research into the distribution of radionuclides in forest litter long after the nuclear tests

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Forest litter is one of the main primary absorbers of radionuclides in forest ecosystems. The aim of this research is to study concentrations and distribution pattern of artificial radionuclides in the litter of Priirtyshie pine forest.

For the sampling purpose, forest areas were selected within the area of the plume of the test conducted in 1949 with radionuclides concentrations in the environmental components assumed to be increased. In total, 20 sites were equipped, where litter samples and mixed soil samples (to the depth of 5 cm using an envelope method) were collected. The litter was dried under natural conditions, after that it was sieved to separate organic components from mineral components. Activity concentration of ^{137}Cs and ^{241}Am was determined using Canberra GX-2020 gamma-spectrometer. Detection limit values for the radionuclides researched were 1 and 10 Bq/kg (for plant and soil samples respectively), the measurement error did not exceed 15-20 %.

The study found that concentration of ^{137}Cs in components under study (with the maximum concentration in the mineral component of the litter being 150±3 Bq/kg) is higher than ^{241}Am concentration (with the maximum concentration of 5.0±1.0 Bq/kg in the top soil layer). Activity concentration values range within an order of magnitude in the organic component of the litter for ^{241}Am (0.23-1.4 Bq/kg) and ^{137}Cs (1.1-41 Bq/kg), and in the top soil for ^{241}Am (0.4-5.0 Bq/kg) reaching 2 orders of magnitude in the mineral component of the litter for ^{137}Cs (8-150 Bq/kg).

Activity concentration of radionuclides researched on average is higher in the litter than in soil: 64% in litter and 36% in the top soil. By the level of accumulation of the radionuclides under study, the descending series appears as follows: *the mineral component of the litter> top soil> organic component of the litter*.

Ability of forest litter to retain radionuclides directly depends on their inventory. The average thickness of litter in the territory researched is 0.42 kg/m^2. The correlation coefficient between litter thickness and activity (% of the total activity in the litter and in the top soil) of ^{241}Am and ^{137}Cs was 0.66 and 0.49 respectively. So, the thicker the litter is, the more radionuclides it accumulates, which proves the importance of the litter in accumulation and distribution of radionuclides in the forest ecosystem as a whole.

As the result of research, a minimum activity concentration of radionuclides was registered in the organic component. A maximum concentration of ^{137}Cs can typically be observed in the mineral component of the litter, while a maximum activity concentration of ^{241}Am was registered in the top soil. Activity concentration of the radionuclides is higher in litter than in soil. It was also found that accumulation of radionuclides in litter significantly depends on its thickness. So, the major part of contamination is in the litter that allows to identify it as the main component characterizing contamination of the forest ecosystem as a whole.

Uptake of the crystal-bound form of tritium by plants

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In the soil of the former Semipalatinsk Test Site (the STS) at the nuclear tests areas, a special crystal-bound form of tritium (CBT) was found. The aim of the work is to study the bioavailability of CBT in the "soil-plants" system. The intake of CBT into plants was evaluated based on the activity of ^{3}H in the organic matter, the value of TLI (translocation index), OBT/TFWT ratio *in vitro*. Preliminary studies were carried out in the field conditions of STS. Samples of *Stipa capillata* were collected at 16 sites near the epicenters of surface nuclear tests, where the activity of CBT in the soil is up to 240 kBq kg^{-1}. From the selected plant samples, it was not possible to obtain a sufficient amount of free tissue water for analysis, which is due to arid growth conditions at the STS. However, in most *Stipa capillata* samples, high concentrations of OBT (from 0.1 to 29 kBq kg^{-1}) were registered. This indirectly indicates that during certain periods of growth of *Stipa capillata*, the level of ^{3}H concentration in the free water composition of tissues reached significant values, since OBT is formed from TFWT. At the same time, ^{3}H was not detected in either air or water of the sampling area. Thus, for *Stipa capillata* only soil was the source of ^{3}H uptake.

To confirm the fact that CBT is being transferred into plants, an experiment was conducted with *Cucumis*, which was cultivated in a greenhouse on soil samples with high CBT activity (40 kBq kg^{-1} on average). The analysis of pore water in soil samples showed insignificant HTO activity (on average 0.04 kBq kg^{-1}). At the end of the experiment, the HTO activity in the pore water was on average 0.74 kBq kg^{-1}. Obviously, ^{3}H is leached out of the CBT in the form of HTO affected by various factors (irrigation, the influence of the rhizosphere). The concentration of TFWT in the leaves, stems and fruits of plants was on average 0.26, 0.12, 0.16 kBq kg^{-1}, respectively, and slightly differed from the activity of HTO in pore water. Concentration of OBT in leaves, stems, and fruits was an order of magnitude lower than that of TFWT (0.02, 0.01, 0.02 kBq kg^{-1}, respectively). In general, the activity of TFWT and OBT in the leaves was significantly higher than in the stems and fruits ($p = 0.95$).

The mean OBT/TFWT ratio was 0.1. The TLI value for fruits was 17%. The obtained parameters show that ^{3}H is leached out of CBT in the form of HTO, which is absorbed by plants. However, this issue remains unsolved and requires additional research.

Gini index test on the real dataset of the radon distribution

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The radon isotope (222Rn - half-life of 3.8 days) is one of the radioactive products of the 238U decay series. It is the only element in the gaseous form of this series. Radon, unlike other solid elements, can be released from rocks, spread in the ground and then be inhaled in living environments where the concentration levels can be very high as compared to the external environment. Rn has been classified as the second leading cause of lung cancer after cigarette smoking. To apply efficient locally based risk reduction actions, dense maps of radon concentration are needed, possibly inferring the expected concentration where fewer data are available through geostatistical interpolation tools.

The simplest geostatistical techniques are based on two-steps generally referred to as variogram fit and kriging (Webster and Oliver, 2000). The variogram provides a quantitative estimate of the spatial autocorrelation of a sparse dataset. Based on this autocorrelation, the kriging allows it to interpolate the available dataset, computing the expected values on a finer grid having a pre-defined resolution.

In this regard, we propose an innovative method, based on the Gini index computation (Loffredo et., 2020; Loffredo et al., 2021), for the realization of interpolated maps (kriging) to describe of the distribution of concentration of Rn. This method appears to be effective in identifying larger-scale spatial correlations that can therefore be correlated to geological properties. This is a very interesting above all because the assessment and mitigation of the risk of exposure to radon cannot ignore the identification of the local geology and its connection with the exhalation of radon.

In this work, the method was applied to retrieve the kriging maps and their connection with geological settings from two different datasets, one in Italy and one in Ghana, in two regions characterized by complex geological features. The measures were performed with passive detectors (solid state LR-115 and CR-39) in different buildings (dwellings and workplace).

Radon exhalation rates and radium concentration in soil samples collected in the industrial area of Tito Scalo (Basilicata Region)

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Radon is generated in rocks and soil by alpha decay of ^{226}Ra and for this reason it is present on the entire Earth's crust, although in varying quantities depending on the geology. It can move very freely with respect to the point of origin in the soil up to distances of one meter depending on the porosity and permeability of the soil. The exhalation of radon from the soil is of great interest as its decay products are the main source of exposure to ionizing radiation for humans. When radon escapes into the outdoor atmosphere it is quickly diluted, on the contrary, in confined spaces such as homes and office buildings, radon can accumulate to harmful levels.

Soil samples were collected in the industrial area of Tito Scalo. The area is characterized by the presence of some large mechanical, steel, and iron industrial plants moreover it is one of the sites of national interest for remediation also due to the presence of radioactive materials deriving from the production of agricultural fertilizers. At the same time the area is surrounded by agricultural soils and by areas of great naturalistic interest such as the oasis of the WWF "Pantano di Pignola". Sampling grid covers all the industrial area of Tito Scalo and some sampling points in the surrounding natural areas used as blank. Measurement of radium concentration and radon exhalation rate in soil samples were carried out by Canister technique. After processing, the soil samples were placed in glass jar and CR-39 detectors were used to records the tracks of α-particles emitted by radon gas. The exposure time of CR-39 was of 30 days. After chemical etching process the tracks produced were counted and radon concentration and exhalation rates were calculated. Also radium content was determined.

