RAP.24

INTERNATIONAL CONFERENCE ON RADIATION APPLICATIONS

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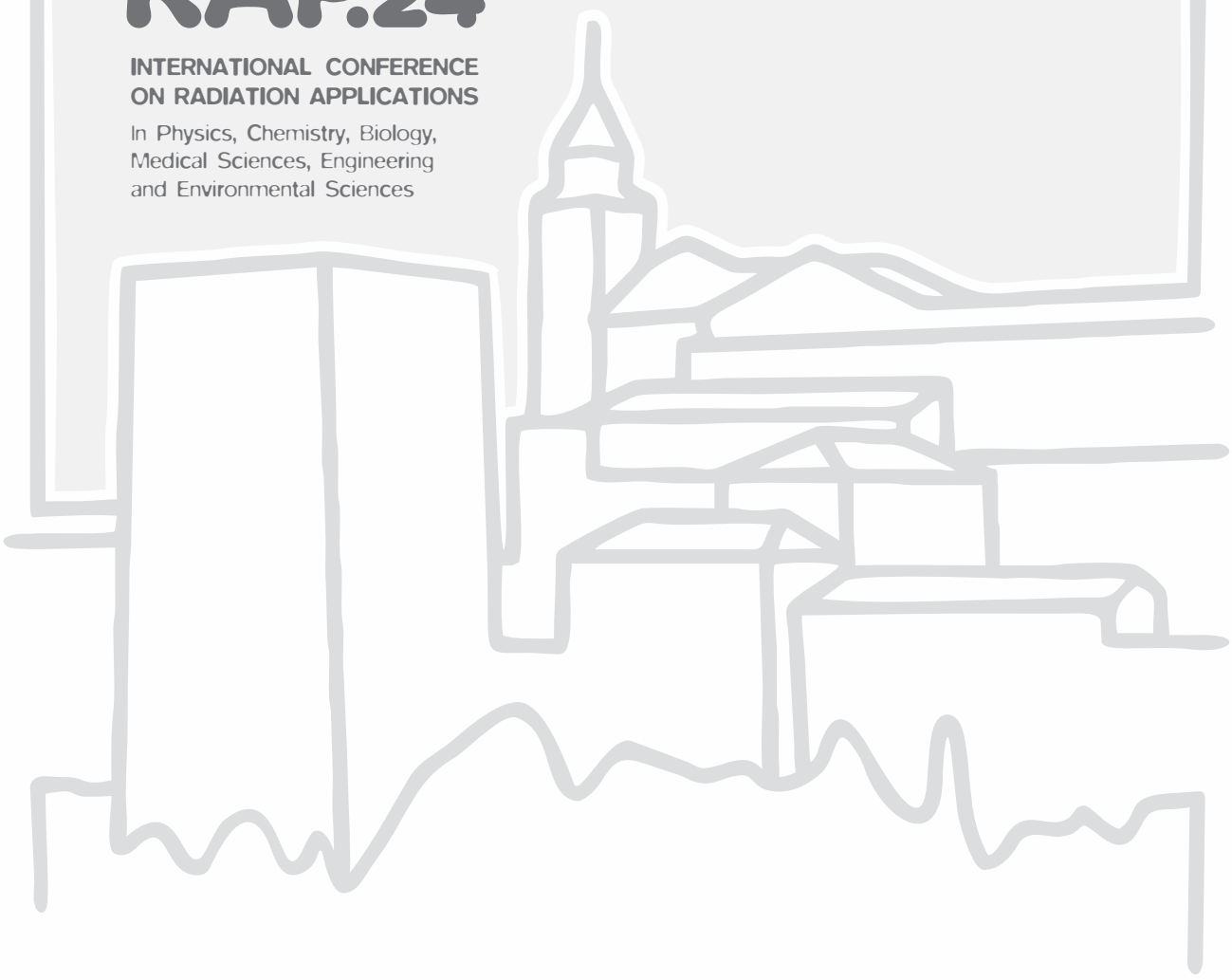

BOOK OF ABSTRACTS

June 10-12, 2024 | University of Granada | Spain | rap-conference.org

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INTERNATIONAL CONFERENCE ON RADIATION APPLICATIONS (RAP 2024)
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TABLE OF CONTENTS

Click on the title of the abstract to access it

INVITED TALKS

CONFERENCE ABSTRACTS

On-chip particle detectors for self-adaptive integrated circuits for space applications

Marko Andjelkovic

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The number of orbital satellites has increased tremendously in the past several years due to the increased use of satellite communications to support various terrestrial applications, such as mobile communications, weather forecasting, navigation, television and radio broadcasting, military surveillance, etc. Currently, there are over 9000 active satellites in orbit, and it is projected that this number will continue to increase in the coming years. In addition, the number of space exploration missions involving both manned and unmanned spacecraft is also projected to increase. Furthermore, the space concepts such as space tourism and solar energy farms are also likely to become reality in the following decades. These trends are imposing the need for novel, more advanced and reliable electronic systems for space missions.

One of the main threats for electronics operating in space is the ionizing radiation, which originates from the Sun, the electromagnetic belts surrounding the Earth, and deep space. Without adequate protection from radiation, electronic equipment may experience malfunction, failure or even physical damage. Therefore, design of electronics for space missions requires to perform detailed assessment of radiation effects, and accordingly apply appropriate design measures to increase the tolerance to radiation-induced effects. In this special session, the recent solutions in the analysis of radiation effects and design of electronics for space missions will be presented.

Modelling the transfer of radionuclides in aquatic environments

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IRSN, France

The transfer of radionuclides in aquatic environments (lakes, rivers, oceans) is controlled by known physicochemical processes, but which remain, sometimes, difficult to reproduce correctly in numerical models. However, a good understanding and prediction of these transfers is essential because these environments have a high risk of being impacted during an accident, since all nuclear power plants are installed at the water's edge. If the effect of radioactive contamination of water on humans would be less than compared to that of a terrestrial environment, the consequences can be strong for the effects on ecosystems and the use of water (drinking water, irrigation,...). Likewise, remediation possibilities are much more complicated for sediments than for soils.

IRSN has developed several types of numerical models to respond to this challenge. They make it possible to simulate the fate of dissolved and particulate radionuclides in rivers or at sea, as well as their transfer to some organisms.

The presentation will describe the main processes taken into account in these models and will be based on various examples of work performed by the researchers from IRSN. They will cover a large spatial scale, from soil inputs in the watershed to sediment deposition at sea. Current studies to integrate new processes or adapt to crisis or monitoring needs will be discussed.

Irradiation facility relevant for fusion materials: IFMIF-DONES

Angel Ibarra[1,2] and the full IFMIF-DONES Teams

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The International Fusion Materials Irradiation Facility – Demo Oriented Neutron Source (IFMIF-DONES) is a research infrastructure for irradiation of the materials to be used in a fusion reactor. The facility would provide a unique neutron source of energy spectrum and flux level representative of those expected for the first wall of future fusion reactors. At IFMIF-DONES neutrons will be produced in 7Li(d,n) stripping reaction with a D+ beam at an energy of 40 MeV impacting on a flowing liquid Li target.

Materials irradiation data under such conditions are of fundamental interest for the fusion community to consolidate the fusion reactors engineering design and licensing and to validate modelling tools for materials radiation damage. The facility will be also able to address some tritium technologies related experiments. Complementary to its role as an irradiation facility the design of DONES allows for the installation of an array of physics experiments which include a collimated neutron beam area and a nuclear physics oriented neutron time-of-flight facility as well as isotopes production and the development of different types of experiments relevant in different scientific and technological disciplines.

The facility is currently in its final design phase within the framework of the EUROfusion Consortium work programme and the Construction Phase just started in the proposed site in the Escúzar Metropolitan Park (located in the province of Granada, 18 km southwest from Granada city).

The talk will present an overview of the implementation, engineering design, and main irradiation characteristics of the facility.

Evaluation of occupational exposure to ionizing radiation, UNSCEAR 2020/2021 Report, Annex D

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United Nation's Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Sweden

This presentation provides an overview of the content of the report "Evaluation of occupational exposure to ionizing radiation", which is the Annex D of the UNSCEAR 2020/2021 report, published in September 2022. UNSCEAR has been collecting and evaluating sources and levels of occupational exposure since 1975 and this evaluation includes assessments of individual and collective doses to workers and estimates of worldwide levels of occupational exposure for the time period between 2003 and 2014. The report also includes analysis of exposure trends. As in previous reports, the evaluation is done for different work sectors and subsectors, involving exposure to natural and human-made sources. The results are presented as annual averages over five-year periods and for the first time uncertainties are addressed. Data for the evaluation has been collected through UNSCEAR Global Survey of Occupational Radiation Exposure, from peer-reviewed literature and from different international organizations. For exposure to natural sources, the estimate of worldwide annual number of workers was approximately 12.6 million, of which 94% is employed in mining industry. The annual collective effective dose from exposure to natural sources was about 24,300 man Sv, and the average annual effective dose about 2 mSv. Due to lack of data, no evaluation was conducted for gas and oil extraction and for radon at workplaces, hence the figures are most likely underestimated. For human-made sources, estimate of the worldwide annual number of workers was about 11.4 million, the collective effective dose about 5,500 man Sv, and the average effective dose about 0.5 mSv. The medical sector dominates and account for about 80% of the workforce and 75% of the collective dose. Worldwide, the estimates for the period 2010-2014 are as follows: annual number of workers approximately 24 million and the average annual effective dose about 1.2 mSv.

Validation of a biophysical model for the radiobiology of radiopharmaceuticals

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The ISOLPHARM project, headed by INFN-LNL, is aimed at the production of exotic radionuclides of medical interest employing the Isotope Separation On-Line (ISOL) technique to develop innovative radiopharmaceuticals. In the last few years, the project has been focusing on the beta-emitter silver-111 as a possible theranostic candidate for radiopharmaceutical therapy. In this scenario, the therapeutic efficacy of radiolabelled compounds on cancer cells can be assessed by radiobiological trials, with the evaluation of the surviving fraction. The radiobiology of radiopharmaceuticals is quite different from the one developed using external radiation beams, since it is characterised by lower dose-rate, longer exposure and dependence on receptor-ligand kinetics. A biophysical model taking into account all these factors has been recently proposed by the ISOLPHARM collaboration and efforts are now being made for its validation with existing data. The key concept of the model is the subdivision of the cells in compartments with progressive number of complex DNA lesions, while its purpose is to predict the time evolution of the irradiated cell population and, contextually, attain a precise estimate of the dose-rate per cell. The comparison of the model's predictions with a reference study regarding Auger therapy using iodine-125 showed that a good agreement can be reached under the assumption that the most severe DNA lesions, having a 1% misrepair probability, are the ones regulating the entire system dynamics.

The effect of extremely-weak microwave radiation in the millimeter range on the bioluminescence of photobacteria *Photobacterium phosphoreum* IMV B-7071

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The bacterial bioluminescence is caused by the reaction catalyzed by bacterial luciferase (flavin dependent monooxygenase), requiring a reduced flavinmononucleotide (FMNH2), O2, and long chain fatty aldehyde (RCHO). The reaction products are the oxidized flavinmononucleotide (FMN), the corresponding fatty acid (RCOOH), H2O and visible blue light. This bioluminescence reaction serves as an indicator of metabolic activity and functional state of bacterial cells. Therefore, the bioluminescent analysis is now widely used for express assessment of biologically active and toxic substances. Bioluminescence of Photobacterium phosphoreum IMV B-7071 are changed upon influence of powered radiofrequency electromagnetic irradiation. But the sensitivity of photobacteria to extremely low-intensity microwave irradiation, both in terms of thermal and non-thermal effects, is unknown and remains a topic of discussion.

Objective. The aim of this study was to investigate the dynamics of bioluminescence in *Photobacterium phosphoreum* IMV B-7071 under the influence of microwave electromagnetic fields with a wavelength of 7.1 mm (42.2 GHz) and an intensity of 20 mW/cm^2. These millimeter radio waves share frequency and amplitude characteristics with those used in modern telecommunication technologies such as 5G and 6G standards, as well as in some therapeutic procedures.

Methods. Bioluminescence studies were conducted in liquid media of standard composition in Petri dishes with a diameter of 5 cm. The height of the liquid bacterial suspension in the Petri dishes was 5 mm. The basic background glow was examined, and bioluminescence was recorded digitally for further image processing using ImageJ. Temperature measurements were taken inside the suspension and at its bottom using a thermocouple with an accuracy of 0.1°C. Surface temperature of the bacterial suspension was measured using a Thermal Imaging Camera (Topdon Tc001) with an accuracy of 0.1°C.

Results. The study results demonstrate that the intensity of bioluminescence in aqueous solutions gradually increases in *P. phosphoreum*, peaking at approximately 2 days before slowly diminishing. Consequently, we investigated the impact of microwave radiation during these periods of peak luminosity. Our findings revealed a minor yet consistent rise in the temperature of the bacterial suspension by 2-3°C at its center, where microwave radiation was applied via the waveguide during the one-hour exposure. Temperature elevation occurred within the initial minutes, followed by stabilization. Importantly, the microwave radiation and resultant slight temperature increase did not affect the overall intensity of bioluminescence. However, it did induce alterations in the luminescent pattern of the bacterial suspension, associated with the “dendritic” spatial arrangement of bacteria within the suspension. Specifically, the central luminescence in the Petri dish quickly diminished and remained absent throughout the microwave exposure duration. Simultaneously, the luminescence of photobacteria shifted towards the periphery, forming a “torus”-like pattern. Upon cessation of the electromagnetic field, the bacterial distribution within the suspension reverted to its initial configuration, thereby restoring the dynamic “dendritic” structure.

Conclusions. Ultra-weak microwave radiation in the millimeter range did not affect the total background luminescence of bacteria. However, small local temperature gradients induced by electromagnetic waves led to the formation of dissipative structures in the bacterial suspension. This phenomenon can be explained by the Benard-Marangoni hydrodynamic effect resulted in the emergence of convection due to temperature gradients and the separation of phases with different surface tension. The surface tension depends on both temperature and the presence of surface-active compounds, which are known to be produced by bacterial cells in order to protect them and to facilitate their movement in the water environment.

Post-accident biota of large radiation accidents and radio adaptation

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Large radiation accidents (LRA, 6, 7 on the INES scale): Kyshtym, 1957; Chernobyl, 1986; Fukushima, 2011 – differ not only in their destructive power, but also in the features of the post–accident biota. They are manifested, in particular, in discrepancies in the estimates of an increasing number of dose-dependent parameters with the corresponding precision indicators of radiobiological experiments. Among them, the decrease in radioresistance described in all studied taxa of Chernobyl by an order of magnitude (Garnier-Laplace et al., 2013; Beaugelin-Seiller et al., 2018) and radio adaptation of plants and animals in Kyshtym and Chernobyl (Fesenko, 2018; Geraskin et al., 2021), including perfect (without anomalies) radio adaptation in common mole vole (Lyubashevsky et al., 2002). However, a decrease in radioresistance and, at the same time, an increase in survival with additional sublethal irradiation of seeds and rodents from the epicenter of the CRA are clearly incompatible. This paradox is overcome by rejecting the hypothesis of reducing radioresistance by the criterion of frequency of anomalies. It is logical to attribute them to marks-evidence of the overcome disaster caused by the CRA, the potential biological danger of which is underestimated. Activates the evolutionarily developed program of defeat and reactivity the complex of its initial effects:

- Acute-subacute emergency sublethal irradiation, followed by prolonged (centuries) chronic.
- Mutagenesis, which is characterized by a disproportionately slow reduction compared to the fall in the dose of chronic radiation.
- Genetic drift in populations of different taxa.
- Dynamic reversible radio adaptation at all levels of the organization of irradiated biota.
- Formation of temporary radiogenic ecosystems (Rhoades et al., 2020) from irradiated fragments of local precursors.
- Epigenetic modification of their biota (shown on Kyshtym rodents and plants in Chernobyl and Fukushima (Vasiliev et al., 2003; Kovalchuk et al., 2003).

The damage-protection complex of LRA is most likely due to the long-term threat of mutagenesis. Its complexity seems excessive to protect the ecosystem from the relatively low risk of individual mutations. But the genetic drift that occurs in small populations is harmful (Lynch et al., 1993; Burri, 2021). The risks of extinction are all the greater for ultra-small LRA populations formed from random individuals with a high level of mutations. Thus, the population – the unit of evolution – is the main target of radiation. This position contributes to the interpretation of LRA bioeffects.

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Epigenetics of ^{90}Sr deposition: Maternal effect

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In the available literature there is no indication of the inheritance of the metabolism of bone seeking radionuclides (in particular, ^{90}Sr) as long-term sources of internal radiation. The presented materials, obtained in the natural environment and in experiment, answer this question positively. Thus, the northern mole vole (*Ellobius talpinus* Pallas, 1770), which lives in families on the territory of the East Ural radioactive trace, shows significant inter-family differences in ^{90}Sr deposition (Starichenko, 2011). The hereditary conditionality of the accumulation of ^{90}Sr in the litters of different females of the same mouse strain (a highly significant family component of variability, r=0.4–0.5; p<0.001) was also revealed in a number of laboratory experiments (Starichenko, 2010, 2018; Lyubashevsky, Starichenko, 2012, 2017). Experiments were conducted on CBA mice under exogenous loads after the end of breastfeeding, including when dividing the brood of one female between alternative influences. Similar results were obtained for bone seeking F+ in an experiment on CBA, BALB/c and BC mice, with a significant absence of interline differences (the effect of the "family" factor is 2-3 times higher than the influence of the "strains" factor). The correlation of accumulation of ^{90}Sr and F+ coincides with the reference correlation of morphological features (r=0.5–0.6; p<0.001). There are no factors other than gestation and milk from different mothers that distinguish mice of the same litter from litters of the same strain kept under the same conditions that lead to different accumulations of ^{90}Sr and F^+. Reviews (Melnic, 2015; Chavatte-Palmer et al., 2018) indicate that lactation as a method of not only nutrition, but also regulation of the development of offspring, appeared in evolution and developed exclusively in mammals. We judge the epigenetic nature of inheritance of ^{90}Sr and F^+ deposition based on literary data (Kitsiou-Tzeli, Tzetis, 2017; Zhao-Jia Ge, Qing-Yuan Sun, 2019) and justify this by the fact (Lyubashevsky, Starichenko, 2012, 2017) that genetically homogeneous brothers and sisters (sibs) differ from each other only in maternal nutrition during pregnancy and subsequent milk feeding. Reviews (Melnik, 2015; Power, Schulkin, 2015) indicate that females transmit biochemical signals to their offspring from the moment of implantation until the end of milk feeding of the cubs, thus modulating their development. That is confirmed by a body of work on the effect of nutrition on epigenetic marks (Jang, Serra, 2014; Murdoch et al., 2016; Ramírez-Alarcón et al., 2019). Therefore, these data can be rightfully considered as another form of manifestation of the maternal effect.

Acknowledgments: The study was carried out within the state task of the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences (No. 122021000077-6).

The SEM characteristics of the "cemeteries" of palynoterates, formed under two local types of radioactive load near the Chernobyl NPP or under climatic extremes of the Neanderthal epoch, and geomagnetic excursion Laschamp

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Studying individual pollen grains from the natural and Chernobyl pollen complexes of the most extreme conditions by light microscopy is unproductive, as under light microscope they have the following characteristics [Ananova, 1966 – data on glacial sediments]: 1. domination of the indeterminable forms; 2. the sculpture and other traits are underdeveloped; 3. flattened; 4. ultra dwarf; 5. occurrence of polyades; 6. of grey colour; 7. with glassy gloss. But it is very important to show these levels on pollen diagrams as indicators of ecological extremes.

In our studies, we used SEM and partly improved the methodology: the macerated sediments with pollen complexes were coated with gold/palladium instead of single pollen grains. The surface soil samples were collected by the Belarussian scientists on the second year after the Chernobyl accident at the Masany and Kryuki sites 12 and 16 km from the ChNPP respectively.

The samples are contaminated with (in Bq/kg):

^{137}Cs: Masany – 52000 and Kryki – 270000;
^{90}Sr: Masany – 14000 and Kryuki – 4500;
^{241}Am: Masany – 150 and Kryuki – 81;
$^{239\text{-}240}$Pu: Masany – 89 and Kryuki – 48.

The Kryuki complex with the maximum of ^{137}Cs looks like the "cemetery" of the monstrous forms with varied deviations of each trait in each form (the evidence of mutagenesis). All monstrous forms are underdeveloped and sterile.

The Masany complex reflects the most severe conditions under the maximum contamination with ^{241}Am, ^{90}Sr and $^{239\text{-}240}$Pu. It resembles the "cemetery" of indeterminable sterile "empty" forms with very thick white colloided exine.

The most severe climatic extreme was determined for the Neanderthal layer of Barakayevskaya cave (modern Caucasian broadleaf forest belt). The steppe and alpine belts contact, and the upper limits of all flowering plants were reconstructed by pollen and ~600 faunal finds. The complex resembles the one described by E.N. Ananova: contours of sterile, thinned, and indeterminable dwarf (10 μm) pollen grains. The monstrous forms are single. Only Betulaceae grains from polyade were determined.

The geomagnetic excursion Laschamp was determined [Pospelova, 2005] in Kostenki 12 for the upper Palaeolithic layer III with domination of horse in its' bottom, and reindeer in the upper part. SEM micrographs [Levkovskaya,2015] have shown the domination of ultra-dwarf and abortive pollen grains of Chenopodiaceae at the bottom of the layer, and dwarf *Betula nana* and *Alnaster* at the top. The optimum of *Picea* divides them.

Two types of pollen "cemeteries" of natural climatic extremes with domination of the ultra-dwarf forms (Kostenki 12) or ultra-dwarf abortive (Barakayevskaya) forms were differentiated. Defective forms are rare. Two Chernobyl type "cemeteries" [Levkovskaya et al., 2022] differ from the natural ones by three dominating pathologies in each form that are the ecological indicators: monstrosity+ underdevelopment+ dwarfism, specifically in Masany the leading feature is underdevelopment, and in Kryky – monstrosity.

Purification of Cs^+ ion by BPA@MOF for the management of contaminated water

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Following the Fukushima Daiichi nuclear accident (2011), which generated a huge quantity of water contaminated with ^{90}Sr, ^{137}Cs and other radionuclides, several systems have been implemented to remove these radionuclides and allow water recycling to reactors for cooling. Cs removal relies on the use of silicotitanate (SARRY system) or transition metal hexacyanoferrate products (ALPS system). These systems are certainly efficient but they also generate significant amount solid waste because their retention power is still quite limited, a few tens of mg/g of adsorbent. However, the efficient removal of ^{137}Cs from aqueous solutions remains a challenge due to its solubility, mobility, and the presence of other competitor ions. The purpose of this study is to investigate the possibility of the effective removal of Cs^+ ion from aqueous solutions by Metal-Organic Frameworks (MOFs) grafted with Prussian blue analogues. Thus, we focused our interest on UiO-66(Zr)-SO_3H and MIL-101(Cr)-SO_3H because of their "green" synthesis and their easily functionalizable organic/inorganic hybrid framework. UiO-66(Zr)-SO_3H and MIL-101(Cr)-SO_3H were synthesized respectively by hydrothermal reaction between monosodium 2-sulfotherephthalic acid (BDC-SO_3Na) and $ZrOCl_2.8H_2O$ and between BDC-SO_3Na and CrO_3. These MOFs were functionalized by Prussian blue analogues (PBA, generic name for metal hexacyanoferrate) to form PBA@UiO-66(Zr)-SO_3H and PBA@MIL-101(Cr)-SO_3H and subsequently characterized by XRD, IR, nitrogen adsorption (77 K) and SEM. The final materials are crystallized, presenting an octahedral morphology. Cs^+ ions adsorption tests on these two MOFs were carried out in batch to study the physicochemical parameters such as adsorption kinetics and adsorption isotherms, and to test the presence of competing ions. The results showed that PBA@UiO-66(Zr)-SO_3H and PBA@MIL-101(Cr)-SO_3H present excellent performances in terms of Cs purification (> 90%), good adsorption capacities (> 100 mg of Cs/g of MOF) in a very wide range of concentrations (from the ppb scale to several hundred ppm) and good selectivity to Cs^+ ions. These adsorption tests also highlighted two different adsorption kinetics.

Polonium sequestration from copper for dark matter studies

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The existence of dark matter in the universe is one theory to explain the missing mass in many cosmological models. Weakly interactive massive particles (WIMPS) are favoured candidates for this material. However, their inherently rare interaction with conventional matter renders their detection challenging. Inevitably, more conventional events are likely to produce a significant background in any detection system, where radionuclide decay is recognized as the principal background source. The NEWS-G collaboration has developed a WIMP detector that utilizes a 60 cm, 99.99% pure copper sphere contained within archaeological lead and high-density polyethylene. This system is located at the SNOLAB (Sudbury Neutrino Observatory Laboratory) facility in Sudbury Ontario at a depth of 2 km. These measures are intended to minimise the contributions of cosmic events and background radioactivity. It is proposed that detection itself will be achieved by the interaction of WIMPs with hydrocarbon and inert gases, which under a potential gradient produce an electron cascade at a central anode.