The first results suggest that radon exhalation rate and the measurement of radium concentration may be useful for the radiological characterization of soils. Moreover, a good correlation between radium concentration and radon exhalation rate was found.

High precision kaonic atoms X-ray spectroscopy at the DAΦNE collider: the SIDDHARTA-2 experiment

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The SIDDHARTA-2 collaboration has built an high precision X-ray spectroscopy system to perform, for the first time, the challenging measurement of the kaonic deuterium exotic atom transitions to the fundamental level at the DAΦNE collider of the INFN-LNF. The experimental apparatus takes advantage of the optimized scintillator systems for the background rejection and a new Silicon Drift Detectors system able to operate in the high background environment of the DAΦNE collider. The system is presently taking data during the DAΦNE commissioning phase in preparation for the kaonic deuterium run. The contribution presents the experimental apparatus and the results obtained during the beam commissioning phase at the DAΦNE collider with the SIDDHARTINO setup.

Dosimetric properties of potassium sulfate measured by optically stimulated luminescence (OSL)

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The optically stimulated luminescence (OSL) method is widely used in dosimetry of ionizing radiation. The OSL phenomenon consists of two stages: excitation by ionizing radiation and stimulation. It results in emission of luminescence with intensity proportional to the absorbed dose. In the OSL method the stimulating factor is the light of appropriate wavelength. The OSL usually occurs in crystalline dielectric materials with a wide energy band gap. Until now only two materials, aluminium oxide doped with carbon and beryllium oxide, were recognized as OSL detectors. Much more materials have found use in the OSL-like thermoluminescence (TL) method. Dysprosium doped calcium sulphate phosphor is one of the most efficient phosphors in thermoluminescence. However, OSL properties of sulphates are much less known. The aim of this work is to study the dosimetric properties of selected sulfate salts using OSL method. Potassium sulfate was chosen due to the small number of reports about its OSL properties. Samples were prepared from analytical quality material. For the preparation of doped samples, the powder (potassium sulfate) was dissolved in distilled water. Then the dopant - cerium sulfate was added. Various concentrations were tested. The solution evaporated slowly at 60 degrees Celsius on a hot plate and recrystalized. The obtained crystals were then fabricated in the form of pellets (5 mm diameter x 1 mm thickness) by pressing crystalline powders at 2 ton/cm2. To increase the luminescent signal, the pellets were annealed in a porcelain crucible in high temperature furnace. Various annealing temperatures were tested. Irradiation were made using 90Sr/90Y beta source. Continuous wave OSL (CW-OSL) measurements were performed using custom made OSL reader HELIOS-1 with green light stimulation. The following dosimetric features were investigated: repeatability of the OSL signal, dose response and signal stability after irradiation. The material was tested for potential use in dosimetry of ionizing radiation.

Analysis of the intermediate checks on the working standards used for routine calibrations of ionizing radiation dosimeters in a ^{60}Co gamma ray beam

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Every calibration laboratory accredited for the conformity with the norm ISO/IEC 17025 has to fulfil the requirements of the norm. One of these requirements is monitoring of the validity of the calibration results. In the Polish Secondary Standard Dosimetry Laboratory (SSDL), it was decided that it will include, among others, periodic intermediate checks on the working standards used for the calibration of the customer dosimeter. According to the norm, when intermediate checks are necessary to maintain confidence in the performance of equipment, these checks shall be carried out according to a procedure defined by the accredited laboratory.

In the literature there are no data concerning the results of the intermediate checks on working standards applied for calibration of dosimeters used for dosimetry in teleradiotherapy, in ^{60}Co gamma ray beam in terms of absorbed dose to water. The aim of this study is to present the method adopted for conducting intermediate checks on the working standards and a criterium of acceptance of these results, useful in routine activities of calibration laboratory in the above-mentioned area.

The material of the study were the results of more than 50 intermediate checks of two working standards each, used routinely at the Polish SSDL (accredited by the Polish Centre for Accreditation, accreditation No AP 155) for calibration of dosimeters in ^{60}Co beam, in terms of absorbed dose to water. These checks were carried out on the same day the actual working standard was used for the calibration of the customer dosimeter. Each intermediate check consisted of a comparison of the mean value of the absorbed dose to water: D_{mean} (based on 10 measurements of the charge M_i, in calibration conditions by substitution, as presented by the IAEA Technical reports 398 and 469) with the value of the dose absorbed to water: D_{calc}, calculated according to the radioactive decay of the ^{60}Co source.

As a measure of the intermediate check a percentage absolute value of the difference between D_{mean} and $D_{calc,}$, in relation to the value D_{mean}, was adopted. The results were analysed statistically in order to establish the agreement of the distributions of both parameters. The acceptance criterion of the result of the intermediate check was established based on the relative percentage value of the combined uncertainty of the measurement of D_{mean}.

The presented method of carrying out intermediate checks, together with the criterion of their acceptance, is estimated as useful for use in routine activities of the calibration laboratories carrying out calibrations of the ionizing radiation dosimeters in the ^{60}Co radiation beam, in terms of absorbed dose to water. After suitable modifications, this method and the criterion of acceptance of the results of intermediate checks could be implemented in other areas of calibration than the one discussed here.

The implantation of polycaprolactone films into the anterior chamber of the eye

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One of the directions in the treatment of the bullous keratopathy is the use of stem cells. However, cultivation of stem cells and their landing on the inner surface of the cornea in order to replace the endothelial defect without using a substrate is a big surgical problem. There is a high probability of cell loss during surgical procedures. Using of films based on polycaprolactone (PCL) thin films with controlled solubility as a temporary material for stem cells may be an alternative to existing insoluble polymers. The purpose of this research is the study the influence of the PCL films implantation on the morphology of the cornea *in vivo* experiment.

The feedstock for the films was obtained by dissolving polycaprolactone (Sigma-Aldrich, England) in the chloroform ($CHCl_3$). *12* pubescent female *Sylvilagus bachmani* rabbits weighing 2.0-2.5 kg were used. All animals were healthy and free of ocular diseases. The Siberian Medical State University Life Science Ethical Review Committee (protocol № 7892 from May 13th, 2019) approved all procedures. PCL films were implanted into the anterior chamber of one animal eye. All animals were instilled Tobramycin Drops (6 times per day), 0.1% Diclofenac Sodium Ophthalmic Solution (3 times per day) and 0.05% Vitabact (4 times per day) in the postoperative period. The overall duration of the experiment comprised 21 days.

It was found that the implantation of the PCL film did not increase an intraocular pressure. According to optical coherent tomography, the cornea had a normal thickness (430-450 μm). 4-5 layers of squamous epithelium with normochromic nuclei represented the anterior epithelium of the experimental animal. Bowman's membrane was unchanged and visualized as a homogeneous eosinophilic strip. Thin-walled newly formed blood vessels with a specific volume of not more than 5%, $p > 0.05$, were found in the corneal stroma. Collagen fibers were located compactly. In some places collagen fibers had increased twisted stroke. Mild leukocyte infiltration (specific volume of leukocyte was less than 3.2%, $p<0.05$) was noted in the stroma. Descemet's membrane was visualized throughout. A single layer of cells represented the endothelial layer. In some places, proliferation of endothelial cells in the form of process cells was observed.

As a result of the research, it was found that the implantation of the PCL films contributes to the development of the mild inflammatory response (mild leukocyte infiltration, newly formed blood vessels, increased twisted stroke of collagen fibers, and presence of strongly acid sulfated GAGs) as a result of the surgery. The study showed the possibility of the PCL films using as a corneal implant in a future.

Sources of funding: The research was conducted with the financial support of the Russian Foundation for Basic Research (RFBR) as part of the project № 20-08-00648.

Effect of annealing temperature on charge storage capability of $Al/HfO_2/Gd2O_3/HfO_2/p\text{-}Si\ (100)/Al$ memory cell

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In this present study, we have studied the effect of annealing temperature on the charge storage capability of $Al/HfO_2/Gd_2O_3/HfO_2/p\text{-}Si/Al$ memory cell. The samples of the memory cell were annealed at different temperatures of 300 ^oC, 500 ^oC, 700 ^oC, and 900 ^oC for 30 min in N_2 ambient. The crystalline structure and surface morphology of as-deposited sample and those samples annealed at different temperatures was examined by x-ray diffraction (XRD) and scanning electron microscope (SEM) technique. The electrical characteristics of the memory cell were also investigated through capacitance-voltage(C-V) and conductance-voltage (G_m/ω-V) measurements. It was found that the annealing temperature had a significant impact on the electrical properties of the device. Moreover, our results demonstrated that devices based on memory cell are promising materials more especially in the non-volatile memory devices.

Keywords: Memory cell, annealing temperature, XRD, SEM, C-V, (G_m/ω-V)

Effects of thickness and annealing temperature on charge trapping of $Al/Al_2O_3/ZrO_2/SiO_2/p\text{-}Si$ (100)/Al memory cell

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In this paper, we have studied and analyzed the effects of thickness and annealing temperature on the charge trapping of $Al/Al_2O_3/ZrO_2/SiO_2/p\text{-}Si$ (100)/Al memory cell. To investigate the effects of thickness of ZrO_2, the memory cell was fabricated with various thickness of 5nm to 15nm by atomic layer deposition (ALD) technique. We found that the thickness had the significant impact on the device-based memory cell. Subsequently, three samples of the memory cell were annealed at different temperatures of 300 ^oC, 500 ^oC and 700 ^oC in N_2 ambient for 30min. We also investigated the effect of annealing temperature on the memory cell through capacitance-voltage(C-V) and conductance-voltage (G_m/ω-V) measurements. It was found that electrical properties of the device were affected by annealing temperature. Furthermore, our experimental results showed that devices based on memory cell are potential materials in electronics devices and more especially in sensors.

Keywords: ZrO_2, thickness, annealing temperature, memory cell, C-V, G_m/ω-V

Plan evaluation of total body irradiation using volumetric modulated arc therapy (VMAT) and helical tomotherapy

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Purpose. In total body irradiations, it becomes hard getting homogenous dose distribution due to inhomogeneous body shape and tissue density variations. The main goal of radiotherapy is to save critical organs while achieving a homogeneous dose distribution at target volume. Tomotherapy and Volumetric Modulated Arc Therapy (VMAT) are new and the most effective technologies used for total body irradiations. The purpose of this study is to compare critical organ doses, Planning Target Volume (PTV) coverage and dose homogeneity on Tomotherapy and VMAT technics for TBI treatments.

Materials and Methods. In this study, the arms and legs were added to the male phantom using rice to simulate the whole body geometrically. The male phantom with arms and legs was immobilized by a vacuum bed and 3 mm CT images were received using Philips Big Bore CT. CT images were received as the upper and lower part of the body and used for contouring in the treatment plans. The entire body, lungs, lens, and kidneys were contoured with 3 mm margin and PTV is created. The prescribed dose was 12 Gy at a coverage of 90% PTV. The maximum dose limits for critical organ doses were 8 Gy for the lung, 7 Gy for the liver and 4 Gy for the lenses. TBI plans were prepared on VoLo 2.0.4 Treatment Planning System (TPS) for Tomotherapy and Eclipse 15.6 TPS for VMAT. The evaluation of the plans was made by comparing the homogeneity index (HI) and the doses taken by the critical organs.

Results. At the end of this study, it was seen that saving critical organs and achieving desired dose distribution are possible for both Tomotherapy and VMAT in TBI treatments. HIs were 0.16 for tomotherapy and 0.29 for VMAT. Mean lung doses (right/left) were 7.61 Gy/7.70 Gy for Tomotherapy and 9.09 Gy /9.23 Gy for VMAT. Mean kidney doses (right/left) were 6.7 Gy/6.51Gy for Tomotherapy and 6.46 Gy/6.43 Gy for VMAT. Lens doses were similar and below 4 Gy.

Conclusions. In conclusion, although both treatment techniques can be applied, more homogeneous dose distribution and lower lung doses are obtained with the Tomotherapy technique. When it comes to deciding for the TBI treatment method, some other crucial points must be considered. Treatment time, planning time, repeatability of treatment, and being comfortable for both patient and team are the other important points.

Keywords: Helical Tomotherapy, VMAT, total body irradiation

The role and contribution of 18F-FDG PET/CT in RAI therapy assessment of metastatic DTC: Case report

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Introduction and purpose. Differentiated Thyroid Carcinoma (DTC) is the most common endocrine malignancy and generally has an excellent prognosis. The treatment paradigm for DTC consists of total thyroidectomy, followed by remnant ablation with Radioactive iodine therapy (RAI), and L-thyroxine therapy; the amount of TSH-suppression must be tailored according to the patient's category of risk. RAI is an important radiopharmaceutical agent in nuclear medicine practice for the treatment of DTC. Although PET/CT has a limited role in the diagnosis, it plays a significant role in the over all post-surgery management of a patient with thyroid cancer. This follow-up role is important, especially in patients with elevated serum thyroglobulin (Tg) levels. The aim of this case report is to present highlights that evaluate the diagnostic value of 18F-FDG-PET/CT in terms of accurate detection of both iodine- and non-iodine-avid recurrence, compared with that of Radioiodine Whole-Body Scintigraphy (WBS).

Materials and results. 51-year-old man undergone bilateral total thyroidectomy and the histopathological evaluation revealed papillary thyroid carcinoma in the nodule. After surgery, RAI therapy was performed. During follow-up, elevated serum Tg levels were detected after 3 years of the disease onset. WBS with I -131 was performed. Whole-body images were obtained using a gamma camera equipped with a high-energy, general-purpose collimator. Recurrent disease detected in thyroid bed and metastatic foci observed in liver. Due to tumour recurrence, resurgery planned, 18F-FDG PET/CT was performed prior to RAI therapy, showed multiple liver metastasis, also detected metastasis in posterior iliac bone and right rib of skeleton. RAI therapeutic dose of I-131 was administered in conjunction with a strict low-iodine diet using a standard thyroid hormone withdrawal protocol. A Post-therapy WBS was performed 5 days after RAI administration. Patient underwent 18F-FDG PET/CT within 9 months after the RAI therapy for evaluation of the treatment response. After RAI therapy PET/CT did not show significant uptake at metastatic lesions in the liver and reduced FDG uptake observed in bone metastases, during serial follow-up PET/CT scan. Stimulated Tg level was also lowered.

Conclusion. 18F-FDG PET/CT is a reliable tool for the restaging of DTC patients who display increased Tg levels. PET/CT detects metastatic lesions accurately as compared to I-131 WBS in the follow-up period.