Actinide contamination represents a significant and pernicious background contribution. Previous analysis of uranium and thorium suggest that these parent radionuclides represent only a partial source of this background. Exposure to radon, particularly Rn-222, during sphere production and transportation may also cause contamination (as recoil of the nucleus during decay embeds radon daughters within the metal). Consideration of daughter radionuclides indicates that Pb-210 and Po-210, with half lives 22.3 y and 138 d, respectively, represent the most important background contributors. As a source of α-decay, reduction of Po-210 is a higher priority.

The present work has focused on the etching of copper surfaces using aqueous hydrogen peroxide and sulfuric acid mixtures, using Po-209. Although, polonium has a favorable standard electrode potential, its vanishingly low concentration favors preferential re-reduction in the presence of copper metal. Thus, a polonium sequestrant has been used to kinetically remove polonium from its solution-metal surface equilibrium. Resin-bound 4,4′(5′)-di-t-butylcyclohexano 18-crown-6 crown ether displays a high affinity for polonium(IV) at low pH. Replicate experiments have studied the fate of artificially contaminated copper surfaces at Po-209 activity of *ca.* 1 Bq/cm^2. Liquid scintillation analysis using alpha discrimination provides rapid and facile analyses of the metal surface, solution, and resin. It is evident that oxidative acidic etching liberates polonium from the copper surface and that careful use of resin at solution loading of *ca.* 2E-3 g/cm^3 provides > 80% Po-209 sequestration. In practice, Po-210 levels within the NEWS-G sphere are a factor of 10^5 lower. Ongoing studies are progressively reducing Po-209 contamination to determine the relationship between activity and sequestration efficiency.

New development of radium analysis in water samples using MnO_2 resin and alpha spectrometry

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A time-saving and optimum procedure for determining Radium in water has been implemented in Kuwait. This new development has been reached including radiochemical separation using manganese dioxide (MnO_2) resin and alpha spectrometry measurements. Radium is separated and retained by the MnO_2 resin, then it is extracted by 5 M HCL/15%H_2O_2 solution. Barium sulfate is precipitated onto the resolve filter followed by alpha measurement. IAEA proficiency test sample 2 was analyzed similarly, and the generated value of Radium-226 (^{226}Ra) was in agreement with the reference value as well as the gamma result analyzed in the same laboratory. The newly developed radium analysis procedure is more efficient for water samples than other radio-analytical techniques due to the low detection limit of alpha spectrometry compared to gamma spectrometry.

Radiochemical purity control of ^{99m}Tc-mertiatiade (MAG-3) radiopharmaceutical

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Several methods have been recommended in the literature for the radiochemical purity control of ^{99m}Tc-mertiatide (MAG-3, mercaptoacetyltriglycine) radiopharmaceutical. The aims of this study were to compare these miniaturized chromatographic systems to verify their true usefulness and to determine the best way to quantify the radiochemical purity of this radiopharmaceutical, which is used in nuclear medicine for purposes of diagnosing the problems in kidneys through renal scintigraphy. Instant Thin Layer Chromatography (ITLC) silica gel and Paper Chromatography using different solvents in different supports are analyzed. The chromatographic systems were: ITLC-SG, Whatman S&S 2589C, Whatman 4 (as support phase) in Acetone, NaCl, MEK, Absolute Alcohol, Ethyl Acetate : MEK 3 : 2, Acetonitrile 50% (as mobile phase). ITLC-SG was found to be the best support for these miniaturized chromatographic methods because it saves considerable time, fits quite well in nuclear medicine department daily routine production, and meets the labelling criteria formulated by the manufacturer.

Track structure based microdosimetry simulation of energy deposition of electron and protons in liquid water using the Geant4-DNA

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The well-known formalism of microdosimetry, which makes it possible to develop a precise quantitative description of the basic concepts of microdosimetry, is frequently used to demonstrate the biological effects of ionizing radiation, particularly at the cellular level. This technique is a well-known tool in microdosimetry, particularly for its use for the stochastic simulation of radiation transport and energy deposition within the irradiated medium. Condensed-history (CH) or track-structure (TS) codes are two broad categories for the different MC codes that are available for radiation transport simulation. Simulation carried out using Track-Structure models in the extension Geant4-DNA. These models estimate macroscopic quantities to the following energy ranges: 0.0001–300MeV for electrons, 0.001–300 MeV for protons. In this work, we used GEANT4/ to generate microdosimetry spectra and dose-mean lineal energies as well as mean specific energy for incident monoenergetic electrons or proton beams in spheres of liquid water or air with dimensions comparable to those of the subcellular structures laying between 2 nm diameter for base pairs, and 300 nm diameter for chromosomes. The ratio water/air of absorbed dose to water or to air is determined both for electron and proton beam. Our results emphasize a good concordance between calculations from Geant4-DNA Monte Carlo simulations and data from the International Commission on Radiation Units and Measurements (ICRU) reports. In parallel with the microdosimetric analysis, we were interested in the analytical calculation of the stopping power and the path of protons in liquid water in a wide energy range. This study showed that it is possible to obtain promising results using simple analytical models with great precision.

Comparison of energy dependence and dose response of the new EBT4 with EBT3 GafChromic film models

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Purpose. For almost two decades, radiochromic films in combinations with inexpensive document scanners [S. Devic et al., "Dosimetric properties of improved GafChromic films for seven different digitizers." Med Phys 2004, vol. 31: 2392-2401] have been used as convenient and precise 2D reference dosimeters for various dosimetry applications [S. Devic, "Radiochromic film dosimetry: Past, present, and future," Phys Med 2011, vol. 27, 122-134]. Dose response and energy dependence of the latest EBT4 GafChromic film model was compared to its predecessor EBT3 model in a dose rage up to 10 Gy for two beam qualities: 6 MV and 120 kVp photon beams.

Methods. Six pieces of both EBT3 and EBT4 GafChromic films models were irradiated using 6 MV and 120 kVp (4.19 mm Al) photon beams to following doses: 0, 2, 4, 6, 8, and 10 Gy. Films were cut into 2" by 3" pieces in size, with longer edge cut along longer edge of the film sheet and positioned along longer edge of the scanning bed, and scanned 24 hours post irradiation with Epson Expression 11000 document scanner. For the 6 MV beam quality film pieces were irradiated within Solid Water phantom at depth of 5 cm and for 120 kVp beam quality at the surface of the Solid Water phantom. Output of the 6 MV beam quality (Varian TrueBeam STX linac) was established using the AAPM TG-51 while the output of the 120 kVp photon beam (Xstrahl ortho-voltage unit) was based on the AAPM TG-61 reference dosimetry protocols. Film response was calculated as normalized pixel values, $(PV_{unexposed}/PV_{exposed})$-1 [S. Aldelaijan and S. Devic, "Comparison of dose response functions for EBT3 model GafChromic (TM) film dosimetry system," Phys Med 2018, vol. 49: 121-126], from green color channel of scanned RGB TIFF images.

Results. The new EBT4 film model has lower sensitivity than its predecessor and exhibits similar energy dependent response [H. Bekerat et al., "Improving the Energy Response of External Beam Therapy (EBT) GafChromic™ Dosimetry Films at Low Energies (≤100 keV)," Med Phys 2014, vol. 41; 022101]. On the other hand, it was found that the latest EBT4 film model demonstrates improved linear dose response when compared to the EBT3 film model.

Conclusions. While the sensitivity of the EBT4 GafChromic film model appears to be lower than its predecessor, it demonstrates similar energy dependent dose response. The sensitivity being lower, similar to the EBT-XD film model [León-Marroquín E. Y, et al., "Response characterization of EBT-XD radiochromic films in megavoltage photon and electron beams. Med Phys 2019, vol. 46: 4246-4256] makes the latest EBT4 film model suitable for high radiation dose measurements in radiation therapy. In addition, the other advantage is that, dose response of the novel film model has better linearity than its predecessor when normalized pixel value of the green color channel from the scanned RGB TIFF images is used.

Proton-induced reactions on enriched 120-Sn at the energies of up to 18 MeV: Comprehensive analyses via stacked-foil target technique

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The reaction cross-section of the proton-induced reactions on enriched tin 120-Sn were measured as a function of proton energy in the range from the respective threshold for each reaction (E_{thr}) up to 18 MeV. We used stacked foil activation technique combined with high resolution gamma-ray spectroscopy

Simulations using SRIM and PHITS codes were performed to determine the energy in each foil. The results are compared with data obtained using the monitor reaction in copper. New experimental cross sections for reactions (p,n) and (p,a) were compared with data from the TENDL-2023 and JENDL-5 libraries.

Radioactive sources used in mining explorations and environmental risks

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Radioactive sources, mainly gamma sources and neutron sources, are widely used in mines for the exploration and extraction of natural resources such as oil, gas, uranium, etc.

The gamma source is generally used associated to a gamma radiation detector, to detect the rays diffused by the rocks of the mine. The ratio of the number of gamma rays scattered to that emitted by the source gives information on the formation's characteristics as composition, density, porosity....

The neutron source is used coupled with thermal and /or epithermal neutrons detectors. The measured ratio of the intensity of the slow-neutrons to those of the source is also related to the physical characteristics of the formations of the explored mine.

It is obvious that the radioactive sources mentioned above provide valuable information on the formations of the explored mine but on the other hands the risks of ionized radiations on environment and workers are not negligible. It is essential to take into account the risks of contamination essentially the contamination of groundwater.

The aim of this study is to find another alternative to the use of neutron and gamma ray sources by replacing the radioactive sources commonly used by another investigative device that is safer for workers and the environment.

Measurement of spectra in mammography using different phantoms

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Evaluation of the performance of all mammographic equipment requires the imaging and interpretation of test objects or phantoms and risk evaluation. This study evaluated by spectrometry technique the linear attenuation coefficients by transmitted intensity of commercially tissue-equivalent phantom for mammography, Computerized Imaging Reference System (CIRS) with different glandularity-adipose content and PMMA. The measurements were realized with x-ray beams produced by Mo/Mo, Mo/Rh and W/Rh. The results are available for the x-ray characteristic photo-peaks ($k_{\alpha 1}$ Mo 17.48 keV and $k_{\alpha 2}$ Mo 19.61 keV). For spectrometry measurements use an AMPTEK XR-100T Cadmium Telluride (CdTe) detector and spectra correction using MCNP6 simulations. The results of linear attenuation coefficients here were compared with experimental (scattering technique) and theoretical values that were previously reported from *Johns and Yaffe (1987)*, *Byng et al. (1998)* and *Poletti et al. (2002)* for $k_{\alpha 1}$ (Mo 17.48 keV). In this work, we show the adequacy of the results found for $k_{\alpha 1}$ Mo with 17.48 keV energy when compared to publications that applied different methods of analysis. In addition, it brings the evaluation of the attenuation coefficient for $k_{\alpha 2}$ Mo with 19.61 keV for the CIRS phantom and the comparison with PMMA results.

Study of the possibility of producing rhenium medical isotopes at electron accelerators

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Theranostics is an innovative and expanding field of precision medicine. Theranostic treatment combines specific diagnostic and therapeutic methods, enabling a transition from conventional therapy to personalised cancer treatment tailored to the individual characteristics of the patient. Radiopharmaceuticals with rhenium isotopes have a high potential for use in theranostics due to their radionuclide properties.

Currently, medical isotopes of rhenium are produced by reactor methods. The radioisotope ^{186}Re is produced in the reaction ^{185}Re(n, γ)^{186}Re by neutron irradiation of a target enriched in ^{185}Re. To obtain ^{188}Re, thermochromatographic separation is used from the parent radioisotope ^{188}W produced in double neutron capture reactions [^{186}W(n, γ), ^{187}W(n, γ)^{188}W]. However, even when using enriched targets, in order to obtain sufficient specific activity of rhenium by this method to solve the problems of nuclear medicine, it is necessary to use nuclear reactors with high neutron flux densities. There are only a few such reactors in the world. Given the complexity and high cost of producing medical isotopes of rhenium, alternative methods are now being sought.

This paper explores the possibility of using electron accelerators for the production of medical rhenium radioisotopes. For this purpose, the software code TALYS 1.96 [doi.org/10.1016/j.nds.2012.11.002] was used to make preliminary theoretical estimates of the flux-weighted average cross sections of photonuclear reactions. Subsequently, an osmium oxide sample was irradiated with bremsstrahlung obtained at a microtron of the Scobeltsyn Institute of Nuclear Physics of Lomonosov Moscow State University with a beam energy of 55 MeV.

The Fermi gas model was used to calculate the theoretical reaction cross sections in TALYS 1.96. The energy splitting of the giant dipole resonance components with different isospins is not taken into account in this model [doi.org/10.3367/ufne.2020.02.038725]. Therefore, reaction yields for (γ, p) reactions were calculated using the weighted average cross section transformation method [doi.org/10.1140/epja/s10050-022-00778-8] for the semi-direct mechanism of photonuclear reactions. To estimate the integral yield of photonuclear reactions, the differential cross sections were convolved with the microtron bremsstrahlung spectrum simulated in Geant4 with an end-point energy of 55 MeV.

In the experiment, a 1.33 g osmium oxide target and tantalum monitor target assembly was irradiated for one hour. The irradiated targets were then measured using Ortec® and Canberra® semiconductor spectrometers with ultrapure germanium detectors. The detectors have an energy resolution of 1.8-2.0 keV for 1333 keV 60Co gamma rays. A ^{152}Eu calibration source was used to determine the gamma-ray detection efficiency of the spectrometers. The gamma-ray associated with the decay of ^{183}O, ^{185}O, ^{191}O, ^{186}Re, ^{188}Re, ^{189}Re, ^{190}Re are reliably detected in the gamma-spectra received. The results obtained are discussed.

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From mapping to quantification: Digital autoradiography of ^{226}Ra in human skeleton

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The United States Transuranium and Uranium Registries (USTUR) studies actinide biokinetics and tissue dosimetry by following up occupationally exposed individuals. Currently, the USTUR employs the ionizing radiation quantum imaging detector (iQID) to map the micro-distribution of alpha-emitting radionuclides in human tissues. This research aims to expand upon the capabilities of the iQID, primarily focusing on quantifying the activity concentrations of ^{226}Ra in bone samples. In this study, two plastic-embedded bone sections were selected from the middle shaft of a left femur and the left side of the thoracic vertebra of a radium dial painter (RDP). These samples were obtained from the National Human Radiobiology Tissue Repository (NHRTR), an integral component of the Registries. The NHRTR preserves an extensive collection of tissue materials from a variety of radium worker studies, including histological bone slides and tissue blocks from RDPs. In this study, the ^{226}Ra micro-distribution was mapped in bones of a female who had worked as a dial painter for 6 years, had an estimated ^{226}Ra uptake of 58.9 MBq, and passed away at age 24. Regions of interest for both cortical bone and trabecular bone were segmented. A computational model was developed to simulate the geometric efficiencies unique to the geometry of each sample, enabling the estimation of volumes and sample masses. This simulation utilized alpha particle transport models based on the particle interactions within the images of individual bone samples. The activity concentrations derived using iQID measurement were compared to results from the radiochemical analysis of these samples. The iQID imaging technique proves not only effective in studying micro-scale heterogeneous radionuclide distributions but also in accurately estimating activity concentrations of alpha-emitting radionuclides.

The use of Fricke gel PVA - GTA detectors and Gafchromic™ EBT3 Ballcube I dosimetry films in Gamma Knife blocked exposures

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The goal of the present study was dose distribution analysis of blocked exposures that were used to treat trigeminal neuralgia (TN) with the Gamma Knife technique using Fricke gel PVA-GTA detectors in comparison with dosimetry Gafchromic films.

The Gamma Knife device is used to treat lesions, both malignant and benign, located within the brain. It is also used in the treatment of TN, which is defined as a one-sided painful condition characterized by brief pain of a paroxysmal nature.

GTA-PVA Fricke gels based on a polyvinyl alcohol (PVA) matrix chemically cross-linked with glutaraldehyde (GTA) provided an excellent performance in dose distributions studies and were proposed for TN dose investigations. For comparison, Gafchromic dosimetry films were also applied. The study was conducted at the Exira Gamma Knife Center located in Katowice, Poland and the analysis were performed in the Institute of Physics, University of Silesia.

The Gamma Knife TN treatment typically consist of a single fraction delivering a dose of 80-90 Gy to a point situated approximately 7.5 mm from the exit of the trigeminal nerve from the brainstem within the trigeminal area. The critical organ during treatment is the brainstem, where exposure blocking with GK is used to lower the maximum dose. The Treatment Planning System, due to technical limitations and the simple calculation algorithm used, often only estimates this area. Hence, the distribution of the dose of blocked exposure became the subject of the presented research.

The presentation will show the results of a study of 9 different treatment plans for trigeminal neuralgia using different types of blocked radiation exposures.

Half-value layer measurements in diagnostic radiology using X-ray multimeters

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With the ever-growing importance of medical imaging in clinical diagnostics, the assurance of high-quality of X-ray imaging is essential. X-ray multimeters, or XMMs, can be used as a specialized tool for improving the quality assurance practices for clinical X-ray systems. They offer a comprehensive approach to evaluate critical parameters such as air kerma and X-ray tube high voltage, and other special quantities, such as half-value layer (HVL), total filtration, irradiation time, product of current and time etc.

The calibration services for most of these quantities are rarely available in Secondary Standards Dosimetry Laboratories, making it hard to establish traceability. Furthermore, calibration conditions and clinical conditions can be significantly different. Maintaining accurate calibration is crucial for ensuring the reliability of measurements and the adherence to standards.

HVL, a critical parameter in X-ray beam quality assessment, plays a significant role in determining the penetrating power of the radiation and influences image quality. Although HVL is commonly measured during QA/QC procedures, the problem is that there is no agreement on how to establish traceability or uncertainties in SSDLs, so harmonized procedures for calibration and testing of XMMs measurements must be developed.

Joint research project 22NRM01 TraMeXi, a project within the European partnership on metrology, is addressing the needs of standardization and metrology related to clinical measurements of parameters related to X-ray beams. Work package 3 of this project aims to develop harmonized calibration and measurement procedures for XMMs. Work was started on establishing reference values of HVL, together with the measurement uncertainty. In addition, XMM indications were compared with reference values for different reference radiation qualities. Preliminary results will be presented. In future work, tests will also be performed in clinical conditions, to evaluate the suitability of device calibration for real use scenarios.

Keywords: diagnostic radiology, measurement uncertainty, Half Value Layer, harmonization, traceability, quality assurance, x-ray multimeter

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Construction of a Compton camera-equipped robotic system capable of moving autonomously towards the radiation source

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At the decommissioning site of the Fukushima Daiichi Nuclear Power Station (FDNPS), it is crucial to understand the distribution of radioactive substances to reduce workers' exposure dose and plan work effectively. Previously, one of the authors of this paper, Sato, successfully visualized radioactive hotspots remotely inside the Unit 1 reactor building of FDNPS using a mecanum wheel robot equipped with a Compton camera, capable of moving horizontally in all directions and turning [Sato Y et. al., Detailed visualization of radioactive hotspots inside the unit 1 reactor building of the Fukushima Daiichi Nuclear Power Station using an integrated Radiation Imaging System mounted on a mecanum wheel robot, Journal of Nuclear Science and Technology, 60, in press, 2023]. However, the robot was manually operated by the author and lacked autonomous movement functionality.

In this study, the robot was equipped with a new function whereby the software on board the robot interprets the visualization results of the radiation source obtained by the Compton camera, determines the direction of movement and moves autonomously. An operational test was carried out in the laboratory using a ^{137}Cs radiation source on the mecanum wheeled robot equipped with an autonomous mobility function and a Compton camera. The Compton camera utilizes a gamma-ray sensor that combines a Ce-doped GAGG scintillator and MPPC as the scatterer and absorber. This is based on the portable Compton camera technology jointly developed by Waseda University and Hamamatsu Photonics K. K. [Kataoka J et. al., Handy Compton camera using 3D position-sensitive scintillators coupled with large-area monolithic MPPC arrays. Nucl Instrum Meth A., 732, pp. 403–407, 2013, Hamamatsu Photonics K. K., Technical note, MPPC, 2017]. Initially, radiation measurements are taken using a Compton camera while the robot is stationary. The visualized image of the radiation source acquired by the Compton camera is then read by the software on board the robot to determine the direction in which the radiation source is located. The robot then moves autonomously toward the source. These steps are repeated.

By interpreting the visualization results of the radiation source obtained by the Compton camera, the direction of the radiation source was identified, and the robot autonomously moved towards it. Further details regarding the control method of the robot and the outcomes of radiation source detection will be presented in depth during the conference.

Testing and qualification of radiation protection instrumentation in France

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The Technical Center for Evaluation of Radiation Protection Instruments (CTHIR in French) was created in 1981 at the CEA (French Atomic Energy Commission) in order to coordinate the actions of the CEA departments in the field of radiation protection instruments for evaluation tests and standardization. After the creation of IRSN (Institute for Radiological Protection and Nuclear Safety) as technical support for the French Nuclear Authority and its separation from the CEA in 2003, the CTHIR remained within IRSN with the following missions:

- evaluation of nuclear and radiation protection instruments;
- standardization;
- study and expertise.

The evaluation of the radiation protection instrumentation consists in verifying the ability of the instruments to fulfil their function by the assessment of conformity to a technical specification. The tested instruments include various passive and active dosemeters, environmental monitors, contamination monitoring assemblies, warning equipment for criticality accidents, instruments for detection of illicit trafficking of radioactive material, etc.

Customers are all radiation protection manufacturers and the national nuclear organizations (CEA, EDF, Orano/Areva and the armed forces). CTHIR works under quality assurance and has been certified according to ISO 9001 since 2002. The technical specifications used for the evaluation of the instruments are international IEC or ISO standards as well as European EN standards.

The performed tests include:

- radiation tests with gamma, X, beta or neutron irradiations verifying the dose (rate) non-linearity, energy and angular dependencies, overload, etc.;
- environmental tests: temperature, relative humidity and moisture and dust protection;
- mechanical tests: drop, vibrations and mechanical shock;
- electromagnetic: electrostatic discharge, radio frequency immunity, radiated emissions, magnetic fields, etc.;
- electrical tests: battery lifetime and power requirements;
- documentation verification.

Since no laboratory can have the necessary expertise to correctly carry out all of the above tests, CTHIR works with around 15 partner laboratories, either accredited according to ISO/IEC 17025 or well-recognized in their field. The main testing laboratories are cited below:

- for gamma, X-ray, betta or neutron radiation: IRSN/LDRI and LMDN, CEA/LNHB, PTB (Germany), NPL (UK) and CMI (Czech Republic);
- for radioactive aerosols and gases: IRSN/LPMA;
- environmental tests: IRSN/LPMA, EMITECH and SERCOVAM.

The CTHIR actively participates in the international standardization process by occupying the secretary positions of IEC/SC45B and CENELEC/TC45B “Radiation protection instrumentation”. Thus, the experience gained during several hundred type test evaluations goes back to the standardization process.

Conformity evaluation according to the requirements of a standard allows an impartial evaluation by CTHIR which guarantees traceability and confidentiality.

Unfolding accelerator-based neutron spectrum by iterative Bayesian method using trans-stilbene scintillation detector

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Accelerator-based neutron sources have become essential for various scientific, industrial, and medical applications since neutrons have unique properties that make them valuable for studying materials, probing atomic structures, and inducing nuclear reactions. However, evaluating the spectrum and flux of an accelerator-based neutron source remains challenging because neutrons are charge-neutral and commonly detected through secondary charge particles. This study presents a simple approach to measuring and unfolding the neutron spectrum of an accelerator-based neutron source using the iterative Bayesian unfolding method. The measurement was performed at the Korea Multi-purpose Accelerator Complex. Neutrons were produced by directing a 100 MeV proton beam to a copper dump target. A trans-stilbene scintillation detector was used to detect emitted neutrons by neutron-proton scattering reactions. Background gamma was rejected by the excellent pulse shape discrimination capability of the scintillators, and neutron flux and spectrum were successfully reconstructed.

Measurement of neutron source anisotropy using the Mini Labyrinth experimental setup

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The research team from the Slovak University of Technology in Bratislava has been developing the Mini Labyrinth experiment for research, education, and training purposes. There have been several versions proposed and more than 10 experiments conducted over the last years. These experiments aiming at demonstrating the principles of radiation protection in practice, as well as investigating potential shielding materials, have pointed out, that there could be potential neutron source anisotropy issues, which could influence the measurement precision and the comparison of experimental results with simulations. In this study, we present the results of the experiments aimed at measuring the axial and radial anisotropy of two frequently used Pu-Be neutron sources in the Mini Labyrinth experiment. The paper also presents the results of the Monte Carlo simulation, in which the effect of identified anisotropy on dosimetry quantities was investigated using the full 3D model of the laboratory.