Keywords: 18F-FDG PET/CT, I-131 RAI therapy, differentiated thyroid cancer

Possible enhancement of the flash effect with a further increase in the proton dose rate

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The flash effect allows reducing radiation damage to normal cells compared to tumor cells with a sparing factor (SF) of ~ 1.75. Proton flash therapy is of particular interest due to the greater conformality of proton irradiation. The experiments conducted so far on proton flash therapy were carried out with an average dose rate $\dot{D}_m$ below 200 Gy/s. The high-current linear proton accelerator of the INR RAS is non-therapeutic and provides a specific irradiation mode, the single-pulse flash (or splash) mode when the entire therapeutic dose is delivered in a single pulse with a duration of about 100 microseconds. In this case, the mean dose rate $\dot{D}_m$ coincides with the pulse dose rate and can reach 10^6Gy/s. In our several experiments, irradiation was carried out in three different modes: in the conventional mode with $\dot{D}_m$< 3 Gy/s, in the "ordinary" flash mode with $\dot{D}$m ~ 60 Gy/s, and in the *splash* mode with $\dot{D}_m$> 30000 Gy/s. We irradiated plates and Petri dishes in the spread-out Bragg peak (SOBP) and in the plateau in front of it. The EBT radiochromic films were fixed on the outside of the plates and dishes. Experiments were carried out on the simultaneous irradiation of tumor and normal cells in the same plates or adjacent dishes. The human cells HCT116 and HT29 were used as tumor cells, and human fibroblasts (ADSC) were used as normal cells. To analyze the reaction and survival of cells, flow cytofluorimetry was used, which, in particular, allowed us to determine the level of cell apoptosis. Our results confirm that the flash effect *in vitro* is manifested in the "ordinary" flash mode for radiosensitive HCT116 cells (SF~1.7), but not for radioresistant HT29 cells. At the same time, in the *splash* mode, the flash effect is observed for both types of tumor cells, with SF up to 9 for HCT116 cells. Statistical analysis showed that the difference in the sparing factor in the flash and splash modes of irradiation cannot be explained by statistical fluctuations. The preliminary conclusion is that the splash mode of proton irradiation may significantly enhance the flash effect and thereby reduce radiation damage to normal tissues and organs.

Combination of photodynamic and radiation therapy

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A combination of radiation therapy (RT) and photodynamic therapy (PDT) can provide a treatment effectiveness increase. A possible mechanism of synergy is the repair suppression of DNA molecules damaged by ionizing radiation, due to the aggressive products of photochemical reactions occurring during PDT. The study of the response of cells to the combined ionizing radiation and photodynamic therapy with various modern photosensitizers (FS)is of significant interest. Visible light and infrared radiation generating singlet oxygen have wavelengths up to 900 nm. The most penetrating light is in the long-wavelength part of this range corresponding to a red light or infrared radiation. X-ray radiation in the region of 80-100 KeV has a penetration depth close to the depth of transmission of red light and infrared radiation. For example, for the X-ray energy of 60 KeV, the 80% isodose depth in water is 5 mm, for the energy of 100 KeV, this value is 8-9 mm. These values are close to the maximum depth of light transmission in the tissue in the so-called therapeutic window of transparency in the wavelength range of 650-850 nm. With this in mind, we developed a stand for radiobiological studies that allows us to irradiate plates with cells with the light of a given wavelength and X-ray radiation with an energy of 50-100 KeV. The area of radiation intensity deviation within 25% is approximately 5*8 cm2, which corresponds to the central wells of plates with 24 or 96 wells. The optical source has two average wavelengths of 665 and 830 nm. By changing the temperature of laser diodes, the maximum radiation wavelength can be changed in the range of ± 3 nm. Currently, the set-up is used to study the survival rate of various cells under combined exposure to LT+PDT. In addition, we can use a 6 MeV medical electron accelerator SL-75-5-MT or even proton therapy installations with beam energy up to 230 MeV as a source of ionizing radiation. However, in this case, the penetration depth of ionizing radiation is much greater and does not coincide with the depth of light transmission. We are planning to move on to experiments with laboratory animals at the second stage of our study. The work is supported by the RFBR grant No. 20-02-00102 “Study of the effectiveness of synchronous photodynamic and radiation therapy”.

Impact of intermediate dose calculation module on thoracic esophagus radiotherapy planning

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Purpose. Radiotherapy is the one of the major treatment modality for thoracic esophagus patients. Delivering high radiation dose to the planning target volume (PTV) while protecting the surrounding normal tissues can be achieved by volumetric modulated arc therapy (VMAT) which is the advanced radiotherapy technique. For creating VMAT dose distributions, optimization algorithms and dose calculation algorithms in commercial treatment planning systems (TPS) are used. Especially in cases of tissue heterogeneity, the final calculated dose volume histogram (DVH) differs from optimal DVH acquired via the optimization procedure. This occurs because of optimization convergence errors. The intermediate dose calculation (IDC) module, which is included in the Analytical Anisotropic Algorithm (AAA), is utilized on optimization of the VMAT plan to solve these differences. The aim of the present study is to investigate the impact of IDC module during the optimization of VMAT for the thoracic esophagus patients.

Materials and Methods. The VMAT plans were generated on Eclipse TPS v15.1 using AAA algorithm without IDC for ten patients with thoracic esophagus cancer. Then, the plans were re-optimized without changing optimization criteria by using same dose calculation algorithm with IDC. The prescribed dose to PTV was 50.4 Gy/28 fr. The homogeneity index (HI) and the conformity index (CI) of PTV, maximum dose of spinal cord, mean dose of heart, the lung volume of receiving 5 Gy and 20 Gy were compared between plans with and without IDC.

Results. The calculated CI of plans with and without IDC were found to be 0.822±0.030 and 0.729±0.039, respectively (p=0.005). The HI values were found to be 0.073±0.017 and 0.126±0.022, for plans with and without IDC, respectively (p=0.005). The maximum dose of spinal cord (p=0.028) and the mean dose of heart (p=0.047) were found lower in plans with IDC. However, there was no significant difference for the volume of the lung receiving 5 (p=0.236) and 20 Gy (p=0.053).

Conclusion. In conclusion, applying IDC on VMAT optimization increases the plan quality in thoracic esophagus patients.

Keywords: Thoracic esophagus cancer, intermediate dose calculation module, VMAT

Experimental determination of α-shape factor and f parameters in ITU Triga Mark II research reactor

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Neutron activation analysis (NAA) is an analytical method used in the determination of concentrations of elements in the sample. One of the most commonly used NAA is the k_0 standardization method. In order to perform the k_0-based NAA method, it is essential to know the neutron spectrum parameters in detail. These parameters are epithermal neutron flux shape factor (α) and thermal to epithermal neutron flux ratio (f). They must be identified for the standardization. The α and f parameters were determined using the Cd-covered dual monitor method and bare triple monitor method. The Cd-covered dual monitor method is based on irradiation of two selected monitors as bare and with a Cd cover. Without using any nuclear data, the α parameter can be solved by measuring the cadmium ratios of the two selected monitors. The other method for determining the α and f parameters is the bare triple monitor method. This method only requires irradiation of three monitors without Cd-cover. In all these methods, irradiation studies were performed in the central thimble at the ITU Triga Mark II research reactor. A gamma-ray counting system (HpGe Detector) was used for measuring foil activation values. In this study, the selected monitors were ^{197}Au and ^{94}Zr for the Cd-covered dual monitor method. The parameters α and f were -0.221±0.018 and 41.826±4.701 for ^{197}Au /^{94}Zr (724 keV) monitors, -0.231±0.019 and 45.941±4.594 for ^{197}Au /^{94}Zr (756 keV) monitors, respectively. Using the bare triple monitor method, α found to be -0.228±0.025, and f was found to be 43.917±3.596. The difference between the α parameters found according to both methods is 1.29%. The difference between the f parameters is 4.6%.

Experimental measurements of a 5G outdoor massive MIMO antenna located in a shopping center

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The fifth generation mobile network (5G) is characterized not only by the expansion of the existing (4G) network, but represents an evolution of the current mobile technologies. Thanks to the use of millimeter waves and massive MIMO technology, it will meet the ever increasing demands of users in terms of connectivity and capacity. The introduction of the new 5G technology is accompanied by problems related to the measurement and evaluation of electromagnetic fields (EMF). The first stage of implementation of 5G requires upgrading existing mobile 2G / 3G / 4G networks, which raises many concerns about the possibility EMF exposure limits to be exceeded. This is especially true for countries with more restrictive legislation than ICNIRP guidelines.

The existing methodologies dedicated to EMF measurements of 2G, 3G and 4G networks are not suitable for 5G and can lead to significant overestimation of the exposure. The reason for that is mostly due to the specificity of the massive MIMO and the beamforming. This necessitated the use of a new approach in the assessment of the EMF exposure.

This report concerns experimental case of evaluating procedure of EMF exposure of the general public from an outdoor 5G massive MIMO antenna. The antenna was located into a shopping center for a demonstration the capabilities of the new 5G technology in front of the public. The power of the massive MIMO antenna was limited to 5 W because it was mounted indoor. For the purpose of the experiment 5G router was placed in different locations in order to steer the beam of the antenna. Test measurements were taken on the path of beam to evaluate the exposure in the premises. Changing the location and the height of the router, we managed to accomplish the safety limits of the EMF exposure (according to the Bulgarian legislation) for the visitors of the demonstration. We performed measurements during Ookla speedtest to simulate the maximum traffic.

As a result, the study can be used for the further assessment of similar cases and demonstrations indoor premises.

Patient and personnel health and safety on using Magnetic Resonance Imaging

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There are two aspects to be considered when using magnetic resonance imaging (MRI) equipment: patient and personnel protection.

In regard to patient protection, the following main issues should be treated: individual characteristics, risk / benefit ratio; exposure time and exposure pattern, etc.

The medical personnel protection is regulated by Directive 2013/35/EU and represents a major challenge in the EMF protection in the working environment. The Directive recognizes that for some activities/circumstances related to the installation, testing, use, development, maintenance of or research related to magnetic resonance imaging (MRI) equipment the use of MRI may not comply with the exposure limit values. In these cases, the regulatory document introduces derogations that provide for risk management approaches for that specific source.

The report presents results of electromagnetic field measurement and evaluation in various MRI units. The results show that the exposure limits for persons at specific risk are exceeded, as well as high values of the magnetic flux density of the static magnetic field in the shielded room are registered. It should be noted here that for the personnel, a serious problem is the movement in inhomogeneous field conditions (in the shielded room), which in turn leads to induction of currents in the human body and as a result transient symptoms such as vertigo and nausea.

Measurement data were used to evaluate personnel exposure and make specific recommendations for health and safety when dealing with such equipment in medical practice.

Study of the effect of UV light on the thermal melting of rat liver nuclei in the presence of multiply charged cations via differential scanning calorimetry

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The non-invasive method of differential scanning calorimetry (DSC) has been used to study the action of UV-light on the thermal stability nuclei from rat liver. Nuclei with condensed chromatin were prepared according to the standart methods in presence of polyamines (20 mM triethanolamine-HCl (TEA), 0.5 mM spermidine and 0.2 mM spermine, 2 mM EDTA, 80 mM NaCl) (N-PA) and in a low ionic strength buffer (20 mM TEA) with 5 mM $MgCl_2$ (N-Mg). EM-pictures of both types of nuclei were similar. The melting profiles of chromatin in isolated nuclei at the scanning rate of 2°C/min in the temperature range 25-110°C were different. In case of N-PA we observed 3 clear structural transitions (Tm) near 75°C (peak 1), 89°C (peak 2) and 102°C (peak 3) with the ratio of the areas under the peaks 15:48:37. They were identified as the melting of nucleosome core histones, of relaxed and topologically strained DNA, respectively. However in the presence of 5 mM $MgCl_2$ there was a integration of the 1 and 2 peaks to a single basic endoterm at Tm near 83°C. We observed also a small peak as the shoulder of the main peak at 89 °C. Values of total ΔH for N-PA and N-Mg were 26 and 32 kJ/mol nucleotides, respectively. UV-irradiation of the nuclei at λ =254 nm and at a dose 1.8 J/m² induced changes in the melting profiles. The most striking observation concerned the peaks 2 and 3 of the N-PA which melted 2-2.5°C below the Tm of control peaks. The relation of peaks 1, 2 and 3 has become 12:60:28 due to a significant decrease peaks 1 (histones melting) and 3 (melting of topologically strained DNA) and the total ΔH decreased by almost half. Peak 2 material with Tm 89° (relaxed DNA) turned out to be the less sensitive to UV-irradiation. In the case of N-Mg the Tm of peaks diminished only by 1.5°C, enthalpy of transition peak 3 decreased by 2 times but total ΔH only slightly reduced to 29.5 kJ/mole nucleotides. We interpret our DSC results as a consequence of UV-induced local distortions in chromatin, reducing the molecular weight of DNA and the proportion of its topologically strained fraction and destabilizing the nucleosome histones octamer. The nuclei isolated in magnesium are less sensitive to UV light than in polyamines. However UV-induced DNA lesions formed throughout nuclear chromatin probably do not cause alternations in its morphology.

High-quality iterative TOF MLEM reconstruction for short scans in total-body J-PET

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The novel modular Jagiellonian PET (J-PET) total-body prototype uses Compton scattering in plastic scintillators for the detection of positron-electron annihilation photons (Moskal P. et al. PET Clin. 2021; 15:439). To increase sensitivity, a multi-layer composition of plastic detectors is proposed, along with a layer of wavelength shifters (WLS), which improves axial resolution (Smyrski J. et al. Nucl. Instr. Meth. Phys. Res. A. 2017; 851:39). Since such geometry enhances blurring factors in detector space, a proper calculation of a system response matrix (SRM) is essential for iterative image reconstruction.

We propose an analytical model for SRM that accounts for the continuous character of the detector strips in the axial direction. A set of 2-dimensional Monte Carlo simulations for the emissions of back-to-back γ-photons was conducted, adjusting the obliqueness angle θ, to acquire statistics for each bin, which was later fitted by a 5^{th} order polynomial functions of θ and transverse coordinates.

A list-mode time-of-flight maximum likelihood expectation maximisation (TOF MLEM) algorithm was modified according to the introduced model for SRM, with various penalties used for the regularisation: one-step-late median root prior (Alenius S. et al. Eur. J. Nucl. Med. 1997; 24:258), relative differences prior (Nuyts J. IEEE Trans. Med. Sci. 2002; 49:56) and anisotropic median-diffusion (AMD) with a finite-impulse-response median hybrid (FMH) filter applied (Ling J. et al. Eur. J. Nucl. Med. 2002; 21:377).

To test TOF MLEM at a relatively extreme mode, we utilised the GATE framework (Jan et al. PMB. 2004; 49:4543) to simulate a short (~ 1-min) scan of a NEMA IEC phantom (NEMA nu 2-2012 standard) inside a 140-cm long J-PET, constituted by 24 modules, each comprising 16 scintillator strips per 2 layers, with WLS in between. The post-smearing was applied to the detection points and TOF according to the assessed temporal (191 ps) and axial (5 mm) resolution. Only true coincidences, 10.5 mln in total, were considered, along with the predefined attenuation map for NEMA IEC used for corrections.

The image quality for the reconstructed NEMA IEC images was estimated, with and without regularisation, and compared with the reference – TOF MLEM algorithm from CASToR framework (Merlin T. et al. PMB. 2018; 63:185005). We observed about 50% improvement of contrast recovery and background variability, using our method, when no penalisation was applied. The best regularisation method appeared to be AMD-FMH, with a further 40% gain in image quality (averaged over six spheres of the NEMA IEC).

To summarise, the proposed analytical modelling of SRM for the total-body J-PET could compensate for the lower sensitivity, compared to the most advanced modern scanners, as well as be extended to account for the non-collinearity, positron range and other factors.

Ultrasound assessment of the adrenal glands magnitude in relation to the visceral body fat distribution in obese women

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Visceral obesity is associated with functional hypercorticism that is characterized with alteration of the hypothalamic-pituitary-adrenal axis and disturbed adrenal glands function. Adrenal glands magnitude has to be dependent on adrenal glands function. The relationship between adrenal glands magnitude and visceral body fat distribution has not yet been discovered precisely. The aim of this study was to discover the diagnostic accuracy of the ultrasound assessment of the adrenal glands magnitude through the adrenal glands volumes and surface measurements in discovering the association of adrenal glands magnitude in adrenal hyperplasia with visceral body fat distribution in visceral obese women.