Development of a novel 2D printing technique for the production of radioactive surfaces

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In the field of radiation protection and emergency response, the significance of radiological monitoring cannot be overstated. For precise and reliable measurements, the calibration of detection systems is crucial, necessitating the use of traceable standards. However, obtaining a calibration source that faithfully represents real-world scenarios, especially for portable monitors in less controlled field conditions, remains a formidable challenge. Available calibration sources often fall short in accurately representing actual conditions, compelling additional corrections during analysis. To address these challenges in calibration and method development for radiological monitoring and for radioanalytical measurements in general, a novel printing technique has been developed. This innovative approach allows for the printing of radioactivity on various surface materials, facilitating method development in the field of radioactive measurements. Leveraging advanced printer technology, this technique ensures precise control over radioactivity on surfaces by generating highly uniform prints according to predefined patterns dictated by the printer's software.

In the presented work, the methodologies employed in creating 2D printed surfaces on canvas material are described. The paper outlines the radioanalytical methods used in the development of these techniques, providing insights into analytical challenges and lessons learned from the acquired results. Printed materials were used as samples in the International Atomic Energy Agency (IAEA) proficiency tests (PT) conducted in 2021 and 2022. Two distinct printed surfaces were prepared for these purposes. The first, utilized in PT 2021, assumed a circular shape simulating a wipe sample. The second, designated for PT 2022, featured a rectangular shape tailored for examination by portable contamination monitors. Both surfaces were spiked with Cs-137 and Pu-239 radionuclides. The activity was expressed in Bq/sample and in Bq/cm^2, for circle and rectangle shape, respectively. The circle had an activity of (11.2 ± 0.4) Bq/sample for Cs-137 and (8.47 ± 0.04) Bq/sample for Pu-239. Conversely, the rectangle contained an activity of (0.327 ± 0.017) Bq/cm^2 for Cs-137 and (0.253 ± 0.015) Bq/cm^2 for Pu-239.

This innovative printing technique opens avenues for improved calibration practices in radiological monitoring as well as in radioanalytical measurements in general, enhancing accuracy and reliability in less controlled conditions.

Thermoluminescence of beta-irradiated $YBO_3:Nd^{3+}$ phosphor synthesized by combustion method: A preliminary study

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This study aims to investigate the thermoluminescence (TL) properties of the YBO_3 sample doped with Nd^{3+}, which is known to be an important candidate luminescence material. The Nd^{3+}-doped YBO_3 phosphor was synthesized at various concentrations (mass%) utilizing the combustion method, and the X-ray diffraction (XRD) pattern of the synthesized samples was compared with relevant standard data. The optimal dopant concentration and optical filter combination for the Nd^{3+}-doped YBO_3 samples were determined through analysis of their TL glow curves. Consequently, TL emissions of the specified $YBO_3:Nd^{3+}$ (0.5%) samples were examined using the IRSL-TL 410 nm filter combination. The $YBO_3:Nd^{3+}$ (0.5%) sample displayed two distinct maxima at approximately 210 ^oC and 390 ^oC, with a linear heating rate of 2 $^oCs^{-1}$, and when the beta dose response of the sample was examined within the range of 0.1-20 Gy, a consistent linearity (b = 0.946, R^2= 0.999) was observed between 0.1-5 Gy. Following 12 cycles of reusability testing, the integrated TL intensity exhibited no significant alterations. A short-term fading experiment of the TL emission of the sample was carried out, and the results showed that up to 7 days, the 1st maxima faded very little, the 2nd maxima almost did not fade at all, but around the 7th day, the intensity of this maxima increased greatly.

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Modification of standard LSC method for determination of uranium in water

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Uranium is a lithophile, reflecting its tendency to remain close to the earth's surface and be strongly bound to oxygen. It occurs naturally in all soils, minerals, rocks, and water. The isotopic mass of natural uranium is dominated by ^{238}U (99.27%), with a smaller abundance of ^{235}U (0.72%) and ^{234}U (0.0057%). Uranium is one of the main contributors to the earth's natural radioactivity which supplies about half of the earth's heat. In refined forms, it has been used to make nuclear weapons and supply nuclear power plants.

A standard method ISO 13169:2018(en) "Water quality — Uranium — Test method using alpha liquid scintillation counting" is usually used for the determination of activity concentration of uranium in water samples by liquid scintillation counting. This paper presents the results of the modified application of the mentioned standard method and calibration results of LS counter Quantulus 1220, Perkin Elmer. The applicability of the method was tested by using three different "two-phase" (water immiscible) scintillation cocktails produced by Perkin Elmer: Ultima Gold F, Mineral Oil, and Opti Fluor – O. For calibration purposes we used a natural uranium liquid calibration source, certified by Czech Metrology Institute, Prague. The innovation in the presented approach is that this calibration source was used as both alpha and beta emitter. As a first step in the calibration of the detector the discriminator factor, PSA was adjusted for each of the used scintillation cocktails. This step ensures the appropriate separation of alpha counts from beta counts in the obtained spectra.

The obtained efficiencies for each of the scintillation cocktails are: for Ultima Gold F 76.9(15)%, for Mineral Oil 85.9(6)%, and Opti Fluor O 67.9(9)%. The minimal detectable activities for the measuring time of 600 minutes are: for Ultima Gold F around 1 Bq/l, for Mineral Oil 1.3 Bq/l, and Opti Fluor O 1.5 Bq/l. To test the developed methodology and procedure natural ground waters were measured with all three scintillation cocktails and results were compared with gamma spectrometry results for the same water samples measured in the Marinelli beaker.

Investigation of spatial distribution of natural radioactivity in soil using gamma-ray spectroscopy and its radiological implications

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Gamma-ray spectroscopy is one of the extensively utilized methods for the identification and quantification of naturally occurring radionuclides in soil, rocks and vegetables. High Purity Germanium (HPGe) detector-based gamma-ray spectroscopy was employed to determine the radioactivity, i.e. ^{226}Ra, ^{232}Th & ^{40}K in soil samples collected from Kumaun Himalaya, India. The activity concentrations of ^{226}Ra, ^{232}Th & ^{40}K were found to vary from 36.54 ± 8.1 to 91 ± 12 Bq kg^{-1}, 27.46 ± 6.70 to 89 ± 11Bq kg^{-1} and 1844 ± 245 to 2443 ± 285 Bq kg^{-1}, respectively. The spatial distributions of the observed radiological quantities are presented in the paper. The measured activity concentrations were used to estimate radiation hazards due to gamma-ray exposure in the investigated areas. No significant health risk was observed due to natural radioactivity in the soil in the area. The results of present study will serve as baseline representative values of natural radionuclides in the soil of the investigated region.

Validation of the method of gross alpha beta radioactivity measurement through international comparisons

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In accordance with the requirements of ISO 17025 for the accredited laboratory and following our efforts as are search institute and laboratory in particular, we have participated in international comparisons through the years 2021, 2022.

The most of the interlaboratory comparison were organized by IAEA Terrestrial Environmental Laboratory under suggestion of ALMERA members. Proficiency Test among environmental radioactivity monitoring laboratories for the determination of gross alpha/beta activity concentration in drinking water. Independent standard methods were used for the reference value determination. The performance of participating laboratories was evaluated with respect to the reference values using relative deviations. Sample preparation and measurement methods used by the participating laboratories are detailed, in particular in the view of method-dependency of the results. The results presented from our laboratory in the above mentioned inter comparisons were all acceptable.

In the year 2021 were in total 8 measurements of gross alpha beta activity in water samples all of them were A (acceptable).

In the year 2022 were in total 8 measurements of gross alpha beta activity in water samples, only one of results was W (warning) and the others A (acceptable). Participation periodically in these inter comparisons contributes to the continuous validation of the method and meantime the self-checking.

Keywords: gross alpha beta radioactivity, water sample, gas proportional counters

Natural radiation background assessment and determination in Tirana District, Albania

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Natural radioactive radiation or the natural background of radiation is the product of the presence in natural ecosystems of radioactive sources of various origins and in particular of Naturally Occurring Radioactive Materials (NORM). The level of natural background radiation varies geographically due to geological changes. Natural radiation is the main source of human exposure to ionizing radiation, where one of the contributors of natural sources of radiation is the radioactive gas radon which is present in atmospheric air and makes the largest contribution to public exposure. For this reason, the study presented in this paper is focused on the assessment and determination of the natural background in Tirana district. Institute of Applied Nuclear Physics with the support of the National Agency for Scientific Research and Innovation of the Ministry of Education and Sport conducted this study for the Natural Radiation Background Assessment and Determination in Tirana District. The average dose rate levels in Tirana district were 0.063 (μSv/h), maximum 0.195 (μSv/h) and minimum 0.013 (μSv/h).

Based on the average dose rate level the calculated annual dose received from the public is 0.183 mSv which is within the allowed dose limit of 1 mSv in a year. As result we can conclude that the dose received from various natural sources for Tirana district population does not constitute any risk on the health of the population and is within the dose limit for the population described in annex II of Regulation No.801 dt.11.12.2019 “On the protection of the public and professionally exposed employees to ionizing radiation.

Assessing ambient radiation: A comprehensive study of airborne natural radioactivity in Albania

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Our study's main objective is to measure and assess the natural radiation levels present in the air in the territory of the Republic of Albania. Institute of Applied Nuclear Physics set up six monitoring stations in different parts of the country to measure how much radiation is present each month and year, and to figure out the total yearly exposure to natural radioactivity in the air. The monitoring system employed for gamma radiation is the GMT-based Gamma Dose Rate Monitoring System. The research has shown that the average radiation level for Albania is about 1.61 μSv ± 0.010 μSv/h, and the yearly estimate is around 587 [KB2] μSv ±0.01 μSv/h. One interesting finding is that for three years in a row, Elbasan had the highest radiation reading, reaching up to 3,477 μSv. This number changed depending on the time of year, with the highest levels often happening during rainy days.

Application of electrolytic enrichment to minimize the detection limit in the case of low-level tritium activity measurement on LSC

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Tritium is a radionuclide, difficult to analyze because of its low beta energy (maximum 18.6 keV). Tritium beta particle has a range in the air of 6 mm, and this leads to difficulty of detection. Liquid Scintillation Counting (LSC) is the accurate technique to measure tritium in liquid samples. Considering the low-level activity of tritium in environmental water (drinking, surface, groundwater, precipitation), it is necessary to perform method which can increase tritium activity to be measurable at liquid scintillation counter and to reduce the minimum detectable activity (MDA). MDA is significant factor in radioactivity measurements providing higher sensitivity of counter. For that purpose, electrolytic enrichment of the water samples must be included when determining the tritium concentration.

Each electrolytic run contains 15 samples and one spike water. When electrolytic enrichment technique is applied, initial volume of each distillate sample is 250 ml. Reduction of the detection limit can be achieved by increasing the enrichment factor during electrolysis by reducing the initial volume of the samples 10-15 times. If system works at 5 A, it takes about 5 days, or 600-700 Ah. Enrichment factor for the given electrolytic cell represents the ratio between net count rate of the spike water enriched during spike run and the net count rate of the spike water before enrichment, after background subtraction. The calculation of the tritium enrichment factor includes enrichment parameter value, number of ampere-hours for the enrichment run, initial and the final volume of the sample, and the Faraday constant. For measurement on Liquid Scintillation Counter, the samples are mixed with the scintillation cocktail in ratio 8:12.

MDA, calculated for 13 electrolysis, conducted during one year (implying the same detection efficiency of 25.7 %, and the same measurement time of samples and background of 18000 s), decreases from 0.41 Bq/l to 0.26 Bq/l, as the enrichment factor increases from 7.99 and 11.98. Volume reduction was in the range 13-20 times (the final volumes of the samples in each electrolytic run are normalized at one value).

Keywords: electrolytic enrichment, LSC, tritium, MDA

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Surface dose analysis of different wound dressings for the IMRT head/neck phantom simulating the head and neck of patients receiving radiation dose with VMAT (Volumetric Modulated Arc Therapy)

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Wound dressings are currently widely used in the patients who have the skin reaction after receiving over three to four weeks to prevent more serious wounds. However, the presence of wound dressings on the treatment field may affect the superficial radiation dose. In this study two wound dressings were measured on the IMRT head/neck phantom when the dressings were placed with VMAT (Volumetric Modulated Arc Therapy) treatment planning.

The standard deviation of the Markus parallel plate ion chamber and EBT3 film in this experiment were all within 1%. The coefficient of variation of the calibration curve is R^2=0.9999 and 0.9916 for the Markus parallel plate ion chamber and EBT3 film, respectively. Compare AQUACEL® Ag+ Extra™ silver antibacterial hydrofiber dressing and DuoDERM® CGF® antibacterial hydrophilic dressing and measure the surface dose and the ratio of the surface dose(D_s) to the depth of 1 cm dose(D_{1cm}) in this study.

The relative dose ratio is shown in Table 1 and presented by added with and without the dressing at the left surface dose was 114.4% for Aquacel-Ag and 122.98% for DuoDerm, respectively. The relative dose ratio is also shown in Table 1 and presented by added with and without the dressing at the right surface dose were 109.74% for Aquacel-Ag and 149.04% for DuoDerm, respectively. In Table 2, D_s/D_{1cm} without the dressings was 84.28% at the left side and 83.23% at the right side, respectively. D_s/D_{1cm} with Aquacel-Ag was 84.53% at the left side and 82.59% at the right side, respectively. D_s/D_{1cm} with DuoDerm was 93.44% at the left side and 87.3% at the right side, respectively. The lack of impact on the deep dose can be observed with Aquacel-Ag, while DuoDerm shows an increase of 9.16% and 4.07% in the D_s/D_{1cm} dose ratio on the left and right sides, respectively.

The placement of dressings in the last few sessions maybe increases the surface dose in the clinical radiation therapy, but reduces the discomfort caused by the transition period when the wound is difficult to heal due to frequent dressing changes, in the last treatment period and it is still necessary to limit the skin dose to an acceptable range. Whether it is dressings of different brands or dressings of the same brand with different materials and thicknesses, measurements are required for comparison. In the future, we hope this data will be used as a reference and evaluate the skin reaction doses due to radiation therapy for the head and neck patients.

Keywords: wound dressing, VMAT, IMRT head/neck phantom

HVL and dose rate response of solid-state detectors in Mo/Mo and W/Al mammography fields

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Mammography reference radiation fields are defined in the IEC 61267 and IAEA TRS 457 standards only for both molybdenum anode and filtration (Mo/Mo) while clinically available mammography units can have different anode/filter combinations. The consequence of this discrepancy is significantly different spectra and a range of HVL between reference and clinical qualities. Considering that the diagnostic dosimeters can display pronounced energy dependence, it is important to test and calibrate them in radiation fields similar to the clinical fields in which they will be used.

Semiconductor X-ray multimeters (XMMs) are commonly used for routine quality control (QC) testing in mammography. Most detectors have individual software settings for different mammography radiation fields, but some anode/filter combinations might not be present, which imposes a problem for QC testing. Most multi-element detectors have Mo/Mo, Mo/Rh, W/Rh, W/Ag and W/Al as standard options while single element detectors may have only one option.

Four commercially available X-ray multimeters were tested in terms of dose rate response and HVL response for two reference mammography radiation quality series, standard Mo/Mo and non-standard W/Al, established in two SSDLs. All XMMs were tested using appropriate settings and inappropriate settings for both Mo/Mo and W/Al, to evaluate the effect of choosing the improper settings. In terms of the dose rate, multimeters had a good response with the correct settings, with deviation below 6 %, while some of the multimeters had a worse response when using the wrong settings, with the deviation up to 19 %. Two of the multimeters displayed a good dose rate response regardless of the chosen settings. Three of the tested XMMs can measure the HVL values, and these values were compared to the reference HVL values. The HVL values had a discrepancy of up to 11 % when using the correct settings, and up to 23 % otherwise. The results show that it is critical for many XMMs to limit their use only to the correct settings in clinical beams. It is recommended to determine HVL manually according to the existing protocols, when calculating the mean glandular dose (MGD), if the HVL measurements are not tested for the used anode/filter combination or if the correct XMM settings are not available.

Keywords: mammography, HVL, dose rate response, reference mammography fields, multimeters, solid-state detectors

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Advancing traceability in medical X-ray imaging dosimetry within the TraMeXI Project: Introduction of AutoSpectr Software for automated computation of X-ray spectra and their parameters

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X-ray imaging plays a vital role in modern medicine, serving both diagnostic and interventional purposes. However, it stands as primary source of artificial ionizing radiation exposure across Europe. Consequently, radiation exposure must be kept "as low as reasonably achievable", enabling safe and justified diagnostics. To ensure this, precise and consistent measurements of patient radiation exposure are of paramount importance, using traceable and calibrated dosimetry equipment. While current calibration procedures in metrology laboratories adhere to established standards and international protocols, they may not fully accommodate recent advancements in medical X-ray imaging technology. The 22NRM01 TraMeXI project aims to critically evaluate calibration conditions vis-a-vis clinical settings and assess the efficacy of various dosimeters used in clinics and calibration. During the initial phase of 22NRM01 TraMeXI project, comprehensive analyses of radiation conditions were conducted that are delivered from various modalities used in conventional radiography, fluoroscopy, mammography, computed tomography and dental radiography. This involved evaluating multiple parameters of X-ray sources encountered in clinical practice which were collected in a survey. Deterministic radiation transport simulation was employed to model comprehensively spectra resulting from clinically relevant combinations of anode materials, filtrations, X-ray tube voltages, and anode angles. These spectra were utilized to create a comprehensive map of radiation quality parameters. This mapping was facilitated by the SpekPy software package, which was used to develop the Python software AutoSpectr v1.0. This software enables the automatic computation of numerous spectra and storage of the complete sets of output radiation quality parameters that SpekPy can calculate as well as the squared signal-to-noise ratio per air kerma SNR_{in}^2. The primary objective of AutoSpectr program is to efficiently compute X-ray fluence spectra and their parameters for any combination of input parameters, treating them as elements in a multidimensional vector space. Input parameters include tube potential, anode angle, width of energy bin, lateral position and position in anode-cathode direction, focus-to-detector distance, exposure setting, anode material, as well as filtration material and thickness. Alongside spectra, the software stores output parameters such as air kerma, 1st and 2nd half-value layer (HVL_1 and HVL_2) for both Al and Cu, homogeneity coefficients, mean energy of the corresponding X-ray spectrum, total fluence, total energy fluence, and the squared signal-to-noise ratio per air kerma. The advantage of AutoSpectr v1.0 was demonstrated through the rapid and automated generation of more than 200 spectra for various modalities and clinical conditions, with corresponding output parameters automatically computed and saved in a structured output file.

Po-210 levels in imported selected seafood samples for consumers in Greece

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In this study, we aimed to assess the activity concentration levels of Po-210 in frozen imported seafood intended for consumption by the Greek population. Frozen imported fish products are popular among Greek consumers due to their lower cost compared to domestically sourced fresh alternatives, making a radioactivity study pertinent.

The predominant source of ingested radiation exposure for the general population stems from naturally occurring radionuclides. The analysis in this study is limited to Po-210, which is expected according to the literature to be the single largest contributor to dose from the diet.

Seafood serves as a significant pathway for the introduction of Po-210 into the human food chain, given its propensity for accumulation in marine organisms. This introduces potential health risks, as Po-210 is an alpha emitter and one of the most hazardous radionuclides.

This preliminary study evaluated the activity concentration levels of Po-210 in nine frozen imported seafood samples available to the Greek population from various vendors. Analysis was conducted on fish tissues, with heads and bones discarded. Concentrations ranged from the method detection limit to 1.53 Bq/kg (w.w.). Measurements were performed by means of a-spectrometry following radiochemical treatment based on a spontaneous deposition of polonium onto a nickel plate.

When comparing the results of these frozen seafood samples with fresh products available in Greece (not included in this study) or with fresh seafood globally, the observed activity concentrations were notably low. This may be attributed to Po-210 decay over time from capture to purchase.

However, it's crucial to note that we couldn't accurately estimate the actual intake of Po-210 from consuming these samples. This limitation stems from uncertainties regarding the sampling date, exact importation time, and duration on supermarket shelves.

Analysis of small closed cabins for whole body counter for background radiation shielding

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Whole body counters (WBC) are designed to measure the activity of radioactive materials incorporated into the body of a person, evaluating the quantity and type of radionuclides internalized and their biological distribution in the human body. The WBC can estimate uptake, retention, and excretion over time of gamma-emitting radionuclides with relatively long half-lives. The detection system must have a good detection efficiency, because for some radionuclides, activities as low as 50 Bq must be detected. For the same reason, the WBC counting chamber must be sufficiently shielded with lead or steel, maintaining minimum levels of background radiation. In this type of measurement, also called in vivo monitoring, background radiation is considered noise and makes it difficult to identify and quantify interactions with the detector arising directly from radionuclides internalized in the contaminated individual. The ORNL and Studsvik in vivo monitoring facilities are classic examples of laboratories with WBC shielded rooms. They have large shielded rooms: (3 x 3 x 3) m^3 and (2.5 x 3 m and 1.9) m^3 respectively. The background reduction is overwhelming, however the resources needed to build such structure are proportional to the shielding effect. This article highlights design aspects of a low background radiation Whole Body Counter (WBC) installation, addressing the use of closed cabinets of reduced volume to attenuate environmental radiation, replacing large iron or lead shielded rooms. The justification lies in the portability and economic feasibility of WBC laboratories, allowing the service of monitoring internal radiological contamination with quality. Comparative analyses evaluate the reduction of background radiation and additional scattered radiation induced in a central detector, including human phantom with internal contamination. Configurations of cylindrical and rectangular cabins and armored room, made of iron, are investigated. The findings show a significant reduction in background environmental radiation in the three types of environments. Enclosed cabins are 10 times more efficient at reducing background radiation than partially fan-shielded beds. A 2-floor build assists in a 50x reduction in background radiation, and enclosed armored cabins reduce background radiation by 2000x. The presence of radiation induced by the cabins is also observed in counts of human phantom contaminated with radionuclides emitting photons of energy higher than the threshold of the disintegration reactions in the constituent material. Mitigating measures, such as internal lead covering, proximity of the detector to the patient by centering on the limited volume, are analyzed. It is concluded that small volume cabins for CCI laboratories are viable structures for in vivo monitoring laboratories.

Keywords: shielding cabins, internal contamination, environment radiation, iron room

Computational and experimental estimation of the calibration coefficient of an *in vivo* counter for ^{18}F-FDG brain activity

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^{18}F-FDG is a widely used PET radiopharmaceutical worldwide, and its demand has increased in the last decade. This increase in demand has led to a higher number of workers involved in its production and clinical use, which in turn increases the risk of internal contamination. Computer modeling has been effective in evaluating and optimizing *in vivo* monitoring systems. Fourteen anthropomorphic computational phantoms, including ICRP voxelized reference adult phantoms and a baby and child phantom, were used in this study to compute calibration coefficients (CC) and explore their fluctuations. Computer simulations were performed using MCNPx to assess the effect of head-detector distance (HDD) variation on the CC value. The detector was positioned at 0 cm (HDD_0), 10 cm (HDD_{10}), 50 cm (HDD_{50}), and 100 cm (HDD_{100}) from the head to evaluate HDD's influence on the CC calculations. A calibration coefficient for *in vivo* monitoring counter for ^{18}F-FDG in the brain was determined using a real plastic head simulator (AM_SiCab) filled with a positron emitter solution ($^{22}Na/H_2O$). The same procedure was repeated with three other physical phantoms whose brain volume was filled with ^{18}F-FDG, whose one of them represents a 32-weeks baby (Baby32w), other a 3D-printed head of RCP_AM of ICRP (CaAM_ABS) and a plastic adult male head (SiCab). A 3"x3" NaI(Tl) scintillator detector was positioned on the HDD_0 at the top of the head simulator. The computational results indicate that as the detector moved away from the head, the percentage difference between the minimum and maximum calibration coefficient ($DCC_{Min\text{-}Max}$) and the relative error (RE) decreased from -38.1% and 12.4% (HDD_0) to -21.0% and 5.9% (HDD_{100}), respectively, for twelve adult phantoms. However, this decrease in calibration coefficient and relative error was accompanied by a decrease in detection efficiency. Additionally, the CC for HDD_0 was approximately 100 times lower than for HDD_{100}. *In vivo* monitoring of internal contamination aims to detect even negligible incorporated activity. Therefore, it is recommended to use the counting geometry with better efficiency (HDD_0). The $DCC_{Min\text{-}Max}$ and RE values for HDD_{50} were practically the same as for HDD_{100}. The experimental results for HDD_0 using physical phantoms AM_SiCab, ^{18}F-SiCab, CaAM_ABS, and Baby32w showed a mean CC value of 69.3, 38.5, 55.9, and 18.6 $Bq.CPS^{-1}$, respectively. The difference between RCP_AM and AM_SiCab was 19%, while the difference for CaAM_ABS was 5%. Baby32w and computational Baby8w differed by 5%. The discrepancies between computational and physical phantoms can be attributed to differences in morphology, elemental composition, and geometry. This study shows that computational phantom sets can offer valuable insights into the sources of uncertainty in *in vivo* monitoring systems and the factors that affect the determination of incorporated activity for specific counting geometries.

Development of a device for the determination of neutron source emission rate based on the manganese bath technique in the Slovak Institute of Metrology

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Slovak Institute of Metrology (SMU) as a National Metrology Institute in Slovakia received funding from Slovak Research and Development Agency for developing a manganese bath under the project No.: APVV-21-0170 in 2022. The project's main contribution is the construction of a primary standard of dosimetric quantities for neutron radiation, which will ensure the realization of the emission rate unit at the highest metrology level and at the same time it will be possible, by other device, measure another quantity, resp. anisotropy also at a sufficient metrological level. In this way, the existing measurement system in Slovakia will be expanded and the need to have traceability to standards of higher orders abroad will be eliminated. Realization of manganese activation through the reaction $^{55}Mn(n,\gamma)^{56}Mn$ in a bath and more accurate calculation of neutron capture efficiency on manganese atomic nuclei was modeled using Monte Carlo transport codes such as MCNP and SCALE 6. By using these transport codes, it is possible to investigate and evaluate the consequences of geometric and material composition or other changes in the model even before they are implemented. Technical completion, initial tests of the manganese bath, and close cooperation with colleagues from the academic field INPE FEI STU contributed to obtain reasonable results. Obtaining information about neutron source emission rate at a sufficient metrological level and implementing this methodology through the development of work procedures at the SMU are the main goals of the still ongoing project.

Introduction of automatic calibration system development for KOMAC

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Radiation monitoring is routinely performed at nuclear utilization facilities, regardless of whether the facility's scale is large or not. For radiation monitoring, portable devices or facility-fixed radiation measurement devices which are fixedly installed at a facility's wall to monitor the radiation dose rate constantly are used. These devices must be calibrated at regular intervals determined by relevant laws and regulations to check their soundness. We have 100 MeV proton accelerator and 10 numbers small accelerators. Within the facility where is operated the 100 MeV proton accelerator, approximately 100 fixedly installed radiation measuring devices are in operation, and their performance is checked through the calibration every year. Within the facility that operates the 100 MeV proton accelerator, approximately 100 fixedly installed radiation measuring devices are in operation, and their performance is checked through the calibration every year.

The process of calibration is very tedious and requires repeating simple tasks. Also, during this process, there are elements that can cause human error. In this paper, we reviewed the overall calibration process for Korea Multi-purpose Accelerator Center (KOMAC) and introduce an automated system self-developed.

Determination of ambient individual exposure dose rate in the Chau Thoi Mountain, southern Vietnam, using a NaI(Tl) detector

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This study investigates the ambient individual exposure dose rates in Chau Thoi Mountain, southern Vietnam, employing a 3-inch x inch NaI(Tl) scintillation detector. The NaI(Tl) detector's deposited energy spectra were recorded. Utilizing a G-factor conversion, we transformed the count rate from the measured energy spectrum to a dose-rate spectrum. This process enabled the determination of both the total and individual dose rates. Specifically, this research focused on measuring individual exposure dose rates for energies of 238.6 keV (Pb-212/Th-232), 352 keV (Pb-214/U-238), 583 keV (Tl-208/Th-232), 609 keV (Bi-214/U-238), 1,461 keV (K-40), and 2,614 keV (Tl-206/Th-232). Measurements were conducted across 18 locations on Chau Thoi Mountain.

Geochemical aspect of Caapucu Height at Southeastern Paraguay by X-ray fluorescence and neutron activation analysis

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The Precambrian is present mainly in two areas in the north and in the south of eastern Paraguay; in the north Apa high, and in the south Caapucu. The latter is constituted by Rio Tebicuary complex; to the north of the Rio Tebicuary is exposed the Caapucu outcrops. More recently, geochemical studies were performed in the Precambrian plug of Fuerte San Carlos, near the Apa River providing analytical data in this regard. In this work hand specimen of granitoid rocks from the southern Precambrian outcrops are studied in some of their major, minor and trace elements aiming to look for relationships with the northern outcrops and their provenance as well as the granitoid type. The analyzed elements were Na, Al, Si, K, Ca, Ti, Mn, Fe, Cu, Zn, Ga, Pb, Rb, Sr, Th, Y, Zr, Nb, Ba, La, Ce, Pr, Nd. Analyses were carried out by EDXRF except for sodium that was analyzed by Neutron Activation. The XRF experiments were carried out using radioisotopic sources of Fe-55, Cd 109 and Am 241 in the Josef Stefan Institute at Ljubljana, whereas NAA was done with an Am- Be neutron source with a flux of 5 x10 ^{7} s^{-1} in the Facultad de Química (UNA) at San Lorenzo, Paraguay. The results of analysis allow to establish *inter alia* indexes, ratios which are related with crystallization, granitoid type etc. The spidergrams standardized to primordial mantle of refractory elements content, show an enrichment of incompatible elements in the samples. Besides, they resemble to those found in Precambrian outcrops from the northern area (eastern and western Paraguay) as well as from Brazil; the latter from Neoproterozoic.

Determination of the content of ^{93}Zr and ^{93}Mo in NPPs radioactive materials

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One of the current tasks related to the operation of nuclear power plants (NPPs) is the assessment of the activities of the radioactive long-lived radionuclides that decay without emitting of γ-rays. Among such radionuclides are the nuclei of ^{93}Mo, which are formed in (n,γ)-reactions on molybdenum isotopes. Activation of the reactor vessel may also lead to the formation of ^{93}Zr, which decays into ^{93m}Nb. The decay of all these radionuclides is accompanied by the emission of electrons and characteristic radiation. As a result, determining their activity in NPP radioactive materials is extremely expensive and time-consuming in the case of radiochemical methods due to the huge mass of NPP radioactive materials.

Based on the above, the purpose of this work is to develop a methodology for determining of the ^{93}Zr and ^{93}Mo activities, by comparing the activity of long-lived radionuclide that emits γ-rays and is present in irradiated structural materials simultaneously with radionuclides that decay without emitting gamma rays. This reference radionuclide is ^{60}Co, which has a half-live of 5.27 years.

To create the methods, the samples of metals and sorbents were irradiated by bremsstrahlung end-point energy of 18.5 MeV at the M-30 accelerator of the Institute of Electron Physics of National Academy of Sciences of Ukraine (Uzhhorod). The induced activity was measured by γ-spectrometers based on HPGe-detectors.

The flux-weighted average yields of the ^{100}Mo(γ,n)^{99}Mo and ^{59}Co(γ,n)^{58}Co reactions were determined, using experimental data from other authors to develop the method for ^{93}Mo. Then the ratio of ^{93}Mo and ^{60}Co activities was determined. From these data, using the natural ratio between isotopes of ^{92}Mo and ^{100}Mo it was determined that the activity of ^{93}Mo in metals is approximately 100-150±20-30 mBq/g.

To develop the method for ^{93}Zr, the flux-weighted average yield of the reaction ^{90}Zr(γ,n)^{89}Zr and the natural ratio between isotopes ^{90}Zr and ^{92}Zr were used. It was found that the activity of ^{93}Zr in the sorbent is about 6±2 nBq/g.

At present, new materials for NPPs have been developed, where the concentration of molybdenum reaches 7.5%. It can be easily estimated that with prolonged operation, the activity of ^{93}Mo, even not directly in the zone of high neutron flux, will reach 100-200 Bq/g. This activity is already higher than the release level for metals and indicates that monitoring of ^{93}Mo activity is mandatory. Despite the very low activity of ^{93}Zr, it should also be monitored, as Zr is used in the reactor's active zone, where its concentration reaches 100%, and the neutron flux is higher by 5-6 orders of magnitude than in structural materials outside the reactor's active zone.

The developed photoactivation methods for determining of the activities of ^{93}Zr and ^{93}Mo significantly simplify their identification, control, and documentation in the structural materials of NPPs and various types of radioactive waste.

On the issue of taking into account the physical characteristics of radiation sources used in combined radiation technologies for sterilization of bone implants

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An analysis of current trends in the development of sterilization technologies for biological objects and medical devices indicates a significant proportion of radiation methods, which make up about 45% of the volume of services provided [Silindir, M. and Özer, A.Y., FABAD // J. Pharm. Sci. – 2009, vol. 34, p. 43]. In this sector of scientific and practical work, gamma-ray sterilization plays a major role. However, advances in accelerator technology provide a strong foundation for using accelerated electron fluxes, which rival X-ray radiation in solving specific tasks, each with its own advantages and limitations. At the same time, gamma rays offer higher penetrating power and uniformity compared to accelerated electrons, but require constant high protection and expensive stationary equipment. Taking into account the mentioned aspects, X-ray exposure falls in between the options listed above. Such a priori conclusions are fully confirmed qualitatively and quantitatively by the results of a number of model calculations. The corresponding study was performed using the GEANT-4 software package [Allison, J. Geant-4. Developments and Applications // IEEE Trans. Nucl. Sci. – 2006. – vol. 53. – no. 1. – p. 270-278]. In the studied physical model, real parameters used in the experimental approbation of the technology of combined radiation sterilization of bone implants at the electron accelerator at the Moscow State University Research Institute of Nuclear Physics were implemented in the construction of computational schemes [Alimov A.S., Bliznyuk U.A., Borchegovskaya P.U. et al. Using accelerated electron beams for the radiation processing of foodstuffs and biomaterials // Bulletin of the Russian Academy of Sciences: Physics. – 2017. – vol. 81. – no. 6. – p. 743-747]. During the calculations, the effects were consistently analyzed when considering various radiation sources – gamma quanta, accelerated electrons, and X-rays. At the same time, the radiation energy, the geometry of the effect varied, and the spatial distribution of the absorbed dose was calculated. Based on the obtained distributions, recommendations for optimizing the conditions and parameters of radiation exposure to the bone fragment are formulated. Their practical implementation makes it possible to achieve a more uniform spatial distribution of the absorbed dose, a uniform volumetric effect of the applied radiation on the treated fragment and, consequently, an increase in the efficiency of sterilization of bone samples. The conclusion is made about the relevance of further studies of X-ray radiation due to the prospects of its use as a technology of choice for specific applications of radiation technologies for sterilization of bone implants.

Algorithm for reconstruction of electron accelerator beam energy spectrum for high-precision dosimetric planning of radiation treatment

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Successful radiation treatment requires not only delivering a strictly defined dose D to the object but also ensuring high treatment uniformity. Treatment uniformity is defined as $K = Dmin / Dmax$, where *Dmin* and *Dmax* are the minimum and maximum doses in the object's volume, respectively.

The dose is determined unambiguously by the amount of radiation delivered to the object and can be easily measured in practice (for example, using dosimetric films or alanine dosimetry).

The homogeneity of treatment depends on several factors, including the type of radiation, the shape of the object, and the energy spectrum of the beam. While the first two factors are easily taken into account during planning, the exact energy spectrum of the beam is typically unknown and cannot be measured in practice. Replacing the exact spectrum with the 'effective energy' can lead to an error in treatment uniformity estimation of up to 20%.

This paper proposes a method for recovering the energy spectrum of an electron accelerator beam from the experimentally measured depth dose distribution produced by the beam. To implement the algorithm, we pre-calculated the depth distributions of absorbed dose in different reference materials during irradiation with monoenergetic beams of accelerated electrons with energies ranging from 100 keV to 20 MeV, with a step of 100 keV, using the *Geant4* software code. The algorithm selects a weighted combination of dose distributions in reference materials from monoenergetic electrons based on the available experimentally measured dose distribution. This combination is chosen to be as close as possible to the experimentally measured one.

To verify the algorithm, experimental measurements of the depth distributions of absorbed dose were performed using a *Varian TrueBeam* medical electron accelerator operating in the 6 MeV and 9 MeV modes. The study compared the reconstructed spectra from two materials: solid water and aluminium.

The reconstructed spectra from the data of each reference material showed agreement, with a discrepancy of no more than 5%.

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Design of a system for the production of radiopharmaceuticals sodium iodide (^{131}I) capsules

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Sodium iodide (^{131}I) capsules (^{131}I-capsules) are a radiopharmaceutical that has been produced for more than forty years in the Laboratory for Radioisotopes of the Vinča Institute of Nuclear Sciences, Belgrade, Serbia. ^{131}I-capsules are used in the treatment of thyroid tumors and hyperthyroidism. For the effective therapy, but at the same time in order to reduce exposure to unnecessary doses, the appropriate activity of ^{131}I is determined for each patient in the so-called personalized therapy.

Radiopharmaceutical manufacturers produce large batches of ^{131}I-capsules of the same activity and do not have the operational flexibility of smaller radiochemical laboratories that are able to manually prepare therapeutic ^{131}I-capsules of any activity. The pouring of the determined initial ^{131}I solution into the gelatin capsules is done manually, wearing protective gloves, in a hot cell with lead bricks, in such a way that, depending on the radioactive concentration of the ^{131}I initial solution, the volume of the ^{131}I-solution is determined, which is applied by syringe into the inert filler in a hard gelatin capsule. In case of applying the wrong activity to the capsule, the necessary amount of initial solution is subsequently added to it in order to correct the activity, thereby extending the operator's exposure time to radiation. The activity of the ^{131}I initial solution, from which transferring into the capsules is carried out, is often more than 200 GBq, so that the doses that the operators receive on their hands, although significantly less than the permitted ones, are large. The cumulative equivalent dose for the year 2022. for the extremities of operators working in the production of ^{131}I capsules is from 32.25 to 83.31 mSv.

The aim of this study is the automation of the production of ^{131}I-capsules that would significantly reduce the radiation dose of the operator and the environment, and at the same time to ensure reliable and more accurate production. This would enable patients to receive the optimal dose of radiopharmaceuticals adapted to their needs at appropriate time intervals while the greatest contribution would be radiation protection of operators involved in the production of ^{131}I-capsules because the dose received in the production process would be significantly reduced.

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A study of the characterization potential of microplastics embedded in soil applying 3D X-ray microtomography

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Microplastic (MP) was detected in the first time approximately fifty years, but only in the recent decades, it emerged as a prominent problem on the global environmental agenda. Given the relatively new research on this problem, numerous issues still need be answered. Among these, the relationship between the origin, shape and size of MPs and their behavior in environment. Despite all efforts spent, scant is known about the individual characteristic of this fragments and their behavior in environment. Part of this problem is related to the difficulty of accurately detecting and characterization of these microparticles in media. To overcome these difficulties, our study aims to use X-ray microtomography (microCT) as a valuable tool. This technique provides the opportunity to comprehend the structure of individual particles in a non-destructive way, allowing observing the same individual particle into media. In the context of this study, analysis was conducted on five distinct MP samples of varying sizes. Table 1 delineate the characteristics of the samples categorized according to the particle size, as through sieving separation, with a consideration of a theoretical value of 1.38 g/cm3. The definition of density value was based on the prevalent material fragment being Polyethylene Terephthalate (PET).

For the quantitative analysis, a cylindrical region of interest of about 10 mm in diameter to 22 mm height was delineated. In terms of pixel matrix, it corresponds 1833 slices, each with dimensions of 900 x 900 pixels.

In this methodology, the capability to detect between 80% and 95% of total MP volume within samples was realized. MicroCT facilitated particle number counting, providing a quantitative measure of total particles, in this study was detected more than 10,000 isolated particles in phantom 0.18 mm.

At present, in this study, microCT has quantified the volume of plastic in sample, providing insights about spatial distribution depth-dependent. Was characterized individual particles based on morphometric parameters to describe their shape. Consequently, our results indicate microCT has capacity to open new avenues of research on MPs in soil.

TOP-IMPLART accelerator: Development toward a user facility

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TOP-IMPLART (Terapia Oncologica con Protoni- Intensity Modulated Proton Linear Accelerator for RadioTherapy) is an RF pulsed linear accelerator developed at the ENEA Frascati Research Center for medical applications, consisting of a 425 MHz, 7 MeV injector, followed by eight 3 GHz SCDTL (Side Coupled Drift Tube Linac) accelerating modules. Proton beam can be accelerated at 63 MeV or 71 MeV (other energy values can be achieved by suitable degraders) in 2.5 μs pulses with a typical repetition rate of 25 Hz and a maximum pulse current of 30 μA.

The accelerator is provided with two beam extraction lines: a low-energy (1-6 MeV) vertical line placed at the exit of the injector using a 90 degrees magnet mainly applied to radiobiology “in vitro” experiments and testing of innovative dosimeters and a high energy horizontal delivery line placed at the output of the linac employing a magnetic scanning system able to accommodate the requirements of different targets.

The accelerator, originally designed as first prototype of a protontherapy system based on a “full linear” layout, promoted the development of engineered versions based on this innovative scheme. Presently, due to the growing interest for a proton beam with the characteristics of TOP-IMPLART in different fields of applications, a strong effort is addressed to evolve the prototype towards a facility available for research and industrial users.

The paper describes the setup, the tools employed to monitor the parameters of interest (dose, fluence, flux) and the experimental results of the beam characterization measurements. An overview of the different applications of the facility is also presented ranging from the bio-medical field including radiobiology studies for the investigation of FLASH therapy mechanism up to the aerospace sector for studying the effects of radiation exposure on biological systems and electronic components.

Cross-section induced uncertainties for manganese sulphate bath technique

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The analysis presented in the paper is focused on the characterization of uncertainties induced by cross-section data in the correction factor calculation for the manganese sulphate bath technique. The manganese sulphate bath is the most common technique used for the determination of neutron source emission rate and is deployed in many metrology institutes around the world. Advances in computational methods and computational power with the improvement of the nuclear data libraries including more information about the cross-section data covariances provide opportunity for full characterization of the contribution of the calculations to the final value and its uncertainty. In this paper, the super-sequence SAMPLER module that implements stochastic techniques is used to assess the uncertainties in computed results. Reaction rates on all nuclides of the manganese solution are computed in 200 cases for several solution concentrations. The results are evaluated by an auxiliary tool. Consideration of nuclear data uncertainty in calculations is a general trend that requires the attention of nuclear researchers and should draw attention in metrology. Additional 1.5 % (one-sigma) uncertainty can be introduced to the overall uncertainty through calculation of the correction factor in according to used nuclear data library and computational system.

Moss biomonitoring of radionuclides

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Samples of naturally growing moss (mainly *Hylocomium Splendense* and *Hypnum cupressiforme*) are widely used for biomonitoring trace elements (https://icpvegetation.ceh.ac.uk/) and much less for tracing gamma-emitting radionuclides, notably ^{129}I, ^{137}Cs, ^{144}Ce, and ^{241}Am. The first attempts to use moss for accessing areas affected by radioactive contamination were undertaken after the nuclear plant accidents on September 29, 1957 at the "Mayak" in the Urals, Russia (then in the USSR) [*Ecology*, No. 3, p. 1998, 196-200, (in Russian)] and in October 8, 1957 at Sellafield in West Cumbria, United Kingdom [DOI:10.1016/0048-9697(84)90007-x]. Mosses were successfully used in 2006-2009 to trace radioactive contamination with ^{137}Cs and ^{210}Pb after most serious of accidents happened in Chernobyl, Ukraine (then in the USSR), on April 26, 1986 [dx.doi.org/10.1016/j.jenvrad.2012.01.018]. Our experience in examination of mosses as biomonitors of radionuclides is demonstrated [www1.jinr.ru/Books/Books_rus.html]. The potential and limitations of moss analysis for studying atmospheric radionuclide deposition are discussed.

Quantitative study of the effect of fertilizers on radioactive content of soil from agricultural lands of Russia

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Terrestrial radionuclides are naturally present in the soil and their extent determine the radioactive level of the soil. The present study aims to quantify the effect of fertilizers on the radioactive content of the soil samples. For this, soil samples collected from the agriculture fields were treated with different fertilizer: Superphosphate ($Ca(H_2PO_4)\cdot 2H_2O$, SP.), ammonium nitrate (NH_4NO_3, AN), potassium chloride (KCl), potassium nitrate (KNO_3), and potassium sulfate (K_2SO_4). The concentration in soil samples varied from 272 to 429 Bq/kg for ^{40}K, 0.08 to 0.16 Bq/kg for ^{137}Cs, 13.79 to 23.41 Bq/kg for ^{226}Ra, 16.37 to 29.24 Bq/kg for ^{232}Th and 1.06 to 1.39 Bq/kg for ^{235}U. The concentration of ^{40}K, ^{137}Cs, ^{226}Ra, ^{232}Th and ^{235}U in the control soil sample was 381 Bq/kg, 2.88 Bq/kg, 19.95 Bq/kg, 24.53 Bq/kg and 1.18 Bq/kg. In the soil samples with K_2SO_4, the concentration of radionuclides was highest and the increase was 13 to 19% as compared to the control soil sample.

Anthropogenic contaminants in glaciers from the Northern Hemisphere

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Fallout radionuclides, and especially Pu have been mainly released into the environment through human nuclear activities, such as nuclear weapon tests, nuclear fuel reprocessing and nuclear power plant accidents. Recent research on the accumulation of anthropogenic contaminants on the surface of glaciers has highlighted a need for a renewed focus on the environmental quality of glacier-fed catchments. Glaciers act as temporary repositories for natural and anthropogenic atmospherically transported substances. This includes contaminants such as toxic metals, persistent organic pollutants (POPs), fallout radionuclides (FRNs), and black carbon. Some of these contaminants have been shown to pose a threat to ecosystem health, for example, FRNs, which have now been reported in multiple regions of the mountain cryosphere including Svalbard, Scandinavia, the Alps and Alaska. Mercury (Hg) is another contaminant of concern as it can be found in higher trophic levels of the food web. Arctic rivers are a significant Hg source to ocean waters, posing potential health risks for communities relying on marine fauna as a food source. Mountain glacier regions including the Tibetan Plateau and Alaska have also been identified as sources of Hg to downstream ecosystems, highlighting a need for an improved understanding of Hg biogeochemical cycling and bioavailability.

Contaminants are effectively trapped in cryoconite granules for long periods due to the “sticky” nature of the material. In addition to cryoconite and other biological communities like glacier mice (colonies of mosses found on some glaciers) are trapped anthropogenic contaminants. All of these components reduce albedo worldwide and can thus be useful in monitoring radionuclide deposition on glaciers. We show that FRNs (^{137}Cs, Pu isotopes) and Hg are not only found in cryoconite on glaciers within close proximity to specific sources of contamination, but across the Northern Hemisphere, and at activity concentrations up to three orders of magnitude higher than those found in soils and sediments in the surrounding environment.

The history of anthropogenic contamination in glacial environments can be reconstructed through modern and professional analysis. Glaciers are open systems and materials preserved within their ice and snow will eventually be released into the downstream environment, including legacy contaminants first emitted to the atmosphere decades ago.

The concentrations of dissolved $^{234,238}U$ isotopes in rainwater collected in Silesia Voivodeship in Poland

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Upper Silesia is one of the most urbanized and industrialized regions of Poland. During smog episodes, high values of particulate matter in the air were recorded. The finest fraction of particles suspended in the air may contain heavy metals and radioactive elements. Combustion of coal and industrial processing may contribute to the emissions of uranium into the air and may increase the effective doses caused by inhalation of airborne uranium particles. Uranium is a heavy metal whose negative impact on the human body is related to its chemical and radiological toxicity. ^{238}U is the parent isotope of the uranium-radium series. In this decay series, a second uranium ^{234}U isotope is present. Uranium isotopes are widely used as environmental traces. Thus, long-term observations of uranium and the $^{234}U/^{238}U$ activity ratio may allow a better understanding of the sources of airborne uranium particles.

Rain samples were collected in semi-monthly or monthly periods, depending on the amount of rainwater, using an open stainless-steel tray with an area of 1.6 m^2. The sampling station was located in the Silesia Voivodship in southern Poland. After rainfall, water was acidified, filtered and evaporated. Then, samples were subjected to chemical preparation. Uranium was separated from other alpha emitters using the ion exchange chromatography. The alpha spectrometry source, suitable for alpha counting, was produced from uranium fraction by coprecipitation with NdF_3 and filtration on a polypropylene filter. The samples' measurements were performed using the alpha spectrometers 7401VR and the Alpha Analyst™ equipped with semiconductor detectors. Samples were measured from a few days to 2 weeks. The results of uranium dissolved in rainwater covering seven years will be presented. Based on the measured $^{234,238}U$ concentrations, the $^{234}U/^{238}U$ activity ratio will be calculated. The seasonal variation of uranium content and $^{234}U/^{238}U$ activity ratio will be discussed. The obtained results allow a better understanding of the sources of U in the air.

A remarkable very small-scale natural radiation anomaly in Poços de Caldas, Brazil

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Natural radiological anomalies occur in nature as results of geological and geochemical variability. They can indicate mineral resources but can also represent a hazard. In this contribution, we report results of the radiometric investigation of a small but intense radiation anomaly that was detected in the course of a regional survey of ambient dose rate in the outskirts of the city of Poços Caldas, Minas Gerais, Brazil and discuss its radiological significance. The anomaly, located on the side of a gravel road, is a few meters large and boasts dose rate up to 5 μSv/h above the local background values, typically 0.2 μSv/h.