Ultrasound assessment was performed of the right and left adrenal glands volumes (VR and VL) and their surfaces (SR and SL). Anthropometric measurements included body mass index (BMI, kg/m^2), as well as waist/hip ratio (WHR) and waist/thigh ratio (WTR) as indexes of visceral body fat distribution in 65 women. The examinees were divided in 3 groups according to their body fat distribution: 1st group with normal body fat distribution with WHR < 0.85 and WTR < 1.45; 2nd group with moderate visceral obesity with WHR (0.85-1.0) and WTR (1.45-1.7) and the 3rd group with extreme visceral obesity with WHR > 1.0 and WTR > 1.7. BMI in the 1st group was 26.7±9.2 kg/m^2, in the 2nd group it was 36.4±5.3 kg/m^2, and in the 3rd group was 40.2±8.9 kg/m^2, which confirmed the 3rd group as extreme obese.

Age correlated highly significantly positively with WTR and WHR ($p<0.0001$), as well as with both VR ($p<0.001$; <0.008) and VL ($p<0.05$; <0.03), but not with SR and SL ($p>0.05$). VR, SR and VL correlated highly significantly positively with WTR and WHR ($p<0.0001$). SL correlated with WTR ($p<0.031$) but not with WHR. VR values were significantly higher in the 3rd group (5.67±3.62cm^3, $p<0.0001$) and 2nd group (2.93±1.51cm^3, $p<0.007$) compared to the 1st group (1.76±0.87cm^3). VL values (5.74±3.97cm^3, $p<0.007$) were significantly higher in the 3rd group compared to the 1st group with VL values (2.01±1.28cm^3). SR values (3.02±1.66cm^2) in the 3rd group were significantly higher compared to the SR values (1.43±0.52cm^2) in the 1st group.

Adrenal glands hyperplasia in visceral obesity could be discovered with great certainty and diagnostic accuracy by ultrasound assessment of the adrenal glands. Extreme visceral obesity was characterized with significantly increased adrenal glands volumes and surfaces. The adrenal glands magnitude was highest in the oldest group of women characterized with extreme visceral body fat distribution. It can be concluded that adrenal hyperplasia in obese women was associated with visceral body fat distribution, it showed dependence on the age and most certainly was assessed by the volumes of the adrenal glands.

Keywords: Ultrasound, adrenal glands magnitude, visceral obesity

Dual-energy X-ray absorptiometric assessment of android to legs ratio index of abdominal obesity in women

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DXA is used to quantify abdominal fat mass and enables precise, accurate body composition (BC) and body fat distribution assessment that is simply determined by the relationship of the regional central, android, abdominal predominantly visceral tissue and fat mass compartments to peripheral regional parts of the body such as android to legs ratios in women with Cushing's syndrome (CS) that are characterized with extreme visceral obesity. These indexes were investigated with DXA as diagnostic criteria and indicators of visceral, abdominal obesity in patients with CS and non-CS women.

DXA measurements were automatically performed with Lunar DPX-NT, Model Prodigy, during BC assessment in total body scans of the android (A) and legs (L) regional tissue mass (T), fat mass (F) and their percentages. DXA indexes of abdominal obesity, calculated as a ratio of A and L regional T and F mass and their % were determined (A/L-T, A/L-F, A/L-Tf% and A/L-F%) in four groups, each consisting of 18 women: 1st group of CS, 2nd group of obese women (O1) not different according to their age and BMI from CS, 3rd group of obese women (O2) with higher BMI of 35±1.2 kg/m^2 and 4th group of control non obese healthy women (C) with normal BMI.

A/L DXA ratios indexes values were highly significantly different among the 4 examined groups and they were significantly highest in CS and lowest in group C. A/L-T value in CS 0.35±0.06 was highly significantly higher compared to all examined groups: 0.23±0.04 in group O1, 0.30±0.03 in group O2 and 0.18±0.02 in group C. AL-F value in CS 0.43±0.09 was also highly significantly higher compared to all examined groups: 0.23±0.07 in group O1, 0.33±0.06 in group O2 and 0.14±0.04 in group C. Percentage values showed lower significance of the difference. A/L-T and A/L-F values were significantly higher in O2 compared to O1 and C and in CS compared to O1 and C ($p<0.0001$) and correlated highly significantly among them as well as with their % values and with BMI in a group of non-CS women.

Significantly higher values of A/L-T and A/L-F ratios in CS and O2 compared to O1 and C indicated predomination of central to peripheral regional T and F mass. These indexes discovered extreme central, abdominal, visceral body fat distribution in CS women in comparison to group O1 and they also could be used in discovering central, abdominal body fat distribution in non-CS obese women with Metabolic syndrome. Significantly higher BMI values in CS compared to C and in O2 compared to O1 were associated with significantly higher A/L-T and A/L-F ratios DXA indexes values that correlated significantly with BMI in non-CS groups and confirmed the association of the higher degree of obesity with more pronounced central, abdominal body fat distribution. A/L-T and A/L-F DXA indexes were discovered as worthwhile DXA diagnostic indexes of central, abdominal obesity in CS and non-CS obese.

Keywords: DXA, Cushing's syndrome, abdominal obesity, android to legs ratio index

Determination of asymptomatic endothelial dysfunction in coronary artery disease in patients with seropositive rheumatoid arthritis with asymmetric dimethylarginine (adma) and myocardial perfusion scintigraphy

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Objective. To compare the values and accuracy of the test of Asymmetric dimethylarginine (ADMA) assessed with myocardial perfusion scintigraphy (MPS), acute phase reactant, C - reactive protein (CRP) and disease activity index (DAS 28) in early diagnosis of untreated Rheumatoid arthritis (RA). To determine whether ADMA changes depend on the disease evolution. ADMA is used as an indicator for endothelial dysfunction.

Method. Using the ELISA technology of DLD-Diagnostika-GMBH, ADMA, the serum has been examined in 70 participants (35 RA who were not treated, 35 controls). In the same time we determined the sensitivity, specificity, predictive value for positive and negative test and accuracy.

Results. Out of 35 examined patients with RA, in 22 we found the presence of ADMA (sensitivity of the test 62.85%). Myocardial Perfusion Scintigraphy appeared in 17 patients (sensitivity of the test 48.57%). Four patients were ADMA and MPS positive. Among 18 MPS negative patients, 9 patients were ADMA positive. Among 17 MPS positive RA, the presence of ADMA was found in 4 patients. Among 18 MPS negative RA, ADMA appeared in 9 patients. In the healthy control group, 8 patients were ADMA positive (22.85%).

Conclusion. ADMA has moderate sensitivity, but high specificity from MPS at untreated RA with coronary artery disease.

Keywords: Asymmetric dimethylarginine (ADMA), rheumatoid arthritis, coronary artery disease

The implantation of polycaprolactone films into the anterior chamber of the eye

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One of the directions in the treatment of the bullous keratopathy is the use of stem cells. However, cultivation of stem cells and their landing on the inner surface of the cornea in order to replace the endothelial defect without using a substrate is a big surgical problem. There is a high probability of cell loss during surgical procedures. Using of films based on polycaprolactone (PCL) thin films with controlled solubility as a temporary material for stem cells may be an alternative to existing insoluble polymers. The purpose of this research is the study the influence of the PCL films implantation on the morphology of the cornea *in vivo* experiment.

The feedstock for the films was obtained by dissolving polycaprolactone (Sigma-Aldrich, England) in the chloroform ($CHCl_3$). *12* pubescent female *Sylvilagus bachmani* rabbits weighing 2.0-2.5 kg were used. All animals were healthy and free of ocular diseases. The Siberian Medical State University Life Science Ethical Review Committee (protocol № 7892 from May 13th, 2019) approved all procedures. PCL films were implanted into the anterior chamber of one animal eye. All animals were instilled Tobramycin Drops (6 times per day), 0.1% Diclofenac Sodium Ophthalmic Solution (3 times per day) and 0.05% Vitabact (4 times per day) in the postoperative period. The overall duration of the experiment comprised 21 days.

It was found that the implantation of the PCL film did not increase an intraocular pressure. According to optical coherent tomography, the cornea had a normal thickness (430-450 μm). 4-5 layers of squamous epithelium with normochromic nuclei represented the anterior epithelium of the experimental animal. Bowman's membrane was unchanged and visualized as a homogeneous eosinophilic strip. Thin-walled newly formed blood vessels with a specific volume of not more than 5%, $p > 0.05$, were found in the corneal stroma. Collagen fibers were located compactly. In some places collagen fibers had increased twisted stroke. Mild leukocyte infiltration (specific volume of leukocyte was less than 3.2%, $p<0.05$) was noted in the stroma. Descemet's membrane was visualized throughout. A single layer of cells represented the endothelial layer. In some places, proliferation of endothelial cells in the form of process cells was observed.

As a result of the research, it was found that the implantation of the PCL films contributes to the development of the mild inflammatory response (mild leukocyte infiltration, newly formed blood vessels, increased twisted stroke of collagen fibers, and presence of strongly acid sulfated GAGs) as a result of the surgery. The study showed the possibility of the PCL films using as a corneal implant in a future.

Sources of funding: The research was conducted with the financial support of the Russian Foundation for Basic Research (RFBR) as part of the project № 20-08-00648.

The utility of dual-energy X-ray absorptiometry (DXA) in the assessment of fracture risk in women with early undifferentiated psoriatic arthropathy sine psoriasis vulgaris with or without joint inflammation

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Objective. Psoriatic arthritis (PsA) is associated with decreased bone mineral density (BMD) and increased fracture risk. The association between BMD and fracture risk in PsA is not well elucidated. We aimed to assess BMD in an PsA cohort of patients with active disease and patients in remission, and to assess the predictive value of BMD on incidence of fractures.

Method. We included 44 patients (median age 55). Patients were invited to follow-up including assessment of remission status and a dual-energy x-ray absorptiometry (DXA)-scan.

Results. Patients with Psoriatic arthritis had significantly lower BMD compared to controls at lumbar spine (16% lower, $p < .0001$), femoral neck (18% lower, $p < .0001$), and total hip (23% lower, $p < .0001$). Recovered PsA patients had higher BMD compared to those with current disease ($p < .0001$ for all measures), but lower BMD compared to controls at lumbar spine ($p < .01$) and hip ($p < .001$). In patients with active eating disorders not otherwise specified, BMD was lower only at the total hip ($p < .005$). We found no association between BMD and fracture risk.

Conclusion. We confirm that PsA is associated with low BMD, whereas BN is not. Remission is associated with higher BMD compared to patients with active disease, but a deficit remains. We found no significant association between BMD and fracture risk, challenging the benefit of the widespread use of DXA scans in women with PsA.

Keywords: Asymmetric dimethylarginine (ADMA), psoriatic arthropathy, coronary artery disease

Adaptation mechanisms of restoration of late radiation-induced injuries in cancer patients after combination therapy

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It was examined 240 patients (with late radiation-induced injuries to the skin, underlying soft tissues and internal organs) who had undergone radiotherapy or combination therapy for breast cancer, cervical cancer, ovarian cancer and Hodgkin's lymphoma at different times. Therapy for radiation-induced injuries developed and being performed at MRRC with the use of pharmacological agents (analgetics, neuroleptics and narcotics), so-called basis therapy, in combination with reflexotherapy may considerably reduce psycho-emotional and pain symptoms of late radiation-induced injuries. The analgesic effect is achieved after the first 3-5 sessions of therapy including reflexo-laser treatment. As a result, the use of analgesics and narcotics can be reduced. This therapy improves the quality of life for patients: they can attend to themselves and add more physical activity to their life. The effects of basis therapy alone and in combination with reflex treatment on immunity were compared. Basis therapy has an immunotrope modulating effect. It restores adaptation mechanisms while reducing immune hyperactivation and immunodepression. By adding reflexo-laser treatment, basis therapy appeared more successful restoring immunological disorders.

Breed characteristics of the biochemical parameters of dogs' blood serum

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Blood samples were taken throughout the year from 107 dogs: 69 males and 38 females. The dogs were of different breeds, ranging in age from 2 to 16 years old, both healthy animals and diagnosed with metabolic, cardiovascular and endocrine diseases. Serum biochemical analysis was performed using an Olympus AU400 automated clinical chemistry analyzer. There were determined: the activity of aspartate aminotransferase EC 2.6.1.1 (AST); alanine aminotransferase EC 2.6.1.2 (ALT); creatine phosphokinase EC 2.7.3.2 (CK); lactate dehydrogenase EC 1.1.1.27 (LDH); alkaline phosphatase EC 3.1.3.1 (ALP), of some others enzymes, as well as the concentration of trace elements.

The results of 12-month monitoring of biochemical parameters of blood serum from dogs were analyzed by methods of mathematical non-linear dynamics. The data array of biochemical parameters of healthy dogs and animals diagnosed with internal non-infectious diseases (IND) was divided into two groups in accordance with the values of enzyme activity and changes in the concentration of trace elements in the blood serum. The first group of animals mainly included dogs of breeds: Beagle, Pomeranian, German Shepherd, Russian-European Laika, Bull Terrier, Black Russian Terrier, Toller, Jack Russell Terrier, Sheltie, Labrador Retriever and some others. In representatives of these breeds (healthy animals and dogs with the same INB), a reference level and a small confidence interval for changes in the activity of alkaline phosphatase and LDH, an increased level of glucose, cholesterol, and the content of potassium, sodium, calcium and magnesium ions were reliably revealed. At the same time, there is a significant variability in the activity of hydroxybutyrate dehydrogenase and CK, which may be specific for these breeds.

In the second group, after the cluster analysis, dogs of the following breeds were collected: Toy Terrier, Pug, Dachshund, Yorkshire Terrier, Kerry Blue Terrier, Rottweiler, French Bulldog, Miniature Schnauzer, Scotch Terrier, Bullmastiff, English Bulldog, Chinese Crested, American Cocker Spaniel, Russian spaniel, golden retriever and a number of others. Representatives of these breeds (healthy and with IND) reliably revealed a wide range of changes in the total protein content, alkaline phosphatase activity, glucose content, a wide scatter of data on the concentration of K^{+}, Na^{+}, Ca^{++} and Mg^{++}. The latter may indicate the peculiarities of mineral metabolism and a higher content of trace elements in the blood serum. At the same time, the low variability of lipase and HBB activity was reliably determined, which may be specific for these breeds.

Some specific features of small cattle wool

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The main method for the examination of animal hair continues to be transmitted light microscopy. However, this method has certain disadvantages associated with the qualifications of an expert and the similarity of the cellular structure of hair in some animal species. Because of the need to determine the species of down, wool and hair in order to avoid falsification, an important point is the development of a technique based on biophysical methods, which will minimize the human factor.

For scientific research, the authors have developed a laboratory setup for determining the redox potential of an alkaline hydrolyzate of animal fluff, wool and hair. The change in the redox potential of the test solution under the influence of a flash of visible light is associated with the presence of sulfur-containing amino acids in the hair keratins. Moreover, after further incubation of hydrolysates in the dark, the value of the redox potential returns to its original value.

Below are some of the results of examinations carried out with samples of fluff, wool and hair from goats and sheep taken from the neck and withers of animals of different age and sex. All samples were of the same color, at least 10 measurements were taken per point, the results were statistically processed. It was found that the change in the redox potential (E, mV) depends on the type of animal, but does not have significant differences in different age-sex groups of the same animal species.

During the study, the following values of redox potentials were determined:

1. Sheep (females, males, lambs, 15 individuals each): the redox potential during incubation in the dark varied within 68.5–70.5 mV; after exposure to light — 61–63 mV. Upon further incubation in the dark, the potential returned to its original value.
2. Goats (females, males, kids, 15 individuals each): the redox potential during incubation in the dark did not go beyond the range of 98.5–100.5 mV; after exposure to light — 91–93 mV. Upon further incubation in the dark, the potential returned to its original value.