As part of a workshop organized by the International Atomic Energy Agency (IAEA), a field measurement exercise was performed at the location, aimed at training for participants and at acquiring more data about the anomaly. Methods used were (a) ambient dose measurement with a back bag scintillation detector and a bGeigie Nano monitor based on a Geiger Müller counter, both coupled to GPS to allow radiation mapping; in addition, the bGeigie Nano was mounted on a drone and airborne measurement was performed; (b) radon concentration in soil and ground permeability was measured; (c) geological samples were collected and analyzed in the laboratory by gamma spectrometry and x-ray fluorescence; and (d) a visual geological assessment was carried out.

The overall result shows that most likely the spot is characterized by an intrusion of uranium bearing zirconite within an otherwise radiologically unsuspecting arenite (sedimentary) rock. The extension of the anomaly could be delineated to be less than about 5 m, with local soil radon concentration in the order of some MBq/m³.

We report the data of the detailed evaluation and show maps of the anomaly. The usability of drone-borne measurement for the purpose is addressed, and in particular the appropriateness of the bGeigie Nano (as representative for monitors of similar kind). We also discuss possible consequences of such findings regarding radioprotection and their suitability for training under field conditions.

Stream sediments exploration for natural radioactivity and ^{238}U, ^{233}Th, ^{40}K bearing minerals. Case study: upper Arges River basin, Romania

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The study provides an overview of the ^{238}U ^{232}Th, and ^{40}K potential of alluvial sediments in an area with geological context favorable to accumulations of this isotopes, contributing to improve information on the mineralogy of natural radionuclides and geochemical processes of preferential enrichment at the individual level, as well as to environmental risk assessment.

The Argeş River is a tributary of the Danube with a catchment area of 12.550 km^2, that flows from the central-western part of the main ridge of the Făgăraş Mountains. In the upper basin, the Argeş River cuts across basement formations represented by metamorphic rocks (schist, gneisses, quartzite, marble, mica-schist's) associated with granite and granitoid massifs, followed by carbonate rocks and, post-tectonic Cenozoic formations (clays, marls, sands, with intercalations of lignite seams). Quaternary is composed of gravels, marls, sands or clays, representing tailings cones or proluvial / eluvial deposits or actual terraces of major tributaries.

The specific activity of ^{238}U, ^{232}Th and ^{40}K in 56 stream sediment samples collected from upper Arges River hydrographic network has been determined by low background gamma-ray spectroscopy using HPGe detector connected with a MCA (ORTEC). The radiological risk was quantified using various indices such as Radium equivalent activity, absorbed dose rate, gamma representative level index, and external and internal hazard indices. The mineral contents of stream samples were examined using Scanning Electron Microscope (SEM) equipped with Energy Dispersive X-Ray Spectrum (EDX).

Thorium levels range from 11 to 111 ppm, with an average of 34.21 ppm, and uranium from 5 to 25 ppm, with an average of 9.33 ppm. Potassium has an average concentration of 456 ppm and ranges from 214 to 815 ppm. The disequilibrium conditions in the majority of the stream sediments under investigation suggest that they are recent. The Th/U ratios of the sediments vary significantly (1.12 and 6.25). The presence of radioactive minerals such as thorite, zircon, xenotime, monazite, or uranium mobilization (as UO_2^{2+} and/or complexes) in connection to Th could be the reason of the high Th/U ratio of the examined sediments. ^{40}K is associated with feldspar mineral series, feldspathoids and micas. The spatial distribution of the natural radionuclides indicates the highest uranium levels in area with occurrence of gravels, marls, sands and clays in middle zone of the Argeş River. Thorium has maximal concentration in northern aria where occurs metamorphic rocks and, potassium has a uniform distribution in the study area. This is attributed to the mountainous terrain causing the natural migration of radionuclides due to vertical climatic zonation. The rock particles move, retaining their native characteristics, and clastic material is displaced into valleys and depressions. All radiological hazard parameters calculated show averages comparable with median values provided by UNSCEAR.

Radiosensitivity of bread wheat varieties treated with physical mutagens cultivated in Albania

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Induced mutagenesis is one of the most used techniques to improve the quality of agricultural products. The use of X-rays is one of the ways to process plant materials to improve their properties. One of the main problems of induced mutagenesis is the assessment of treatment doses interval of biological materials for their processing. Calculation of radio-sensitivity is the first step in induced mutagenesis to improve the traits of different varieties. Our study is based on the selection of four varieties of winter bread wheat cultivated in Albania. We have selected four varieties of bread wheat; DAJTI, UBT-1, UBT-2 and KIA-1. Irradiation of bread wheat seeds was carried out with X-rays generated by the RS-2400Q irradiation unit for the evaluation of radio-sensitivity tests, at the Institute of Applied Nuclear Physics in Tirana. In the Induced Mutagenesis Laboratory of the Department of Biotechnology the seeds of the four varieties were tested for their germination ability in Petri dishes before radiation treatment. Seeds of four bread wheat varieties were placed in a 60% glycerol desiccator for 4–5 days to obtain a standard moisture content of 12–14%. Referring to IAEA protocols and different publications, we chose for irradiation six X-rays doses of 50, 100, 150, 200, 300 and 400 Gy. The quantity of seeds for each treatment was the same and five days after seed irradiation, the biological material was planted in greenhouse pots. Seeds treated with 6 doses of radiation and the control were planted in three replicates each. The seeds planted in the greenhouse were watered every two days. The percentage of seed germination was assessed by counting the number of seedlings 7, 14 and 21 days after sowing. Survival percentages were assessed by counting viable plants 30 days after sowing. In each pot, the good plants were counted, their germination and growth phases were carefully observed and photographed. Plant height and root length were measured after 30 days. To obtain an effective and useful mutation with high probability, a growth reducing dose (GR50) and a lethal dose (LD50) were used in the radio-sensitivity test. The radio-sensitivity of bread wheat was calculated from observations and measurement results. The high radiation doses of 300 Gy and 400 Gy for X-rays, caused significant damage to the seeds of bread wheat DAJTI, UBT-1, UBT-2 and KIA-1 varieties. The Albin plants were observed in pots with seeds irradiated with 200 Gy, which significantly reduced the number of surviving plants. In the plants of DAJTI, UBT-1, UBT-2 which belonged to the irradiation dose of 200 Gy, the number of plants that survived after 30 days was not more than 9 to 12 developed plants. The KIA-1 variety was less resistant and at the dose of 200 Gy, more than 75% of the plants were lost. Following the radio-sensitivity test, the three most appropriate doses to irradiate the seeds of these bread wheat varieties of were 50, 100 and 150 Gy for the experimental field.

Keywords: X-rays, radio-sensitivity test, radiation, bread wheat

Natural radioactivity in raw material and waste from coal-fired power plant Kakanj, Bosnia and Herzegovina

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The study observed the levels of natural radionuclides (^{238}U, ^{235}U, ^{232}Th, ^{226}Ra and ^{40}K) in samples of coal, fly ash, slag and waste materials used and produced in coal burning power plant Kakanj, Bosnia and Herzegovina.

The activity concentrations of ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra and ^{40}K in used coals were in ranges 12.7 – 257.4 Bq kg^{-1}; 0.6 – 11.9 Bq kg^{-}, 1.9 – 45.8 Bq kg^{-1}; 8.7 – 358.5 Bq kg^{-1}; 9.8 – 436.3 5 Bq kg^{-1}, respectively.

Ranges of observed natural radionuclides in fly ash were, as follows: 79.0 – 159.1 Bq kg^{-1}; 3.5 – 8.2 Bq kg^{-1}; 39.0 – 60.5 Bq kg^{-1}, 89.3 – 191.4 Bq kg^{-1} and 233.3 – 504.4 Bq kg^{-1}, respectively.

Levels of ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra and ^{40}K recorded in slag samples were: 68.91 – 148.72 Bq kg^{-1}, 2.82 – 11.97 Bq kg^{-1}, 38.98 – 49.76 Bq kg^{-1}, 84.93 – 128.84 Bq kg^{-1} and 248.33 – 353.82 Bq kg^{-1}, respectively.

The results for the ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra and ^{40}K of ash and slag from the landfill showed results similar to those of ash and slag, and they were in the following ranges: 69.37 – 156.55 Bq kg^{-1}, 2.85 – 7.21 Bq kg^{-1}, 37.53 – 50.09 Bq kg^{-1}, 88.32 – 151.45 Bq kg^{-1}, 278.01 – 360.24 Bq kg^{-1}, respectively.

The main risk indicators (radium equivalent activity, gamma index, external and internal hazard indexes) calculated from the obtained results have not pointed on the significantly increased risk for the population in surroundings. Variability of the uranium and radium levels in coals as well as their high recorded scale ranges indicated on the risk of potential increasing of their activities in some future coal layers.

Tritium accumulation by farm crops acutely exposed to tritium oxide for a short while

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Tritium entering the environment in the form of tritium oxide (HTO) is easily incorporated into the trophic structure of an ecosystem, in which man is a final link. In this aspect, much attention is paid to the study of tritium uptake and incorporation processes and its possible contribution to human radiation exposure on ingestion of contaminated crop products. The study aimed at assessing the accumulation of inorganic and organic forms of tritium in vegetables contaminated by a short-term accidental release of HTO.

Commonly cultivated farm crops were selected as experimental plants: lettuce, tomato and haricot. Plants were pre-raised in plastic vegetation vessels on background soil until the ripening stage. Plants were exposed at underground nuclear test locations of high HTO concentrations in the surface air. The duration of exposure was 6 hours. Temperature, relative humidity, and atmospheric pressure were measured during the experiments. Plant samples were collected 6 hours later in three replications. Air samples were collected using a tritium collector 'OS 1700' (AMETEK, USA). Tritium in the free water of plants' tissues (TFWT) was isolated using a special unit. Organically bound tritium (OBT) was isolated using a 'Sample Oxidizer' unit. Tritium activity was measured by liquid scintillation spectrometry using a QUANTULUS 1220 spectrometer. The minimum detectable activity of tritium was 0.7 Bq/L.

The temperature during the exposure varied from 21 to 35 C°, the relative humidity – 28 to 56%, PAR – 870 to 1,485 μmol/s/m² and tritium activity in the air – 1,234 to 4,071 Bq/L.

TFWT distribution in leafless crops can be represented as the following descending series: 'leaves > stems > fruits'. The TFWT maximum in leaves is obviously due to the continued diffusion of OBT with water vapors into a leaf's mesophyll. The activity concentration of OBT in aboveground parts is an order of magnitude lower compared to TFWT, which is attributed to the biochemical pathway of this form in plants.

A comparative analysis of values of HTO, OBT concentration ratios and the translocation index showed that the accumulation of the isotope in edible parts of crops on aerial uptake of tritium oxide is largely influenced by external determinants of the photosynthesis rate as well as by morphological features of edible parts.

According to the conservative estimate, the contribution to the internal dose by ingested tritium on consumption of 1 kg of vegetables contaminated due to a short-term tritium oxide release, proceeding from the absolute activity of radionuclide forms, for HTO will be: lettuce – 42 and 110 nSv; tomato – 1 nSv; haricot – 6 and 10 nSv, respectively. For OBT: lettuce – 6 and 5 nSv; tomato – 7 nSv, respectively. Considering that the annual limit on food intake of free and organically bound tritium by the public is $2.1 \cdot 10^7$ Bq and $8.3 \cdot 10^6$ Bq per year, respectively, a possible tritium contribution to the internal dose would be negligible.

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Assessment of a possible impact by uranium mining at the Grachevskoye deposit on the ecological situation around the Soumalkol Settlement

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The major uranium inventory at endogenous deposits is focused in the North Kazakhstan where 12 uranium deposits were developed until the mid-90s. By the mid-90s, owing to a rapid drop in prices of uranium mining products and followed by the suspension of production, virtually all of the waste storage areas maintained by facilities (mines) that were engaged in mining development of uranium deposits proved to be unattended. As a result of underground mining of uranium ores, the regional area has collected, as recently reported, about 61 mln tons of radioactive waste totaling 168.4 thous. curie. Uncontrolled emission waste is becoming a permanent man-made factor of the radiation effect on the public living near uranium mining facilities. A regional center, Soumalkol settlement, is from among the ones affected by consequences of uranium mines developed. As reported by the regional committee on the sanitary and epidemiological inspection, the settlement was found to have areas of elevated EDR values. Development consequences of Grachevskoye uranium deposit were considered as one of the causes that determined radioactively contaminated areas. The thing is that there is a mothballed uranium mining facility (MUMF) Grachevskoye 5 km northwestward of the settlement. The deposit Grachevskoye is affiliated to the Grachevskiy ore cluster and, as administratively divided, is located in the North Kazakhstan region. MUMF Grachevskoye mined uranium ore underground. Next, ore was partly dressed by heap leaching, following which, it was transported in containers by rail to the Stepnogorsk mining ironwork.

In addition, an open pit of building materials (rubble) on the settlement's northern outskirts was considered as one possible source of radioactive contamination. Thus, to reveal a source of radioactive material entry into the settlement territory, a radioecological survey of the settlement location, MUMF Grachevskoye and rubble mining open pit was conducted. A source was identified from the data on EDR values and the distribution pattern of naturally occurring radionuclides in rocks.

At the location of MUMF Grachevskoye, in a 0.73 km^2 area, a gamma survey showed a zonal distribution pattern of EDR values. Background values are specific to the central part, eastern and western outskirts. The sizes of maxima zones vary from 1*1 m to 10*10 m., where EDR reaches 14 μSv/hour. EDR measurements in the open pit and settlement area showed that EDR values range from 0.09 to 0.8 μSv/hour with a background that is specific to this terrain – 0.09 μSv/hour. Abnormal values of the gamma field are noted within the construction open pit and at 4 local spots of the settlement. For the assessment of the nature of abnormal areas in the settlement territory, the distribution pattern of EDR at these sites was analyzed. EDR measurements were plotted, then analyzed showing that the distribution pattern of EDR around the settlement is bimodal. The left modal value corresponds to background values in the region, and the right one coincides with the modal value in EDR distribution at the construction open pit. EDR distribution modal value for the mine ranges from 0.13 to 14 μSv/hour. Preliminary data quoted indicate that local spots in the settlement are attributed to the utilization of open pit rubble when carrying out construction activities.

The correlation of radionuclide ratios for different areas is an important indicator for evaluating a man-made impact on test soils. In this case, the quantity of the isotope ratio Ra-226/Ra-228 is an important indicator for evaluating a source of man-made impact on settlement soils. Values of the isotope ratio Ra-226/Ra-228 at spots vary as follows: at the deposit Grachevskoye – 0.5 to 12.5; at the open pit – 0.6 and in the soil of Soumalkol settlement – 0.4 to 0.8 Bq/kg.

Thus, gamma survey and correlation results of radionuclide ratios contained in soils of the deposit Grachevskoye, the open pit and the Soumalkol settlement showed that Soumalkol soils are exposed to a man-made impact from the open pit under development.

Tritium accumulation by crops during chronic root uptake of tritium oxide

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This paper presents assessment results of tritium accumulation by crops on chronic root uptake under hydroponics conditions. Such crops as pepper, cucumber and haricot were chosen as experimental plants. Water with a tritium activity of 56 kBq/l in the form of an oxide (HTO) was chosen as a nutrient solution base. The duration of plant exposure was a complete growth cycle. A light flux was fed through the artificial phyto illumination system. Plant parts were sampled at the ripening stage in 3-4 replications. Tritium activity concentration in samples was measured by liquid scintillation spectrometry. The minimum detectable activity of tritium during the measurement with 'QUANTULUS 1220' was 0.7 Bq/l.

In the course of vegetation, tritium activity in the nutrient solution of hydroponic units averaged 3 times the intervention level (7.6 kBq/l). Tritium distribution pattern in the free water of three crops' parts at the ripening stage had no distinct regularity. For example, the highest tritium activity in pepper and cucumber in the tissue free water (TFWT) was noted in stems, the lowest – in leaves and fruits, and in haricot's parts it showed virtually the same values. Overall, tritium activity concentration averaged 3 times the intervention level only for plants' tissue free water. Activity values of the organically bound form of the isotope (OBT) did not exceed the intervention level being by a factor of 1 or 2 lower. The concentration of organically bound tritium was uniformly distributed in each crop's parts. The concentration ratio of TFWT due to the chronic uptake of HTO points to steady-state equilibrium between tritium activity concentration in the nutrient solution and the tissue free water. However, crops were different in their abilities to accumulate tritium in the organic matter. The lowest ability to accumulate the organically bound form of the isotope is noted for cucumber, the highest – for haricot, which is evidently attributed by physiological features of plants.

Based upon experimental values of tritium activity concentration in crops' fruits, a potential contribution to the human internal dose was conservatively estimated if any contaminated crop products are consumed. The contribution by man-made tritium to the public internal dose from crop products contaminated as a result of the chronic root uptake of HTO was found to be negligible and will be simultaneously defined by several factors: the level of activity concentration in an input source, morphological features of farm crops and also by vegetable consumption rates.

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Bioaccumulation of radionuclides in hoofed animals inhabiting the Semipalatinsk Test Site

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The Semipalatinsk Test Site (STS) is characterized by sites with high radionuclides concentration in natural components (soil, water, plants). Wild animals for amateur and commercial hunting inhabit these areas including big hoofed animals – elk (*Alces alces Gray, 1821*), roe deer (*Capreolus pygargus Pal., 1771*), saiga (*Saiga tatarica Lin., 1766*) and Argali (*Ovis ammon Lin., 1758*) listed in the Red Books of the Republic of Kazakhstan and the International Union for the Conservation of Nature. The radionuclides entering these animals can also enter man. Therefore, the study of radionuclide features of bioaccumulation by animals at STS is highly interesting. Thus, within the framework of various scientific programs, animal tissues and organs were sampled for the radionuclide analysis in the STS territory by trapping individual animal species for scientific purposes and collecting biological material from the carcasses of dead animals. The possible radionuclides concentration in wild hoofed animals is also assessed by calculation, from activity concentrations of radionuclides in feces of these animals collected from different test site areas.

The direct measurements of activity concentration in the tissues and organs of studied animals showed that the content of radionuclides in hoofed animals inhabiting various STS areas is different. The activity concentration of ^{137}Cs in tissues and organs ranges from 0.2 to 170 Bq/kg. The maximum values are recorded in the muscle tissue of animals. The possibility to determine ^{137}Cs in the bone tissue of argali during its lifetime was established by determining the activity concentration of this isotope in animals' horns. The activity concentration of ^{90}Sr varies from 2 to 4.3×10^{3} Bq kg^{-1}. The maximum values were noticed in the bone tissue and horns of animals. The activity concentration of $^{239+240}$Pu ranges from 6.4×10^{2} to 72 Bq kg^{-1}. The maximum was noticed in the horns of argali from the "Degelen" site. The activity concentration of radionuclide in animals' tissue free-water tritium (HTO) varies from 0.026 to 77 kBq/l, and in the form organically bound tritium (OBT) – 0.03-16 kBq kg^{-1}. In some cases, OBT dominates in tissues and organs suggesting that tritium had been present in the diet of animals relatively long before. In other cases, HTO dominates, which may suggest that there has recently been a continuous tritium intake by these animals. There are also cases where the content of HTO and OBT show the same order of magnitude, which may indicate that the animal has consumed tritium in its diet for a long time.

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Radionuclides and heavy metals in soils in Novi Sad Municipality

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Pollution of soil as a result of industrial progress leads to soil degradation, loss of basic soil functions, and threat to the environment and living beings. Various industrial activities such as mining, power generation, use of fertilizers and pesticides, wastewater discharges, solid hazardous waste disposal, or exhaust emissions are the main sources of heavy metals and radionuclides. In addition to anthropogenic sources, soil also naturally contains these elements. This paper presents radionuclides and heavy metals amounts in urban soils taken in Novi Sad Municipality, Serbia. The main goals were to define the relationships between the total element content in the studied soil samples, to determine the availability and mobility of possible toxic elements and the potential health risks.

Twenty-one soil samples were analyzed. Of interest were points near registered sources of pollution (e.g. industry) and roads, but also points far enough away, which were assumed to be outside the influence of certain pollutants.

Gross alpha and gross beta activities as well as the gamma spectrometry were defined for each soil sample. In addition, the total content of heavy metals (Cr, Pb, Cu, Zn, As, Mn, Co, Cd, and Ni) was determined using X-ray fluorescence spectroscopy (XRF). To define the mobility and bioavailability of heavy metals, two leaching procedures (using Milli-Q deionized water and $CaCl_2$ as extraction solutions) were performed.

The investigated soil samples were found to be alkaline, with lower values of conductivity (around 230 mS/cm). Mean calculated values for gamma absorbed dose rate in the air, annual effective doses, radium equivalent activities, and external hazard index showed that the radioactivity of investigated soil does not pose a health risk. The content of Cr, Pb, Cu, Zn, As, Mn, and Ni varied in a wide range, whereas the content of Cd and Ni was extremely low in all soil samples. Among heavy metals, Mn was the highest mobile, whereas Cr and Pb were the most stable, probably incorporated in the crystal lattice of inorganic soil components.

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Variability of cosmogenic Be-7 fallout in eastern Lithuania, 2020-2024

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It is known that the high of troposphere and solar energy amount depend on latitudes as well as seasons. Data are presented in [doi.org/10.1016/j.asr.2005.04.093] showing Be-7 specific activities in location 35°-36° North latitudes and 139°-140° East longitudes in 2002-2004. In [Global Nuclear Safety, vol. 4 (37), pp. 17-29. ISSN 2499-9733] are described data of atmospheric Be-7 input onto surface in location 47°-48° North Latitudes and 39°-40° East Longitudes during long-term period from 2001 to 2011 years. [doi.org/10.1029/94GL00391] presented earlier measured data between 30° North and 30° South latitudes above Pacific Islands, in 1981-1985. Because Be-7 is produced in the stratosphere and the upper troposphere, geographical location is very important.

Our Be-7 data represent location 54°-55° North latitudes and 25°-26° East longitudes. Measurements of monthly collected precipitation were attributed to period from 2020 January to 2023 December.

The biggest fallout of Be-7 in June was observed in June 2020 (454.9 ± 9.0 $Bq \cdot m^{-2}$) and in June 2022 (330.7 ± 8.3 $Bq \cdot m^{-2}$) for the investigated period. In these years the biggest amount of precipitation was also in June. In 2021 more rainy were July and August, and in 2023 – August, and maximum of Be-7 fallout moved to these months. After calendar summer Be-7 fallout value decreases rapidly, however, it is observed moderate rise in Autumn (October or November) and increase of precipitation amount was observed only in 2023 (in other years concentration of Be-7 in precipitation was bigger). For investigated 48 months the correlation coefficient between precipitation amount and Be-7 fallout was 0.77.

In August 2022, Be-7 content was investigated in flora (rowan leaves and mosses) from 8 sampling points located in pine forest. It is not observed the correlation between Be-7 specific activity and humidity of rowan leaves. The Be-7 data varied from 245 ± 12 to 456 ± 16 $Bq \cdot kg^{-1}$ dry weight. The correlation coefficient between Be-7 loads in mosses ($Bq \cdot m^{-2}$) and moisture amounts (a cover layer of surface in pine forest) is 0.52. The variation of Be-7 load was between 140 ± 15 and 358 ± 21 $Bq \cdot m^{-2}$. It is noticed that the reason for the Be-7 fallout variation in pine forest depends on different forest layers surfaces overlapping projection in opposite to open aired precipitation sampling.

Uptake of gold, silver and copper nanoparticles in *Calendula officinalis* and their effect on plants' biochemical parameters

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The features of copper, gold and silver nanoparticles accumulation and translocation in segments of *Calendula officinalis* under root exposure conditions were investigated. Plants were irrigated for 28 days with solutions, containing nanoparticle in a concentration range of 1-100 mg/L. Transmission electron microscopy allowed to determine size and shape of nanoparticles, while their uptake in plants was assessed using Proton Induced Gamma Emission (silver and gold) and ICP-OES (copper) techniques. Differences in the nanoparticles uptake in plants segments were identified. The gold content in aerial parts of calendula (1-33 mg/kg) significantly exceed the maximum content of silver in experiments performed in similar conditions: 3.59 mg/kg in leaves and 3.96 mg/kg in flowers and was comparable with copper content. Effect of nanoparticles on the content of total chlorophyll, carotenoids and antioxidant activity in aerial parts of experimental calendula plants was investigated. Obtained results present great interest for plant nanotoxicology.

Using natural radionuclides to trace sediment dynamics in a coastal zone

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Natural radionuclides contain in sediment composition of samples in coastal zones, especially Ra-226, Ra-228 and K-40, can be used as tracers of several sedimentary dynamics processes, helping to identify potentials littoral areas of erosion and accumulation. In this context, in previous studied done in Las Canteras beach (Gran Canaria, Spain), we had found that the minimum values of the activity concentrations of Ra-226, Ra-228 and K-40 were in the erosion zones while the maximum values were more frequent in the accumulation zone. After a granulometric and mineralogical analysis, it was also observed that the values of maximum activity concentrations of Ra-226, Ra-228 and K-40 were found in samples with low density and large grain size and, besides, were associated with an increase in K-feldspars during accumulation periods. Now, this method developed in Las Canteras beach using these radionuclides as tracers of sediment transport, is also applied in other beaches such as La Laja, also located in Gran Canaria, and Legrana, in Greece. Measurements were carried out, not only with a Canberra Extended Range (XtRa) Germanium but also using the KATERINA in situ detector from the Hellenic Centre for Marine Research. Moreover, the preliminary results obtained for both type of measurements show that, overall, both describe a similar sediment distribution pattern where the erosion and accumulation zones are related to minimum and maximum values of Ra-226, Ra-228 and K-40 activity concentrations respectively.