Thus, an obvious difference in the values of the redox potentials of different animal species is visible: the differences between the potentials of hydrolysates of sheep/goat wool samples of the order of 30 mV were reliably identified. Based on the results obtained, it can be concluded that the dependence of the change in the redox potential can be used in the examination to determine the species of animal hair.

Public health significance of mobile application “Neurogame” for evaluation of attention, concentration and motor skills

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Nowadays, mobile phones are widely used in the form of smart devices and provide a wide range of possibilities, whereas they are much more than just regular phones. The main purpose of this paper was to develop a custom mobile application ‘Neurogame’ for Android operating system based on an open source platform for mobile devices, designed to evaluate and monitor the performance of respondents from different age groups, and to test the cognitive functions: attention, concentration and fine motor skills.This is a retrospective study that covers the development of the tool and testing of the application on 154 healthy children, conducted in the period 2018-2019.

The game provides data for total Tries (t T), total Misses (t M), total Hits (t H) and reaction time or total time (t h) in milliseconds, which are the variables to be used in the statistical analysis. From the total number of 154 respondents from the database, 44 percent were female and 56 percent were male. The average value of total number of hits (t H) was 49 (48.5) hits for healthy children from the age of seven (7) to fifteen (15) years, while the average value of reaction time or total time (t h) was 345 milliseconds for healthy children from the same age.

The application enables data processing of an accurate and objective evaluation of attention, motor skills and concentration level among the young population. In order to continuously improve the cognitive state, recommendations for strengthening the use of mobile applications in everyday learning practice will be the result from the obtained data assessment of healthy school children.

Future plans refer to the development of web platform that will be connected to the application and will enable the distribution of the analyzed results to the relevant stakeholders, such as parents, teachers or health professionals, in order to further treat the established condition(s).

Analysis of trace elements concentrations in mosses in Northern Greece based on PMF model

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Mosses are suitable for biomonitoring the deposition of trace elements from the atmosphere to terrestrial systems. They are able to collect and retain particles from the air. The fact that the uptake of nutrients and water from the ground is negligible, gives the advantage of estimating the concentrations of elements in a low-cost way. Additionally, the simplicity of the sample collection and their analysis make them important for the evaluation of the impact of trace elements on ecosystems and humans.

Ninety-five samples of *Hypnum cupressiforme* Hedw. were collected in Northern Greece during the summer of 2016. Mosses were collected according to the Protocol of the European Moss Survey ICP Vegetation. They were analyzed to the content of trace elements using Neutron Activation Analysis (NAA) technique. The elemental concentrations were determined and the Positive Matrix Factorization Model (EPA PMF 5.0) was applied for the apportionment of their sources. Thirty species were used for source apportionment (Na, Mg, Al, Si, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, As, Br, Rb, Sr, Mo, Cd, Sb, Cs, Ba, La, Ce, Tb, Hf, Ta and Th).

Five sources were revealed: soil dust, aged sea salt, road dust, lignite power plants and a Mn-rich source. The soil dust source contributed the most to almost all samples. The dry climate of Greece favors the resuspension of the soil even over long distances and through different transport mechanisms trace elements are deposited on mosses. Furthermore, two areas with significant impact of human activities were distinguished: the area of Ptolemaida (West Macedonia) and the area of Skouries. In the first one, high concentrations of Ni, Cr, V and Co were found and are connected with the emissions from the lignite power plants that are located in the area. Finally, the area of Skouries is the second most impacted area, with the mining activities and the vehicular traffic playing an important role in the elevated concentrations of Mn, Ni, V, Co, Sb and Cr.

Heavy metals and ^{210}Pb in Helsinki, Finland for the years 1995–2005

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In the current study, weekly filters collected in Helsinki, Finland during 1995 – 2005 underwent energy dispersive X-ray Fluorescense (ED – XRF) analysis, for the determination of their content in Pb, Br, Zn, Cu, Ni, Fe, Mn, Cr, V, Ti, Ca, K, Cl, S, Si, Al and Na. More specifically one weekly filter per month and per year was analyzed.

In the Scandinavian countries, the atmospheric background deposition levels decreases as one moves toward the north. This pattern is especially pronounced in the case of lead, vanadium and cadmium and implied that this is at least partly associated with long-range transport to southern Scandinavia from the heavily industrialized areas elsewhere in Central and Eastern Europe. The highest concentrations for those elements are mainly found in samples from South Finland, where Helsinki is located. However, being on low ground almost surrounded by water, Helsinki is also vulnerable to pollution from local emissions.

The analysis indicates that the observed concentrations of Pb remain relative stable throughout the period 1995-2005 with a slight increase trend and values ranging between 7 - 53 ngr m^{-3}. High average concentration of Pb, 500 ngr m^{-3}, was typical of the air in central Helsinki throughout the '60s, but after '70s was decreased to around 150 ngr m^{-3} (Mattsson and Jaakkola, 1979). The observed average concentration of lead in the present study equals with 17.7 ngr m^{-3}, reveals a decrease of its concentration of the order of one magnitude since '70s.

The Finnish Meteorological Institute has collected daily aerosol samples for the years 1995 – 2005 for radioactivity monitoring purposes. Airborne ^{210}Pb is a decay product of ^{222}Rn emanating from the soil. Due to its long half-life (22.3 years) ^{210}Pb accumulates relatively into the atmosphere. Thus it can be used as an atmospheric tracer for long-range transported air masses. Anthropogenic lead emissions have low content of ^{210}Pb, so the anthropogenic lead emissions tend to decrease the specific activity of ^{210}Pb in the atmosphere. The ^{210}Pb specific activity is the ratio of the ^{210}Pb activity concentration to the total concentration of stable lead. The observed values of this ratio vary between 3.5-58 kBq gr^{-1}. Previous reported values in Southern Finland ranges between 0.67-39 kBq gr^{-1} and between 3.9-91 kBq gr^{-1} in Northern Finland (Paatero et al., 2015).

Vanadium, which is mainly emitted from coal and oil burning and from refineries, had a clear decline trend. But V, along with other metals such as Zn, K and Pb, can be characterized as being road-specific heavy metal. Close to roads these metals are mainly derived from combustion residues and losses from fuels and engine, transmission oils and abrasion from tires. V had a relatively high correlation with Ni while its correlation with Pb, Zn and K was weak. This fact possibly indicates heavy oil source. The observed concentration of V ranges between 0.37 - 24 ngr m^{-3}.

For the elements of Cu and Zn, a high correlation coefficient was observed (R = 0.89) is an index of traffic source. The average concentration of Cu equals with 30 ngr m^{-3} and of Zn with 46 ngr m^{-3}. Due to the stabilizing effect of the cold sea surface during the summer months, the difference between winter and summer in air concentrations of elements such as Cu, Zn is small.

The results also indicated a clear declined trend for Fe and Ca and a slight decrease for Ti and Si. The observed correlation coefficients between these elements indicate the existence of soil source. The observed average concentration of Fe, Ca, Ti and Si in the present study equal with 162 ngr m^{-3}, 136 ngr m^{-3}, 12 ngr m^{-3} and 224 ngr m^{-3} respectively.

A decrease trend in sulphur was also observed, with values ranging between 135 -2008 ngr m^{-3}. The levels of harmful atmospheric S are currently low in Finland as compared with those in many European areas. The current decrease is the result of reductions of emissions from energy production, reduced use of industrial fuel oil, the introduction of new alternative energy sources, as well as improvements in the production methods in many industries.

PUBLISHER: Sievert Association, Niš, Serbia
Oblačića Rada 24/29, 18105 Niš, Serbia
www.sievert-association.org

FOR THE PUBLISHER: Jugoslav Karamarković

YEAR OF PUBLICATION: 2021

EDITORS: Aleksandar Jakšić, Jugoslav Karamarković

COVER DESIGN: Vladan Nikolić

TECHNICAL EDITING: Saša Trenčić

PROOF-READING: Saša Trenčić

ISBN: 978-86-81652-03-9

www.rap-conference.org/21/BoA

ISBN-978-86-81652-03-9