Beyond the state-of-the-art solutions for *in situ*, long-term monitoring of radioactivity in the marine environment: The project RAMONES

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The challenges in performing in situ, long-term monitoring of radioactivity in the marine environment has remained a stronghold which the international research community has not yet fully conquered. The main limitations are due to the harsh and remote underwater locations, the water-induced attenuation hindering radioactivity detection, and the scarcity of instruments developed explicitly for underwater operation. To overcome such obstacles, innovation in sensory technology and autonomous marine robotics can be a game-changer in carrying out radioactivity measurements in large water volumes in a continuous, real-time mode.

To that direction, the EU H2020 FET project RAMONES (RAdioactivity Monitoring in OceaN EcosystemS) has introduced new approaches, investing on innovative sensors aboard autonomous gliders, and developing a new class of instruments offering in situ gamma spectroscopy, radiation imaging and radon monitoring in the water column and near the deep ocean bed. In the present paper, recent developments in the RAMONES class of novel instruments, their deployment in the marine environment, and results from measurements in the field will be presented.

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Recent achievements in gamma irradiation-induced degradation of pesticides for wastewater treatment

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The rapid development of the food industry induced excessive worldwide pesticide production and application. The negative impact on human health and the environment is observable, even when those chemicals are applied in low concentrations. As persistent chemicals, various pesticides remain in water, soil, sediments and bioaccumulates in organisms, so finding methods for their successful degradation becomes a significant topic. Advanced oxidation processes have emerged as one of the promising techniques for pesticide degradation, and gamma irradiation has been extensively studied in the past decade. Previous studies have shown that a wide range of gamma irradiation doses were applied to remove different groups of pesticides and their various concentrations. Despite numerous studies, currently, there is no facility equipped for pesticide degradation via gamma irradiation. A proposed degradation mechanism includes the interaction between gamma rays and water molecules, leading to the generation of multiple reactive species. These species non-specifically react with organic compounds, resulting in partial or complete degradation. By-product formation is documented and indicated that depending on the pesticide species, some of them, such as chloride, sulfate and phosphate anions, can be toxic, thus affecting the removal from wastewater. Nevertheless, depending on the type, by-products are usually less toxic and can be further degraded by an increase in irradiation dose. The efficiency of pesticide radiolytic decomposition depends on several factors, such as absorbed dose and dose rate, initial concentration, molecular structure of the pollutants, and pH value. The combined effect of gamma irradiation with other chemicals and techniques has been extensively researched in recent years. Various coupling methods have contributed to reducing the amount of gamma irradiation required for partial or complete degradation of pesticide molecules. High degradation efficiency was achieved by coupling gamma irradiation with oxidizing agents such as H_2O_2, O_3, N_2O, and similar, while coupling with humic acid had the opposite effect. Coupling with other methods has not been extensively studied, but given its successful application in removing other organic pollutants, more research papers are expected on this topic. The synergistic application of diverse wastewater treatment methods presents opportunities for designing modular or mobile plants that fulfil commercial requirements. Investigating various coupling systems contributes to achieving sustainable development goals, including improved management of water resources and reduced waste generation.

An extensive study on the impact of building and construction materials on radiation exposure: Incorporating airborne gamma surveys, ^{222}Rn and ^{220}Rn exhalation rate testing, mineralogical surveys, high-resolution microscopic scans, and geostatistical analysis

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This paper presents a comprehensive multi-stage investigation into the influence of building and construction materials on radiation exposure in Ireland. Employing a multidisciplinary approach, various methodologies were integrated to achieve the following objectives:

I) Preparation of the first risk map distinguishing between radon and thoron potentials for the Republic of Ireland.

II) Estimation of the degree of potential thoron interference in previous radon surveys in residential buildings using CR-39 detectors.

III) Introduction of a simulation model to convert the dose received from radon and thoron to the unit of mSv per annum, commonly used for evaluating gamma exposure dose. Generally, 1mSV per year is considered a safe material to be used indoors.

IV) Identification of quarries with potentially high radon and thoron levels through pilot research, followed by drone surveys utilizing gamma (D230A) and Lidar (Zenmuse L1) detectors.

V) Implementation of a campaign involving the testing of over 150 samples, including natural stones (both native and imported), aggregates, geological core samples, and demolished waste, for 222Rn and 220Rn exhalation rates using SARAD RTM 1688.

VI) Utilization of High-Resolution Microscopy and Tescan TIGER MIRA3 FEG-SEM equipped with motorized backscatter electron and colour cathodoluminescence detectors for fully quantitative elemental mapping and mineral liberation analysis, aiding in the identification of specific minerals within building materials that may contribute to high radiation emissions, particularly thoron emission, which poses a greater dose risk than radon and gamma radiation. It is highlighted that thoron was previously neglected in radiation studies, but recent research confirms its potential for posing an even higher risk than radon. Additionally, building and construction materials are considered the main source of thoron emission from buildings.

VII) Advanced geostatistical models, such as Partial Least Squares (PLS), Ordinary Least Squares (OLS), and logistic regressions, were utilized to produce risk maps, identification of thoron interference, and investigation of the correlation between 222Rn/220Rn exhalation rates and the occurrence of mineralogical anomalies.

The investigation yielded significant findings: a risk map distinguished radon (central to North West and South East) and thoron (County Donegal, North East and South/Southeast) potentials areas in Ireland, the potential thoron interference in previous radon surveys was estimated to be around 20%, and a simulation model converted doses into mSv per annum showed that for some materials the combined dose effect values as high as 4 mSv per annum. Drone surveys identified the risk map's workability to identify quarries with high radon and thoron levels and to be a reliable tool for high-resolution radiation mapping. Testing of building materials revealed their contributions to exhalation rates, particularly thoron and some (e.g., imported Chinese granite and Galway granite) showed remarkably high thoron exhalation rates. Radon exhalation rates were found to be in the low to medium range. Advanced microscopy pinpointed minerals driving radiation emissions (e.g., thorium phase minerals like thorite, and thorianite were responsible for extremely high thoron activity). Also, the significance of other minerals like zircon, monazite, and rutile in radon and thoron productions was evaluated. These results emphasize the need to consider radon and thoron separately in dose exposure assessments and inform targeted mitigation efforts. Geostatistical models facilitated accurate risk mapping and identified correlations between exhalation rates and mineralogical anomalies, guiding future research and regulatory decisions in radiation protection and public health.

Study on zeolites for radon adsorption and detection

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Radon is a radioactive noble gas omnipresent in the environment, being part of the ^{238}U and ^{232}Th decay chains present in the Earth's crust. The gas can easily leak through the ground, but also be present in natural construction materials, into the environment, and migrates into indoor places where it can be a carcinogen when inhaled. Studying the content and removal of indoor radon is crucial for the evaluation and mitigation of its radiological risks to public health. Since more than 100 years, the removal by adsorption of the radon has been performed on activated charcoal. There is little progress in the field of radon adsorption at ambient conditions; the main progress is in the use of zeolite materials, having well defined three-dimensional porous structure and radiation resistance. This study concerns a report on the state of the art about this focus concerning the application of zeolites in radon adsorption, furthermore proposing an optimized approach for measuring the radon content in indoor environments and, consequently, its removal. Understanding the behaviour of radon with zeolites could lead to their stable use in radon mitigation actions in enclosed environments, and to the development of a new radon detector, like activated charcoal. Synthetic zeolites, mainly 13X, are most effective in radon adsorption (~90%) than natural zeolite (40%-70%).

Based on these findings, a new research approach is developed based on the following points:

(i) zeolite 13X;

(ii) ^{222}Rn from a Pylon Rn-1025 source of ^{226}Ra, ^{220}Rn from a source of ^{232}Th oxide salts;

(iii) a radon-proof chamber where the gas diffuses, monitored by an α-spectrometry device based on the electrostatic collection of radon daughters;

(iv) γ-spectrometry device, based on the hyperpure germanium detector, for the characterization of the zeolite 13X before and after the radon exposure in order to estimate its adsorption capability.

The creation of a new device based on the radon adsorption by zeolite for the indoor monitoring is a future goal. Adsorption systems based on zeolites have the potential to replace activated charcoal as material of choice, allowing to facilitate the development of simple and compact radon adsorption systems.

The first remediation of elevated radon levels in one public school building in Croatia – A case study

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Targeted indoor radon survey in 117 schools and 87 kindergartens of Istria County were systematically measured by track-etched detectors from November 2013 until February 2015. Detectors were exposed for one year in every playroom in kindergartens and selected classrooms and offices evenly distributed across areas and floors in schools. The obtained average indoor radon concentrations were higher than the reference value (300 Bq m^{-3}) in 15.5% of kindergartens and 21.0% of schools including this elementary school of interest in Pula. The national radiological protection authority as a first and temporal mitigation method suggested the school administration to increase natural ventilation as frequent as it is possible during working hours. In this particular school building integrated follow-up radon measurements were performed during 2018-19 by track-etched detectors exposed in every classroom and office. Simultaneously, continuous radon measurements were conducted by TSR3 radon detectors which were exposed for several weeks during the heating season and the time resolution was adjusted to 1-hour. The observed daily variations of radon concentrations showed a strong dependence on increased natural ventilation during working hours; a significantly decrease of radon concentrations in the morning and early afternoon and a consequently increase at night and during weekends. However, increased natural ventilation reduced radon concentration in the building during working hours only by 15% and therefore, the design and application of some more effective radon reduction techniques were suggested. The project of radon mitigation was proposed in September 2021 by one architectural bureau and realized during spring 2022. At six locations around the school building, radon sumps were created underground beneath the building which serve as the lowest pressure points in the ground to collect radon gas from the soil rather than it being drawn into the building. Pipeworks and inline fans were installed on the outside walls of the building to continuously exhaust radon from the sump into the atmosphere outside the building. The effectiveness of the installed system was checked during the IAEA Regional Workshop on the best practices for reducing radon concentrations in buildings held in Pula in November 2022. During three days, 25 continuous radon monitors (RadonEye Plus 2, Corentium Pro, Tesla TSR4 and AlphaGUARD) were exposed across areas and floors in the school building. Results of this short-term measurements show that radon concentrations were reduced to levels well below 200 Bq m^{-3} when the system was fully operable (all fans are switched on). Radon concentrations rapidly increased when fans were switched off. Optimization of the installed system for energy-saving purposes was recommended.

Measurements of radon content in water and radon mass exhalation rate in soil samples collected from high cancer incidence area in India

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Introduction. Radon as a single largest contributor of natural radiation exposure and its contribution in enhancing lung cancer incidence is widely known. According to NCRP Report (2020), Mizoram has one of the highest lung and stomach cancer incidences in India, which demands necessity to study the concentration of carcinogenic elements like radon in this area. An intensive monitoring of concentrations of natural radiations in this environment of high lung cancer incidence area has been carried out in the last decades. Previous reports indicated that radon/thoron and their progenies concentration in indoor air of dwellings of this study area were less than the permissible limits. It was also found that in spite of high altitude, the average natural gamma measurements showed a low quantity.

Materials and Methods. In this report, the study was extended to measurement of radon concentration in water, carried out in samples collected from a total of 27 water sources like bore-well, stream, spring, etc. located in Kolasib district of Mizoram, India. Scintillation based radon detector Smart RnDuo was employed for the measurement of radon concentration in water. The same instrument was also used for the determination of radon mass exhalation rate in collected soil samples near these water sources. Radon measurements using Smart RnDuo are based on detection of alpha emitted from radon and its decay products formed in a scintillation cell. An Indigenous smart algorithm has been implemented in the micro-processor, which automatically compensates the background counts due to residual decay products of radon and thus able to measure radon concentrations in a continuous fashion. It has high sensitivity for radon and the advantages also includes that its sensitivity is free from the influence of environmental parameters like humidity and trace gas concentration.

Results. The measured values of radon concentration in water were found to be in the range of 0.66 ± 0.04 Bq/l to 19.82 ± 0.88 Bq/l, with an average value of 7.63 ± 0.41 Bq/l, while the radon mass exhalation rate in soil samples ranges from 15.04 ± 3.40 mBq/kg/hr to 50.47 ± 7.29 mBq/kg/hr, with an average of 28.74 ± 4.20 mBq/kg/hr. The radon concentration in water obtained in this study were found to be well within the safe limit range of 4-40 Bq/l for radon concentration in drinking water as recommended by UNSCEAR (1993), and were also found to be much lower than the European Commission recommended reference level for radon in drinking water, which is 100 Bq/l (European Commission, 2001).

Discussion and Conclusion. From the radon concentration in water obtained, ingestion and inhalation dose were calculated and were found to be well below the critical value set by WHO (2004). Also, a weak, but positive correlation (R^2=0.284) between radon concentration in water and radon mass exhalation from soil was obtained in this study. These data will provide baseline information for studies of environmental radon anomalies in the area which is of high lung cancer incidence.

Keywords: high cancer incidence area, inhalation dose, ingestion dose, Smart RnDuo, soil samples, water sources

The health effects of exposure to low-levels of ionizing radiation in Talysh, Azerbaijan

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The exposure of humans to radiation from natural sources is unavoidable. Radiation exposure from natural sources varies globally and within a country depending on the geology and altitude where people live. According to the International Committee on Radiation Protection, 40-75% of total human exposure to natural radioactive sources comes from radon and its decay products. In 1987 radon and its decay products were classified by the International Agency for Research on Cancer as being carcinogenic to humans. A study of the radon problem in Azerbaijan shows that its distribution in space is uneven and mosaic in nature. The regions with the highest concentrations are confined to the mountainous folded massifs of the G. Caucasus and Talysh, while those with the lowest concentrations are confined to the lowlands. The main objective of the study was to assess the results of the current monitoring of the radiation situation in the Talysh region and the correlation analysis between the life expectancy of the population and radon levels in their places of residence.

Radiometric studies had covered five districts of the Talysh region: Masalli, Lyankyaran, Astara, Yardimli and Lerik. Radon volume activity in residential areas was measured with Radon Scout and Radon Scout Plus radiometers from SARAD. They were installed in residential premises for several days. Radon volumetric activity in soil and water was measured by using RAD7 radiometers (DURRIDGE). The radiation levels were measured by using dosimeter radiometer MKC-AT1125. On the basis of the obtained data the maps of distribution of radon volume activity for Talysh region has been constructed. According to this map, the Lerik region, known for its long-livers, is characterized by a relatively high level of radon. According to the current regulatory document in Azerbaijan, the indoor radon volume activity should not exceed 200 Bq/m^3. Medical investigations are carried out among 24 long livers, 30 their close relatives and 30 members of the control group. In villages where centenarians live, the level of indoor radon varies between 100-200 Bq/m3 (on average about 150 Bq/m3).

The results of studies have shown that there is a certain positive correlation between low-levels of ionizing radiation in dwellings and longevity.

Determination of radon gas activity level in bottled drinking water from different companies in Albania

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In many countries, the groundwater supply is the main source of drinking water. Since these waters are in constant contact with the rocks, if there are high concentrations of uranium, radon gas will be released and will come into contact with the water. Although the amount of radon inhaled through breathing is greater than the amount swallowed through drinking, it is very important to increase the awareness of national authorities and the public about the risk of exposure to radon. In the Decision of Council of Ministers no. 957, dated 2.12.2015, Regulation "On the guideline levels of radon concentration in the internal environment and the concentration of radionuclides in goods, with the effect of the general public", Article 6, point 2, the value 100 Bq/l is defined as a reference level for the concentration of radon in water for public consumption. Currently, there is no monitoring plan for the concentration of radon gas in water samples in Albania.

The aim of this research was to determine the level of radon gas activity level in bottled water, the most used in Albania. In this study some bottled water samples that are produced from different private companies from different regions of Albanian natural resources are analyzed. Two parallel measurements were performed for each of them.

The results showed that the levels of radon gas activity level in all bottled waters samples were within reference level of 100 Bq/l.

Examining radon levels in soil gas and atmospheric air near the surface soil-air interface

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Radon exhalation from the Earth's surface plays a pivotal role in elevating radon levels within buildings. Recent research underscores the potential use of outdoor radon levels in identifying priority areas for radon and exploring the impacts of climate change. A comprehensive understanding of radon exhalation from soil is crucial for modeling and studying the underlying mechanisms.

Two commonly employed quantitative methods for determining radon exhalation face notable methodological challenges:

(1) Studying the time-dependent radon accumulation in a standard volume in contact with soil reveals challenges. Theoretical modeling suggests that radon accumulation in a closed volume, resulting from back-diffusion from air to soil, influences the radon concentration profile in the top few centimeters of soil, impacting the exhalation rate.

(2) Analyzing radon concentration profiles and fitting them to diffusion profiles at depths up to 1 meter with 10 cm intervals reveals significant deviations from assumed diffusion profiles, introducing potential biases. Furthermore, the limited sensitivity of widely used radon samplers and detectors poses methodological challenges.

Despite the critical importance of understanding radon exhalation, there is currently no established method for determining the radon concentration profile in the top 10 cm of soil in an unperturbed manner. The introduction of a new generation of highly sensitive radon detectors, combining solid-state nuclear track detectors with activated carbon fabric (D. Pressyanov, *Scientific Reports* 12 (2022) 8479), presents a promising solution. Additionally, identified activated carbon fabric maintains high adsorption capacity even under high humidity conditions (D. Pressyanov et al., *Appl. Radiat. Isot.* 200 (2023) 110941). These detectors allow quantitative determination of ^{222}Rn at levels below 10 Bq m^{-3} within one week, facilitating the study of radon concentration profiles in the upper 10 cm of the soil layer. The innovative concept involves using a thin metal rail with attached detectors (Kodak-Pathe LR-115/II) covered by activated carbon fabric (ACC-5092-10). The rail is inserted 10 cm deep into the soil, with a part of the detector strip exposed to the ground layer of air. This report presents a pilot experimental study of ^{222}Rn distribution in the surface layer of soil and adjacent air within a few centimeters of the soil surface. Experimental scenarios include radon exhalation in open air and within a closed volume, with examinations of alterations in the ^{222}Rn profile due to accumulation in the closed volume. The report also discusses compensation/correction for the influence of ambient temperature and humidity.

Radon concentration and estimated dose in farmland, Rustenburg, South Africa

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Radioactive gas radon is the most significant natural source of human exposure to ionizing radiation, contributing more than 50% of the total radiation dose received from natural sources by human beings. In this study, an AlphaGUARD portable radon detector was employed to measure radon concentration in soil and estimate the effective dose in humans using ICRP regulations for various exposure periods. The concentration of radon in soil was found to vary from 129.53 Bq/m^3 to 659.60 Bq/m^3, with a mean value of 363.61 Bq/m^3. The calculated effective doses received by the public due to radon were found to range from 3.92 mSv/yr to 19.97 mSv/yr with a mean value of 11.00 mSv/yr. The average effective dose was well above 0.1 mSv/yr and 1.10 mSv/yr reported by the World Health Organization and United Nations Scientific Committee on the Effect of Atomic Radiation, respectively, posing significant risk to humans. The results highlight the necessity of assessing radon exposure risk to strengthen awareness and mitigate possible threats to public health. The results provide a solid basis for policy-making to reduce exposure to radon as low as reasonably achievable while also serving as a baseline for future measurement and monitoring in the study area.

Indoor radon levels at FIMIF, PUT

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The inhalation of indoor ^{222}Rn is one of the most important pathways causing prolonged exposure from natural radiation sources. Given the World Health Organization's classification of radon as the second leading cause of lung cancer globally, this research contributes to the broader efforts of monitoring indoor radon levels. This study investigates indoor radon levels at the Faculty of Mathematics Engineering and Physics Engineering, Polytechnic University of Tirana, located in Tirana city, Albania. This building consists of two floors. Radon concentrations were measured using the professional radon monitor AlphaGUARD PQ2000 PRO which is a portable radon monitor with high storage capacity. This is an ionization chamber (0.62 l), designed for measuring radon in air, soil and water. Measurements were taken in 7 offices, 9 classrooms and 4 labs on the ground floor and 1 office, 6 classrooms and 2 labs on the first floor. Measurements were taken during the winter season with emphasis on altitude variations. Radon concentrations in the ground floor rooms ranged from 63 to 209 Bq m^{-3}, with only one room exceeding 200 Bq m^{-3}, and from 47 to 122 Bq m^{-3} on the first floor. The annual effective doses for students and staff were calculated to be from 0.33 to 1.46 mSv y^{-1}. This addition of new data points not only enriches the national radon measurements database but also underscores the ongoing necessity of radon surveillance in educational environments, particularly in regions prone to higher concentrations.

Lessons learned from the 2022 campaign of the measurement of indoor radon concentration in dwellings

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Indoor radon concentration in Albania has been investigated through various campaigns during 1999 and 2014, building the first steps toward the realization of the distribution map of radon. The 2022 campaign is a continuation of these campaigns aiming to further study the influence of measuring indoor radon concentration between living room and bedroom. This study is extended throughout the country in order to have a representative result comprising geological and seasonal characteristics of different populated areas. Approximately 60% (out of 69 measurement locations) of the indoor radon measurements were performed in houses, while the remainder in apartments. The average bedroom-living room indoor radon concentration in houses were found to vary from 13 to 454 Bq/m^3 with an arithmetic mean of 68 Bq/m^3 (median 49 Bq/m^3), while in apartments from 24 to 144 Bq/m^3 with an arithmetic mean of 54 Bq/m^3 (median 47 Bq/m^3). The relatively lower concentrations found in apartments is mainly due to apartment floor height, varying from 1st to 7th floor. The ratio of radon concentrations between bedroom/living rooms showed values varying from 0.3 to 4.1 in houses and 0.5 to 3.7 in apartments. The distribution is positively skewed with median value of 1.0 in houses and 1.1 in apartments. The slight difference between houses and apartments can be an indication that the lifestyle is a factor determining bedroom radon concentrations. However, these results support our proposal that radon concentration measured in living room and/or bedroom is representative for the determination of environmental radon exposure of the population in dwellings.

Indoor radon levels at historical area of Shkodra City

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This study presents the first comprehensive assessment of indoor radon activity concentrations in the old historical zone of Shkodra, Albania, a region known for its rich cultural heritage and traditional buildings. Given the potential health risks associated with prolonged exposure to high levels of radon, our research aimed to evaluate the indoor radon activity concentrations in this area to understand the potential impact on public health and to contribute to the development of local radon mitigation strategies. Utilizing a systematic sampling approach across various locations within the historical zone, we measured indoor radon levels using the professional radon monitor AlphaGUARD PQ2000 PRO which is a portable radon monitor with high storage capacity. The results showed that radon concentrations ranged from 42 to 126 Bq m^{-3}, aligning well with the geological characteristics of the area. The lowest values were recorded in areas where there have been reconstructions. These findings indicate that the radon levels in Shkodra's old town are within the limits according to European Legislation for Radiation Protection, suggesting a low risk to the inhabitants' health regarding radon exposure. However, the study also underscores the importance of continuous monitoring and assessment of radon concentrations, particularly in areas with significant historical and cultural value, to ensure public health safety and inform future urban planning and preservation efforts. This research contributes valuable baseline data on radon levels in Shkodra city and highlights the need for integrated approaches in managing environmental health risks in historical urban settings.

Parallel half-year-long radon concentration measurement at TCAS

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Radon is a colorless, odorless, and tasteless radioactive gas originating from the ground which can permeate enclosed spaces and pose serious health risks to humans when chronically inhaled. At the Technical College of Applied Sciences in Zrenjanin continuous measurements of radon concentration were undertaken during the summer and autumn of 2023. Radon levels were monitored in four rooms located in the basement and ground floor levels, covering an area of approximately 4000 m^2, where previous short-term tests had indicated the highest radon concentrations. Detectors were positioned approximately 1 meter above the ground and away from doors, windows, walls, and heating sources. These rooms remained in normal use throughout the measurement period. Two types of detectors were utilized simultaneously, placed in close proximity to each other. Radon concentrations were assessed using active-type radon detectors branded as Airthings, alongside CR39 track detectors. The radon concentration values obtained with CR39 detectors demonstrated good agreement with the results obtained using Airthings detectors. The statistical Z-test was employed for analysis.

Radon measurements and occupational dose assessment in Greek tourist caves

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Radon measurements within cave environments have been carried out for scientific purposes for several decades. The implementation of the European directive issued in the country in 2018, along with the national radon action plan, mandates the assessment of occupational exposure to radon. Within this context, radon measurements were conducted in five tourist caves. Several detectors were spatially distributed within each cave in order to estimate the worker exposure. Additionally, measurements were conducted in the Petralona cave over three consecutive periods. Solid-state nuclear track detectors were utilized for all measurements. Dose assessment was conducted following the dose convention factor of ICRP-137 for caves as proposed by the Commission Recommendation 2024/440 of 2 February 2024 on the use of dose coefficients for the estimation of the effective dose and equivalent dose for the purposes of Council Directive 2013/59/Euratom. The dose assessment was performed taking into consideration the operational timetables in each cave. The doses recorded are lower than 10 mSv/y.

CERN-DRD3 collaboration on solid state detectors R&D

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The European Commission for Future Accelerators initiated formation of several large CERN based detector R&D collaborations which should follow the research goals described in the ECFA Detector R&D roadmap document. DRD3 was recently formed encompassing 143 institutions from around the world with more than 700 scientists involved. The goal of the collaboration is to further develop semiconductor detector technologies mainly for high energy physics experiments, but also for applications in medicine, nuclear physics, space and photon sciences. The structure of collaboration and the goals of its working groups will be presented. The strategic funds have been assured by different funding agencies to support the collaboration research goals. The collaboration is open to a wide community and will also enable its members access to some large equipment such as test beam, laser and irradiation facilities.

Fabrication of silicon-based PIN photodiodes and evaluation of preliminary electrical characterizations for radiation applications

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Silicon-based PIN photodiodes with 3.7 x 3.7 mm² sensitive regions were fabricated in this study. The electrical properties of PIN diodes were investigated at room temperature. The dark current of silicon PIN photodiodes has been found to be 200 nA at a reverse voltage of -70 V. The PIN photodiodes have also been found to reach the full depletion mode at -40 V and has capacitance value of 5.5 pF. The photo-sensitive region of the photodiode was illuminated with 450 nm and 650 nm laser light. The photon current of 310 nA was obtained at a reverse voltage of -70 V for 450 nm laser light. The experimental results also showed high dark current value and low photocurrent efficiency. The problems affecting the electrical performance of PIN diodes have been addressed in this study.

Keywords: photodiode, silicon-based PIN photodiode, electrical characterization, radiation sensors

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3D dosimeter sensor based on the commercial PIN photodiode BPW34S

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Introduction. Ionization chambers, MOS transistors, and photodiodes are commonly used as sensors for dosimetry [doi.org/10.1002/mp.13089]. The first can be considered as a gold standard in this field but all of them have some disadvantages. In this work, the angular dependence of the PIN photodiode BPW34S [doi.org/10.1002/mp.14921] was studied and a solution using a three-dimension sensing structure was tested to reduce this dependence.

Methods and Materials. Radiation source and experimental setup: Irradiation tests were conducted with a linear accelerator (LINAC) Elekta Versa HD (Elekta Solutions AB, Stockholm, Sweden), placed at "Hospital Universitario Clínico San Cecilio" (Granada, Spain). The photon beam was produced with an electric potential of 6 MV. DUTs were located in the radiation isocenter (at 100 cm) and were irradiated with a field of 10x10 cm^2. Fifteen irradiation sessions, at different incident angle, were programmed with an average dose rate of 6 Gy/min to provide an accumulate dose of 3 Gy (Si) per angle. The devices were irradiated from -180° to 180° in steps of 15° obtaining a total accumulate dose of 45 Gy. To study and compare the results of an individual sensor and the 3-D sensor, first, one photodiode was irradiated and then the mentioned 3-D sensor was studied under the same conditions.

Reader Unit. The reader unit developed in our research group was used to monitor the photo current induced by the photon beam [doi.org/10.1002/mp.14921]. Sensors were reverse biased at 10 V, and the device's induced current was converted to voltage with a transimpedance amplifier based on the operational amplifier TL072 (Texas Instruments, Dallas, TX USA) with a feedback resistor of 4.7 MΩ, achieving a theoretical current resolution of 80 pA. However, the circuital electronic noise limited this resolution to 200 pA, which is enough for our application.

Results. To reduce the angular dependence of the PIN photodiode, we propose a cube made of ABS (Acrylonitrile Butadiene Styrene) which include one sensor per face. ABS was selected to build the body of the cube as it has a similar density to the water. Moreover, all the photodiodes were connected in parallel mode to obtain the sum of the photocurrent induced by the radiation. After the irradiation tests, a maximum sensitivity dependence of 35.3% was found for the induvial photodiode. In contrast, for the proposed sensor, this dependence was reduced to 10.6%.

Conclusion. In conclusion, the suggested 3D sensing structure is capable to reduce the angular dependence more than 3 times. Therefore, this together with the low degradation founded in this photodiode model [doi.org/10.1002/mp.14921] are promising results for future application in *in vivo* dosimetry.

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The impact of the gain in Trenched LGAD on ghost signals by comparing the Trenched PIN to Trenched LGAD

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Our previous work shows the presence of ghosts in interpad (IP) region and in the periphery region of pixels in segmented Trenched LGAD where double trenches are used as isolation structures in IP region. The same analysis is performed on trenched LGADs without gain layer (trenched PINs) to resolve the mystery behind the underlying mechanism responsible for anomalously large signals which is also extraordinarily extended in time. One of the hypotheses is that punch through mechanism is responsible for the lateral flow of charge originally accumulated between trenches in the IP region (induced by leakage current) and then multiplied in the gain layer (in pixels). Isolation of pixels and strips with trenches becomes an attractive solution where the need for a high fill factor is demanded. Thus, understanding the underlying mechanism for extraordinarily strong ghosts (self-triggered events) in double-trenched LGAD is of crucial importance in the future minimization of the IP region in densely packed pixels.

Improvement of timing properties of Ce-doped multicomponent garnet scintillators by heavy aliovalent codoping

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Fast scintillators are currently in demand for the development of radiation detectors in medical imaging and high energy physics applications. Ce-doped multicomponent garnets exhibiting exceptional flexibility for substantial variation of their composition without detrimental deterioration of the crystal structure are prospective as fast scintillators. Acceleration of scintillation response by aliovalent codoping due to the change in valency of Ce ions and the elimination of detrimental influence of trapping levels is already demonstrated.

In this work, we study the influence of heavy aliovalent codoping on the luminescence decay time. A set of $Lu_{0.8}Gd_{2.2}Ga_{2.5}Al_{2.5}O_{12}$:Ce,Mg thin layers with nominally constant Ce content of 1% and different Mg contents in the range from 0 to 6000 ppm have been grown for this study on $Gd_3Ga_{2.7}Al_{2.3}O_{12}$ substrates by isothermal dipping liquid phase epitaxy using $BaO\text{-}B_2O_3\text{-}BaF_2$ flux. Time-resolved cathodoluminescence (CL) and photoluminescence (PL) and transient absorption spectroscopy in the temperature range from 80 K to 600 K were employed.

The spatially resolved CL spectroscopy revealed bright emitting pits on the layer surface and proved that the increased emission intensity is caused by enhanced light extraction, whereas the pits do not introduce any additional emission centers.

A substantial acceleration of Ce emission with increasing Mg codoping level was observed. This acceleration and the temperature dependence of PL intensity and time evolution at resonant excitation directly to the emitting level 5d1 or level 5d2 of ion Ce^{3+} were interpreted by introducing a model accounting for two types of emission centers: regular Ce^{3+} ions and Ce^{3+}+Mg^{2+} centers consisting of Ce and Mg ions located in close proximity. We revealed that the centers Ce^{3+}+Mg^{2+} have a smaller energy barrier for thermal depopulation and a barrier-free channel for nonradiative recombination. The properties of the composite emission centers do not significantly depend on Mg content in the layer. Increasing codoping level results just in an increasing share of emitting centers Ce^{3+}+Mg^{2+}. The comparison of PL and CL intensities in the samples with different codoping level shows that the losses of excitations at emitting centers strongly dominate over the losses occurring during the excitation transfer to the centers.

In conclusion, we showed that the response time of scintillator based on Ce-doped garnet can be substantially accelerated by heavy codoping due to the transformation of the emitting centers Ce^{3+} to the centers Ce^{3+}+Mg^{2+} having lower energy barrier for thermal quenching and a temperature-independent channel of nonradiative recombination. This acceleration occurs at the expense of the emission intensity, however, at an acceptable level for certain applications.

Measurement and Monte Carlo simulation of diamond detector sensitivity to 14 MeV neutrons

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Continuous efforts are necessary for improving the performance and expanding the applications of single crystal diamond detectors (SCD) in medical and high energy physics. We present a characterization of thin SCDs under 14 MeV neutron irradiation to assess their neutron sensitivity. Measurements were performed in current mode and single pulse mode at the 14 MeV Frascati Neutron Generator (FNG). The detectors were realized in Schottky diode configuration at "Tor Vergata" University of Rome. The detectors were used in both un-biased and biased mode at different voltage values to observe currents and thus evaluate sensitivity trends. The detectors showed an outstanding linearity versus neutron fluxes and a remarkably low sensitivity to this radiation, in terms of C/n, making them suitable for diagnostics of neutron-mixed particle beams. A Monte Carlo model built with the well-known Geant4 simulation toolkit is also presented. The absorbed energy spectra obtained with the simulation were compared with the experimental ones, to verify and select the correct physics list. Once the correct physics list for neutron is chosen, Geant4 has shown not only that it can simulate with excellent accuracy the sensitivity of detectors to neutron radiation, but once the model has been calibrated respect to experimental data, it is possible to estimate the thickness of the detector's radiation-sensitive region.

Characterization of a HPGe-based spectrometer for in situ, long-term operation near the seabed

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High-resolution and long-term spectroscopy studies near the seabed at large depths are practically non-existent with current instrumentation and methodology. Studies at large depths in the oceanic environment would allow for interdisciplinary applications including investigation of radiation-related geological phenomena, legacy nuclear waste, and dose calculations on the local ecosystem. The current state-of-the-art instrumentation includes mainly low-resolution instruments presenting drawbacks in reliable analysis of complex gamma spectra acquired underwater.

The RAMONES project (RAdioactivity Monitoring in OceaN EcosystemS) introduces a novel HPGe-based spectrometer utilizing electromechanical cooling for the crystal, overcoming the need for liquid nitrogen supply typically required for this type of detectors to allow for continuous operation near the seabed. GASPAR (GAmma SPectrometer for mARine studies) is designed to be deployed on a seabed benthic laboratory or aboard a mobile Remotely Operating Vehicle (ROV).

The harsh environmental conditions prevailing near the seabed make the characterization of the instrument, prior to its final deployment, a task of major importance. Sophisticated Monte Carlo simulations have been performed to examine the response of the spectrometer under various scenarios. In this paper, results from the simulations carried out will be presented along with technical details of the instrument during its development and deployment phase.

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Energy resolution evaluation of 3x3 mm² GAGG:Ce scintillators coupled to various SiPMs

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GAGG:Ce (Gadolinium Aluminum Gallium Garnet doped with Cerium) crystals coupled with SiPMs (Silicon Photomultipliers) form a scintillator-based detector system commonly used in various fields such as medical imaging, high-energy physics, homeland security and radiation detection. The purpose of this study is to compare the energy resolution of GAGG:Ce crystals of different thickness values (from 4 up to 20 mm), under 662 keV excitation. Comparisons were conducted among scintillator crystals purchased by Furukawa and Epic crystals and photomultipliers from various companies (Ketek, SensL/Onsemi and Hamamatsu), all featuring a pixel size of 3x3 mm². Each scintillator detector with the front-end electronics was placed into a light tight black box. The digitization of the pulses and the acquisition of the energy spectra was carried out with the CAEN desktop digitizer. A DPP-CI control software of CAEN was used for the triggering as well as the signal processing of the digitized pulses. The surfaces of the GAGG:Ce crystals were polished and subsequently wrapped with Teflon tape and kept in dark for 24 hours before measurements in order to minimize the phosphorescence effect. In order to assess the proportionality of detector's energy response a Co-60 radioactive source was used. The square root of the linear fitting of the plot of the photopeak centroids versus the gamma energies was found almost 1 indicating a linear response. Excellent energy resolution values were achieved for GAGG-HR crystals when coupled to 30035 C–Series (Onsemi) SiPM achieving 4.9% for 3x3x5 mm³ and 5% for 3x3x8 mm³ size. Furukawa GAGG:Ce crystals demonstrated consistent energy resolution ranging from 6.6% to 7.2%. Employing the PM3350 Trench type SiPM of Ketek, GAGG-HR single crystals achieved the best energy resolution values of 5.5% for 3x3x5 mm³ and 5.7% for 3x3x8 mm³ sizes. Furukawa GAGG:Ce samples of 3x3x5 mm³ crystals yielded an energy resolution value of 6.8%. When using the S10362-33 Series SiPM from Hamamatsu, the best energy resolution values were obtained with the S10362-33-050 SiPM coupled with 3x3x8 mm³ GAGG:HR crystals, resulting in an energy resolution of 8%.

Keywords: inorganic scintillators, silicon photomultiplier, energy resolution, $Gd_3Al_2Ga_3O_{12}$:Ce

SEE Tests of candidate commercial of-the-shelf (COTS) electronic components to be used in Space Radiation Monitor

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YRM (Home Grown Radiation Monitor) is being developed for operation on satellites and is designed to mea3sure proton flux between 6 and 200 MeV in 8 bins of kinetic energy and trapped electron flux in Low Earth Orbit for 5 years, with a possible upgrade later for deployment on Geosynchronous Orbit. Development models, called SB.0, consisting of 2 energy bins for protons have flown on sounding rockets and the next version, SB.1 with 4 energy bins for protons, is under construction. Commercial off the shelf electronic components are planned to be used in YRM to reduce cost. Therefore, Single Event Effects testing and analysis of the critical candidate electronic components is necessary to reduce the operational risk, data loss and loss of communication.

The electronic components used in YRM are commercial off the shelf components to reduce cost. In order to minimize operational risk, data loss and to ensure no loss of communication occurs during the YRM mission, a test card consisting of 12 of the candidate electronics for the control card was designed. SEE tests up to $3x10^{11}$ protons/cm^2 fluence were performed on the electronic components on the test card at METU DBL (Defocusing Beam Line) facility with 30 MeV protons.

The 12 candidate commercial of-the-shelf (COTS) electronics include two power managers whose product codes are TPS2420RSAT and MAX891LEUA+T respectively, three interface transceivers with product codes PCA82C250T/YM,115, MAX3485AEASA+ and HI-2579, one interface receiver with product code AM26LS32AIDG4, an interface driver with product code AM26LS31AIDG4, a flash memory with product code MX30LF2G28AD-TI, a sensor with product code LMT01DQXR, a programmable time with product code SE555DR, an ADC with product code ADC128S102CIMT, a DAC with product code MAX5253BEAP+, alongside with generic transistors and resistors. The components with the specific product codes MAX3485AEASA+ (interface transceivers) and SE555DR (programmable timer) had never been investigated for their readiness to perform in harsh radiation environments. With the single event effects (SEE) on all the components with these specific model codes will be investigated and discussed in detail for the 30 MeV proton energy.

The SEE test setup consists of a “Control Card” and a “Test Card”. The test flow is as follows:

1. Control card will be powered on and initialization sequence will be sent to establish communication with it.
2. The latch-up circuitry will be activated to supply voltage to the tested DUT and the current driven will be checked.
3. The specific bypass relay for the DUT will be activated and the current driven by the DUT will be checked.
4. During the SEE testing DUT’s response (in bits) will be checked, and any unexpected response will be counted for SEE cross section calculations.
5. The currents driven by each component will also be checked to see for any effects to the accumulated dose.

The control card communicates with the test card through UART and SPI interfaces and using a multiplexer and switching relays can choose one of 15 addresses on the test card, which corresponds to device under test (DUT).

Determination of electrical parameters of the gallium nitrite-based photodiode with simulation

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A photosensor based on gallium nitrite (GaN) with a 2000 μm^2 sensor area was designed with the Silvaco ATLAS simulation tool. In order to improve the sensor's performance under ultraviolet light, p-type gate region was used in the architectural structure, and multiple junctions were created in the structure using aluminum nitrite (AlN) and aluminum gallium nitrite ($Al_{02}GaN_{08}N$). The dark current of photosensor is $3x10^{-6}$ A. During the sensor's testing, photon current was approximately $2x10^{-4}$ A when exposed to a 360 nm wavelength, 5 mW/cm^2 power light. This implies that the photosensor has a spectral response of 8000 A/W and can be used for flame detection.

Keywords: GaN sensors, TCAD simulation, UV detection, flame sensor

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Low-Pressure Multi-Wire Proportional Chamber (LPMWPC) for fission fragment detection: Application in nuclear forensic analyses

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A detecting system consisting of a multiwire low-pressure proportional chamber has been developed for fission fragments detection. Using the system, fission fragments (FFs) generated by the ^{252}Cf and ^{239}Pu source were measured. Very good alpha-fission discrimination was achieved and it was shown that the quality of measurements does not change in a huge flux of alpha particles. It is proposed to use detection systems to detect certain actinides from a mixture by the presence of fission fragments.

Characterization of the ionization chamber CRGR10-C5B-UG2 under a high dose rate Co-60 source

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IFMIF-DONES project endeavors to create an environment where materials can be thoroughly examined under stringent radiation conditions. The presence of various sensors becomes imperative in such environments. This work focuses on characterizing the response of one of these sensors, the ionization chamber CRGR10-C5B-UG2 from Photonis (Mérignac, France), which is designed to endure high doses of radiation. For this purpose, its response under a gamma radiation environment has been studied using a high dose rate Cobalt-60 source.

Irradiation sessions were performed at Nayade facilities of CIEMAT (Madrid), where several Cobalt-60 sources are available, capable of delivering a high dose rate. The week prior to the tests, the CIEMAT team conducted a dosimetry of the radiation conditions, ensuring that the dose was 21.9 kGy/h.

The Keysight B2985B electrometer has been used to acquire the signal, capable of detecting up to 0.01 fA and polarizing the devices up to 1000 volts. In the designed setup, signal shielding has been consistently maintained, largely mitigating signal noise

The electrometer was located in the control room, next to the pool, and to establish the connection, the cables were fed through a hose until reaching a fully sealed metallic container that fits into the holder of the sources.

The ionization chamber was polarized at various voltages within the plateau region to confirm the low voltage effect on the obtained measurements.

To obtain the sensitivity of the device, two measurements were registered while the ionization chamber was positioned in the holder. For the first sensitivity calculation, the recorded current was integrated over 2 minutes, with a data sampling frequency of just under 2 Hz, whereas in the second calculation, the sampling frequency increased to 70 Hz, but only a few seconds were integrated. Additionally, before integration, a median filter is applied to the data.

The sensitivity obtained was of *2.77±0.03 pAGy/h*, *2.83±0.03 pAGy/h*, *2.83±0.05 pAGy/h*, and *2.87±0.06 pAGy/h* with 120, 150, 180 and 200 V of bias voltage respectively.

After these preliminary tests, it has been confirmed that the response of the chamber is close to the expected values, being the sensitivity value provided by the manufacturer 3 pA/(Gy/h) with a bias voltage of 150 V and a Co-60 source. Further studies are expected to be conducted, potentially involving other radiation sources, and studying the linearity of the response to varying dose rates.

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NFC-dosimeter for MOSFET sensors with higher voltage operation

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Introduction. To enhance the quality of radiotherapy treatments, in vivo dosimetry is widely used to monitor the radiation dose administered to patients. Different desktop dosimetry systems have been developed for this purpose, but they need complex power management systems, thereby significantly increasing the cost and the system complexity. As an alternative to these systems, we present a portable, battery-less, and wireless system. The system leverages Near Field Communication (NFC) technology along with an NFC-enabled smartphone equipped with a custom application for measurement, data storage, and cloud-based publication to follow-up the patient's treatment progress. The tag utilizes the NFC link to harvest energy and communicate with the smartphone. The presented system is an enhanced version of the previously developed NFC dosimeter, featuring a variable current source to bias different interchangeable pMOSFET modules at Zero Temperature Coefficient (ZTC) drain currents, thereby minimizing thermal dependence. Additionally, it incorporates a DC-DC boost converter to include stacked configurations or RADFETs requiring high bias voltages.

System Description. The incorporation of the DC-DC boost converter extends the maximum voltage operation of the dosimeter compared to previous designs. To maintain the battery-less configuration, a supercapacitor is included, which must be charged before the boost converter can begin operation. The charging, measurement, and communication processes are managed by the tag's microcontroller. With the enhanced voltage operation, the system can now handle transistors with higher source voltages, such as the 3N163 (Vishay Siliconix), both in single and stacked configuration. Furthermore, the system features a programmable source current controlled by the 8-bit microcontroller DAC to operate with different pMOS transistor models with different I_{ZTC} values. Irradiation tests will be conducted using a LINAC Elekta Versa HD (Elekta Solutions AB, Stockholm, Sweden), situated at the "Hospital Universitario Clínico San Cecilio" (Granada, Spain), using a 6 MeV beam.

Conclusions and Future Tasks. Various transistors, both in single or stacked configuration, can be managed thanks to the programmable source and the higher voltage operation achieved with a low-power consumption boost DC-DC converter in a battery less NFC tag. The inclusion of the supercapacitor resolves the power requirements of the DC-DC boost converter, requiring a charge period prior to the measurement process. In summary, the current work proposes an enhanced wireless and battery-less NFC-based system that boasts capabilities comparable to desktop reader units, all at a reduced cost.

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YAG:Ce scintillator detector for gamma radiations

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A new detector with Cerium-doped yttrium garnet (YAG:Ce) crystal plate was ensemble. The crystal of YAG:Ce made in China at Hangzhou Yong Hee Photonics Co. Ltd had 0.2% Cerium activator and was grown by Bridgeman method. Because the maximum of the peak emission of YAG:Ce is situated at 550nm, this means that the readout can be made with a PIN photodiode. The dimensions of the crystal plate were 18x18x10mm^3. The photodiode used in this experiment was of type S3208-04 made in Japan by Hamamatsu with an active area of 18x18mm^2 which is not affected by magnetic fields. The signal from this detector was fed to a charge sensitive amplifier. Two positrons sources of ^{48}V (with energies of 511 keV, 983.5 keV, 1312.1 keV) and ^{22}Na(511keV, 1274 keV) were used to measure the energy resolution obtained with YAG:Ce detector. It was find a value of 4.8%, bigger than the energy resolution obtained for CsI(Tl)(2.8%) with the same PIN photodiode readout and the same charge sensitive preamplifier. Also, the YAG:Ce crystal was polished on all faces and then was wrapped with black paper on lateral faces. The YAG:Ce crystal is non-hygroscopic in comparison with NaI(Tl) and CsI(Tl) crystals and so it can be used in high temperature and ultra-high vacuum conditions for a long time. The decay time of 70ns for YAG:Ce is smaller than the decay time for the CsI(Tl) which make it a fast detector. Indeed, the YAG:Ce crystal is very good to replace the old crystals used in gamma radiation detectors from a positron emission tomography(PET) scanner and from other types of end detectors used for high energy experiments.

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A guided tour in the description of irradiation dynamics of molecules and nanoparticles

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The theoretical study and understanding of irradiation of molecules and nanoparticles is essential to understand mechanisms underlying irradiation of any material. Irradiation often takes place locally and finite systems are thus key examples to understand in depth processes underlying the response of any system, from atom to bulk. Such intermediate size systems require elaborate methods including account of detailed quantum effects.

Although such refinements may look superfluous for macroscopic systems it turns out not to be the case. A typical example is the one of electronic circuits subject to accidental irradiation, for example by cosmic rays. The increasing miniaturization of these circuits may make them extremely sensitive to irradiation and the quantum limit, namely the scale at which quantum effects become unavoidable, is in close reach. The case of biological systems is a bit different but again requires an understanding at molecular level which soon calls for quantum details.

We make a rapid survey of theories available to attack such quantum situations in the far-off equilibrium regime characteristic of irradiation scenarios. We focus on real time approaches which are both well adapted to such scenarios and which provide a rather transparent view of numerous mechanisms.

We discuss general methods, their capabilities and their limitations. We also point out major challenges in the field. We illustrate these various facts of irradiation scenarios on a few typical examples.

The talk is based on a recently published book: https://www.amazon.fr/Guidebook-Real-Time-Electron-Dynamics/dp/0367651262

On the development of carbon-free gas diffusion electrodes to improve the zinc-air rechargeable batteries performance

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Among the metal-air battery designs considered to display the most promising potential to replace Li-ion technology, the rechargeable Zn-air battery has attracted considerable attention as one of the most viable options due to its theoretically very high energy density, low operating costs, long life cycle, high safety and reasonable environmental compatibility. Here we report the progress in implementing the recently developed novel design of a "monolithic" gas diffusion electrode (GDE) with improved mechanical stability in which both the gas diffusion layer (GDL) and the catalytic layer (CL) are fabricated from one and the same material, applying hot pressing technology. The approach of replacing the noble metal catalyst (e.g., Ag) with bifunctional transition metal oxide (TMO) catalysts and protecting against corrosion by removing the carbon component in GDE was successfully exemplified. Of the various catalysts attracting attention to date for high battery performance through enhanced both oxygen reduction reaction (ORR) and oxygen evolution reaction (OER), transition metal oxides with perovskite-like structure were selected owing to their intrinsic catalytic activity and structural flexibility for acceptance of a wide range of cation substitutions. The oxidation states of the constituent cations and their distribution over the two kinds of sites in the perovskite structure strongly affects the TMO properties. By using polytetrafluoroethylene (PTFE) as a hydrophobic binder and $La_{0.8}Sr_{0.2}MnO_{3-\delta}$, (LSM) and $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ (LSC) as catalysts, hot pressed onto a stainless steel mesh, which works as a current collector, we produce the so-called "monolithic" carbon-free GDEs, where the traditional GDL made of carbon-based material is avoided and thus the corrosion rate is reduced. The electrochemical characterization involving volt-ampere characteristics, charge/discharge tests and electrochemical impedance measurements at room temperature was carried out. Sensitive techniques such as neutron and X-ray diffraction combined with scanning electron microscopy (SEM) and EDX-analysis were also applied to improve the understanding of structural stability and recharge-related properties as an important step in the development of an innovative design of rechargeable zinc-air cells with high performance carbon-free reversible GDEs. Acceptable coulombic and energy efficiencies were obtained. Comparison with state-of-the-art carbon-based GDE (teflonized carbon blacks, Ag/Co_3O_4 catalyst, PTFE) confirmed that the implemented catalysts can successfully replace the classic catalysts containing precious metal and carbon support. The best electrochemical performance demonstrated the LSM-based GDE.

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Comparison of the effects of different film coating techniques on the structural and electrical properties of $HfSiO_4$/n-Si

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Sensitive regions of RadFETs (Radiation Sensing Field Effect Transistor) consist of SiO_2 due to high interface quality and easy production. In order to make these devices more sensitive to low doses or more resistant to high doses, alternative materials for the sensitive region should be sought. In recent years, high-k dielectrics have been the focus of studies conducted for this purpose. One of the biggest difficulties encountered in high-k MOS (Metal Oxide Semiconductor) structures is the film and semiconductor interface quality and the resulting high interface state density. Therefore, $HfSiO_4$ was coated on n-Si (100) using RF magnetron sputtering and Electron Beam Physical Vapor Deposition (EB-PVD) systems and the structure was annealed under nitrogen at RT, 300 ^oC, 500 ^oC, 700 ^oC, 900 ^oC in this study. The crystal and bond properties of the films were analysed by XRD and XPS (X-ray photoelectron spectroscopy). The change in binding energy of the peaks representing oxygen-defective bonds depending on the depth (surface and six depths in the film, and interface) was examined with the XPS depth profile. Afterwards, metal contacts were formed on $HfSiO_4$/n-Si structures by DC magnetron sputtering and MOS capacitors were obtained. The effective oxide charge and interface state densities were calculated for each device using electrical characteristics. In the last part of the study, a connection was established between structural analyses and electrical characteristics, and it was determined which method produced $HfSiO_4$ film gave better results in terms of electrical performance. It was found that the interface state density was lower in the structures produced with the EBPVD system compared to those produced by RF magnetron sputtering.

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On the structure and magnetic properties of $BaFe_{10}Al_2O_{19}$ nanohexaferrites

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M-type hexaferrites have attracted strong attention for many years due to their exceptional magnetic properties favourable for various specific applications, including permanent magnets, high-density recording media, microwave absorption devices and stealth technology among many other targets. Herein, we report the effects of diamagnetic dilution of exchange interactions in M-type hexaferrites expressed through the structural, morphological, and magnetic properties of Al-substituted barium hexaferrite ($BaFe_{12-x}Al_xO_{19}$, x=2) powders investigated by X-ray and neutron diffraction, scanning electron microscopy and SQUID magnetometry.

For the substitution of Fe by Al in $BaFe_{12}O_{19}$, there is contradictory evidence in the literature. Some authors generalize partial deterioration of the magnetic parameters and in particular the saturation magnetization, while others report certain characteristics improved, e.g. increased coercivity. To also address the possible effects of the preparation procedure, the studied hexaferrites were synthesized using two different soft chemistry methods, sonochemical co-precipitation and auto-combustion, followed by high-temperature annealing of the precursors. X-ray and neutron powder diffractograms revealed the formation of well crystallized single-phase in the P63/mmc space group. The presence of only one magnetic entity but in different valence states and the corresponding interactions of cations distributed in the crystal lattice sites contribute to the diverse magnetic behavior. Depending on the soft chemistry method, powder samples consisting of particles with an average size of 80 - 200 nm were produced. The particles with a size below 110 nm did not possess a completely formed hexagonal shape. The sonochemical co-precipitation powders have an average particle size of 160 nm with well-developed hexagonal shape and the hysteresis loop shape is typical for two magnetic phase material. The critical diameter for single-domain barium hexaferrite particles is about 460 nm and makes it plausible to infer that both preparation routes resulted in single-domain $BaAl_2Fe_{10}O_{19}$ nanoparticles characterized by a narrow size distribution. The particles were agglomerated due to the strong attractive magnetic force and high surface energy of the nanoparticles. Room temperature values of the saturation magnetization M_s and coercive field H_c for sonochemical co-precipitation powders were 59 emu/g and 2.4 kOe, whereas M_s and H_c of auto-combustion powders were 15 emu/g and 5.8 kOe, respectively. The temperature dependence of magnetization in ZFC and FC measurement at 100 Oe indicated occurrence of magnetic phase transitions in the temperature range 260-300K for the sonochemical co-precipitation powders and around 80K for the auto-combustion powders.

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Stress effect during double irradiation of WC-10Co alloy with high-energy xenon ions and 1.25 MeV gamma

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Tungsten carbides with cobalt as a binder at various volume fractions (WC-xwt.%Co), also known as "hard metal alloys", have found wide application in various fields such as cutting, rock drilling and machining tools due to their high strength and hardness, good fracture toughness and wear resistance at high temperatures. In addition to the well-documented advantages with respect to their thermophysical properties the hard metal alloys possess also a combination of suitable nuclear properties (large thermal neutron absorption cross-section, high atomic packing). The increased ductility due to the presence of Co is expected to result in reduced material sputtering in the plasma, which should lead to increased duty cycle times. The available data about the tolerance of the hard metal alloy to irradiation is mainly focused on ion implantation procedures, used for improving its tooling properties by enhancing its surface mechanical properties. We report results on the structure of a hard metal alloy of WC-10 wt.% Co before and after irradiation with gamma rays and swift heavy ions. For irradiation we used a ^{60}Co gamma irradiator to accumulate a gamma dose of 157, 1569, 3609 and 4708 kGy at a dose rate of 6.05 Gy/s and 167-MeV ^{132}Xe ions generated at four fluences (ion/cm^2): 1.0×10^{12}, 5×10^{12}, 1.0×10^{13} and 3.38×10^{14}. Positron Annihilation Spectroscopy (PAS) was used to study the dose dependence of defects' structure influenced by the 1.17 MeV and 1.33 MeV gamma energy. The microstructural evolution with increasing irradiation fluence was evaluated from X-ray diffraction (XRD) and neutron diffraction (ND) data. The Rietveld method using the FullProf software was used to reveal the structural details and phase composition from measured XRD and ND diagrams. The diffraction data unambiguously show a decrease in interplanar distances *d* with increasing irradiation dose, relative to the peak corresponding to the (001) crystallographic direction. A pronounced increase in the intensity of the specific peak and a simultaneous decrease in its width are clearly observed. We address the local effect caused by the kinetic energy of the bombarding ions, which energy is converted into heat, leading to the migration of defects to the surface of the grains and a reduction of the internal stress between the carbon and tungsten layers in the studied alloy. The effect of pushing the cobalt atoms and their migration into separate two-dimensional regions along the tungsten layers (dislocation loops of cobalt atoms) is also discussed. The mentioned effect was already considered for the WC-6wt.%Co alloy (DOI:10.1016/j.ijrmhm.2022.105865), but the presence of a higher percentage of cobalt in the studied alloy provided additional clarity in the analysis of the formation of the dislocation loops, as well as the kinetics reflecting the formation of secondary tungsten carbides from the rich W-C phase diagram enriched with x wt.%Co.

Extraction-chromogenic systems for gallium(III) based on azo dyes and xylometazoline hydrochloride

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Two liquid-liquid extraction-chromogenic systems for Ga^{III} based on azo dyes (ADs) and xylometazoline hydrochloride (XMH) were studied. The ADs used were 4-(2-pyridylazo)resorcinol (PAR) and 4-(2-thiazolylazo)resorcinol (TAR). The optimum conditions for the formation of ternary complexes with general formula $(XMH^{+})[Ga^{III}(AD^{2-})_2]$, which are readily extracted into chloroform, were found: pH, AD concentration, XMH concentration and extraction time. The following extraction-spectrophotometric characteristics were determined: absorption maxima (λ), molar absorptivities (ε_λ), limits of detection (LOD), limits of quantitation (LOQ), constants of extraction (K_{ex}) and fractions extracted (E). The system in which AD = PAR has better performance: $\varepsilon_{512} = 9.9 \cdot 10^4$ dm^3 mol^{-1} cm^{-1}, LOD = 2.8 ng cm^{-3}, LOQ = 9.4 ng cm^{-3}, Log K_{ex} = 4.1 and E = 97 %. Extraction equilibrium with this reagent is achieved in a short time (only a few seconds) and the optimum pH interval is wide (5.1 – 7.8).

Keywords: gallium(III), azo dye, xylometazoline, ion-association complex, liquid-liquid extraction, spectrophotometry

Study on the complex formation of the anionic chelate of Mo(VI) with bidentate ligand and the cation of monotetrazolium salt for its potential determination in biological systems

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The complex formation between the yellow anionic chelate of molybdenum(VI) with the bidentate ligand 3,5-dinitrocatechol (3,5-DNC) and the organic tetrazolium cation of 2-(4-iodophenyl)-3-(4-nitrophenyl)-5phenyl-2H-tetrazolium chloride (INT) in the liquid-liquid extraction system Mo(VI)–3,5-DNC–INT–H_2O–$CHCl_3$ was studied by spectrophotometric method. The optimum conditions for the chelate formation and extraction of the ion-associated complex Mo(VI)–3,5-DNC–INT were established. The equilibrium constants, needed for the quantitative assessment of the extraction equilibrium, were calculated. The molar ratio of the components, determined by independent methods, showed that the complex could be represented with the general formula $(INT)_2\{MoO_2[O_2C_6H_2(NO_2)_2]_2\}$. Based on the values of the equilibrium constants, the recovery factor, and the analytical characteristics, we can conclude that the extraction system Mo(VI)–3,5-DNC–INT–H_2O–$CHCl_3$ can be applied for determination or trace of Mo(VI) in ion associated form in biological, medical and pharmaceutical samples.

Keywords: molybdenum(VI), 3,5-dinitrocatechol (3,5-DNC), 2-(4-iodophenyl)-3-(4-nitrophenyl)-5phenyl-2H-tetrazolium chloride (INT), ion-association complex, liquid-liquid extraction, spectrophotometry

Using FTIR, FT-Raman and XRF techniques for characterization of perlite bearing construction material and its sources of provenance

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Berislăveşti Monastery is a valuable monument of late feudal architecture, founded by the boyar Sandu Bucşenescu and his wife Maria. The monastic complex is located 8 km from Călimăneşti, in Berislăveşti commune, Vâlcea, Romania. Recent rehabilitation works of the cell complex highlighted the need for some restorations. For characterizing the materials and finding the most inspired restoration solutions, a series of samples were extracted. Some are new renovation plasters, applied to the lower part of the wall on the west side of the complex, on the face from the inner courtyard of the monastery, and others are original plasters (probably dating from the interventions carried out during the 20th century), from the eastern side of the enclosure wall, the outer face. Although the general appearance of the plasters was very similar, the petrographic analyzes showed that the plaster used for the western wall includes, besides lime mortar, an unknown material in its composition, unlike the eastern wall of the enclosure. It was most likely a constructive solution that would confer an improved behavior concerning a permanent contact with meteoric waters. FTIR, FT-Raman and XRF techniques, were able to highlight the entire composition of the plaster on the western wall. It includes perlite, a natural material that, through thermal treatments, leads to an expanded form, with heat-insulating and sound-insulating properties. Perlite is an amorphous volcanic glass that, through the thermal expansion process, loses water and acquires a light structure, with a density several times lower. It is a non-renewable material, the best-known sources of raw material in the context of the Romanian construction market being: China, Turkey, Greece, Hungary. Extraction quarries are also known in Romania, although the main sources are exhausted. The comparative analysis of FTIR, FT-Raman and XRF spectra on sintered materials from different origins were able to establish the composition, the specific impurities and finally the source of the original perlite used in the plaster formation. Most probably it originated from Romania. Chemical analyzes completed the information regarding the recipe: 25% white granules and fine sand / mineral bearing impurities, and 75% calcite in the final plaster. In principle, compared to the original recipe: 1/3 granules and 2/3 quicklime. The heating of the granules to remove water, assuming the existence of the amorphous form $SiO_2 \cdot nH_2O$, and the subsequent mixing in quicklime, was highlighted. Application and hardening can produce the removal of water not only by drying, but also by three-dimensional distribution in the mass of the plaster during restoration of amorphous silica.

New X-ray fluorescence analyses on Scythian-type arrowheads and arrowhead-shaped tokens from Histria and Tomis (Romania)

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The Scythian-type arrowheads modified to be used as tokens and the specially cast tokens in the shape o arrowheads are possible creations of the Greek colonies from the western coast of the Black Sea during the Archaic period. They are part of the category of Greek items which had a strong influence on the local communities, in the context of economic and commercial exchanges, and through the diffusion in the Istro-Pontic space and in the northwestern coast of the Black Sea. The presence of arrowhead-shaped tokens in the local environment of the Dobrudja area is no longer an insignificant part of the repertoire of monetary signs discoveries. The documented material was subjected to elemental composition analysis in order to identify technological production processes and to identify some clues regarding the origin of the constituent metal (from the perspective of metal ores and geological deposits). These pieces were analyzed using the X-Ray Fluorescence (XRF) method, following which two types of alloys were identified: the "classical" Cu-Sn-(Pb) bronze, which is the most common, presenting variable amounts of Sn (in order to increase hardness) and Pb (to facilitate easier casting), and the another with a Cu-Sn-Pb-Sb combination.

This result could be interpreted in various ways:

- the existence of either distinct chronological stage of making the respective items;
- different raw material sources exploited in order to obtain two types of alloy; or
- their production in two different production centers. One problem to solve is the presence of antimony and manganese in the metal composition.

Antimony is a component of polymetallic geological deposits, its presence being an indicator for the use of enriched secondary sulphide ores (fahlerz ores) in bronze metallurgy, ores including copper, arsenic, antimony, but also, in small quantities, silver, nickel and bismuth. Antimonial bronze is suggested to be present in southern Russia, in association with pyritic copper mines in the South Caucasus.

Co-60 gamma irradiation response on the structural and electrical properties of silicon nanowire-based Al/SiO_2/SiNWs/n-Si MOS devices

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In this work, we synthesized Silicon nanowires (SiNWs) using metal assisted chemical etching method (MACE) and determined the gamma-irradiation response on Al/SiO_2/SiNWs/n-Si MOS devices. XRD and SEM techniques were used to study the crystalline structure and surface morphology of the fabricated SiNWs. The gamma irradiation response of the MOS capacitors was investigated by exposing the capacitors at a dose rate of 20Gy/h to a total dosage in the range of 1Gy to 40Gy. The C-V and G_m/ω-V measurements were performed before and after gamma irradiation at 1MHz. The shifts in the flat-band voltage ΔVfb and mid-gap voltage ΔVmg along with an increase in accumulation capacitance indicates that irradiation induced defects in the oxide layer and is responsible for the interface trap charges.

Keywords: silicon nanowires, cobalt-60 gamma ray irradiation, oxide-trap charges(ΔNox), interface-trap charges(ΔNit), interface states density(Dit)

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Machine learning model for classification of space radiation

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The aim of this research is to create a model which can help classifying the gamma and hadron radiations (for example, in astrophysics and semiconductor device reliability analysis) using machine learning (ML) techniques like Logistic Regression, Decision Tree, Random Forest, and Gradient Boosting. The research motivation was to distinguish between gamma and hadron rays and gain insights into the most energetic and exotic phenomena occurring in the universe. By separating these two types of rays, the scientists can filter out background noise and focus on the genuine gamma-ray signals. This distinction ensures that observations and measurements are not contaminated by hadronic signals that can mimic gamma-ray signatures. Deploying these separation ML techniques, the processes associated with gamma rays, such as birth and death of stars, cosmic explosions, and behaviour of matter in extreme conditions, as well as, the processes associated with hadron rays, such as single event effects (SEE) in semiconductor devices can be reliably investigated. Performance metrics of the selected machine learning techniques (Accuracy, Precision, and Recall) have been calculated and presented in a table.

Keywords: machine learning, gamma radiation, hadron radiation, classification

Robust systems and technology dissemination for space applications: From cross-layer analytics to an open-access reliability framework

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IHP is one of the world's leading research institutions in the field of silicon/germanium electronics. In this field, it has extensive, closely coordinated expertise in semiconductor technology, materials research, high-frequency circuit design and system solutions that are currently applied in several domains, but in particular in the space one. Space domain, across the years, has become the natural IHP's vocation. Facing this reality, this paper briefly describes the recent technological achievements and pave the next years' roadmap of the IHP's System Architectures (SyA) Department on the design of cutting-edge integrated circuits (ICs) for space application. Among these achievements, it is worth mentioning the development of multicore processors based on the RISC-V architecture, silicon lifecycle management based on on-chip cross-layer sensing and analytics, and an open-access reliability framework to allow ease-access, to scientists, engineers and students from all over the world, to the company's technology.

Agile hardware development flow for radiation-hardened system in aerospace applications

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As transistor technology advances into the deep nanometer range, modern Integrated Circuits (ICs) face increasing radiation-induced challenges, particularly in applications where reliability is crucial, such as in space missions. The agile hardware development approach, known for its adaptability and rapid IC development, stands out as a promising alternative to conventional water- fall methodologies. This paper proposes a high-reliability agile hardware design platform, designed for rapid integration and evaluation of radiation-hardened system designs. It includes features such as reliable IP integration, agile fault injection, and real-time system reliability monitoring and adjustment. Our method encourages continuous cycles of integration, evaluation, and improvement, facilitating swift adaptation of IC designs to the demands of radiation-hardened environments, while avoiding both over-protection and under-protection of the system. By adopting agile practices, we can significantly shorten the development timeline for reliable systems, ensuring the ICs achieve the required levels of radiation protection and strike a balance between system reliability, time-to-market, performance, and other critical factors.

A survey on multi-level fault injection in AI accelerators

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As the deployment of artificial intelligence (AI) accelerators becomes increasingly prevalent across various domains, ensuring their reliability and robustness under adverse conditions is essential, particularly in safety-critical applications (i.e. automotive, healthcare, space missions, etc.). Fault injection analysis emerges as an essential technique for evaluating the reliability of AI accelerators against various fault models at multiple levels of abstraction. This study presents a comprehensive survey of multi-level fault injection (FI) techniques in AI accelerators, encompassing physical, logical, architectural, and software levels. We explore various fault injection methodologies and aim to provide insights into the challenges, trends, and future directions in multi-level fault injection analysis for AI accelerators. Each abstraction level of FI analysis presents unique insights into different aspects of the system's reliability and resilience, allowing for targeted improvements and optimizations to improve overall system performance and safety. Future 6G communication infrastructure systems, serving as the central nervous system of a digital economy, are expected to consist of integrated ground, aerial, and space communication systems. In this regard, the criteria for speed, reliability, security, and seamless connectivity will reach unprecedented levels, and the requirement for a thorough reliability analysis will become even more critical. Thus, understanding the strengths and limitations of different fault injection techniques at various levels of abstraction can assist in effectively evaluating and enhancing the resilience of AI accelerators, thereby advancing the deployment of AI models in safety-critical applications.

Peakrad – A completely European, ITAR-free microcontroller for space applications

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In the past few years, low-cost small satellites have become the focus of researchers. Space agencies have demonstrated their potential for scientific research and practical applications in Earth Observation, Science Mission, Human Spaceflight, Space Transportation, Telecommunications, Navigation, Space Security, Robotic Exploration, Unmanned Aircraft Systems (UAS), Defense Applications, etc. The availability of low-cost small satellites is an important issue for various scientific and commercial projects. The recognized potential for revolutionizing space science, experimentation, and operational use empowers small satellites to be part of a strong business future in space applications. In such a scenario with exponential growth, it is possible to observe that today's small satellites are mainly powered by traditional electronics, increasing new capabilities but reducing the reliability of such systems compared to traditional missions.

In this context, the EU project MORAL targeted the development of a microcontroller IC called Peakrad and the corresponding accompanying software. Peakrad is a completely European, ITAR-free microcontroller for space applications. It is based on the novel Peaktop architecture (incl. novel open access ISA) and includes a formally-verified C compiler, real-time operating system, toolchain, and corresponding demonstrator board.

One key aspect of Peakrad development is the radiation hardening methodology, which is implemented at the different abstraction layers. At the level of complex digital sequential cells, the TMR (triple modular redundancy) methodology has been applied for filtering SEUs while timing filters address SETs. SETs in control logic are addressed by specific combinational cells and pre-tested for SET sensitivity. The error accumulation is addressed at the system level using ECC and scrubbing in memory.

The complete RTL processor core was developed and verified in extended simulations. The complete RTL platform is also mapped to an FPGA used for co-verification. After the final integration and back-end design, the Peakrad was fabricated targeting the SG13RH technology. The fabricated chip was functionally tested and evaluated under radiation. Radiation test results show that the Peakrad remained functional within the specifications after 106 KRad(Si) for total ionizing dose (TID), and according to single event latch-up (SEL) results obtained at high temperature, it is not sensible to destructive radiation events. The linear energy transfer (LET) threshold for non-destructive events (SEE – SEU – SET) exceeds 15 MeVcm2/mg, so it is not sensitive to protons. SEE rates presented for a typical GEO orbit are considered very low; therefore, the Peakrad microcontroller is suitable for any space mission orbit and duration.

The role of low-energy (< 20 eV) electrons in astrochemistry

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We demonstrate for the first time that Galactic cosmic rays with energies as high as ~ 10^{20} eV can trigger a cascade of low-energy (< 20 eV) secondary electrons that could be a significant contributor to the interstellar synthesis of prebiotic molecules whose delivery by comets, meteorites, and interplanetary dust particles may have kick-started life on Earth. For the energetic processing of interstellar ice mantles inside dark, dense molecular clouds, we explore the relative importance of low-energy (< 20 eV) secondary electrons—agents of radiation chemistry—and low-energy (< 10 eV), non-ionizing photons—instigators of photochemistry. Our calculations indicate fluxes of ~ 10^{2} electrons cm^{-2} s^{-1} for low-energy secondary electrons produced within inter-stellar ices due to incident attenuated Galactic cosmic-ray (CR) protons. Consequently, in certain star-forming regions where internal high-energy radiation sources produce ionization rates that are observed to be a thousand times greater than the typical interstellar Galactic ionization rate, the flux of low-energy secondary electrons should far exceed that of non-ionizing photons. Because reaction cross-sections can be several orders of magnitude larger for electrons than for photons, even in the absence of such enhancement, our calculations indicate that secondary low-energy (< 20 eV) electrons are at least as significant as low-energy (< 10 eV) non-ionizing photons in the interstellar synthesis of prebiotic molecules. Most importantly, our results demonstrate the pressing need to explicitly incorporate low-energy electrons in current and future astrochemical simulations of cosmic ices. Such calculations are critically important for interpreting James Webb Space Telescope infrared measurements, which are currently being used to probe the origins of life by studying molecules found in ices near star-forming regions.

Effects of proton irradiation on probiotic strains

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Cosmic radiation is comprised from energetic protons (~95%) and nuclei with energy of >10 MeV/u. Since probiotics use at space stations, to study evolution and changes in the properties of probiotics under stressful flight conditions, including proton irradiation is need. Here we report the important genetic and physiological characteristics of two yeast probiotic agents – Biocodex (Franch) and Puratos (Belgium), and two new lactobacillus strains after proton irradiation.

The results of the previous study strongly indicate a close relatedness of *Saccharomyces boulardii,* derived from the Biocodex (French) and Puratos (Belgium) probiotic agents, to *Saccharomyces cerevisiae* laboratory strains. Morphological and physiological characteristics of commercial *S. boulardii* were consistent with those of laboratory strain of *S. cerevisiae*. However, *S. boulardii* isolates show some differences, particularly in relation to nucleotide sequences, ploidy, antibiotic resistance, which are important characteristics for a microorganism to be used as probiotics. In parallel two *Lactiplantibacillus plantarum* (L6 and L9) from traditional product "katak" were used. They were pre-selected as candidate probiotics, with high viability in simulated *in vitro* gut passage.

Proton exposure was performed at the clinical proton beam facility of the Medico-Technical Complex (LNP JINR, Dubna). Lyophilized cells in Eppendorf tubes were irradiated with unmodified 170 MeV proton beams (LET 0.54 keV/μm). Dose rate was 0.6 Gy/min. A 52-mm Plexiglas absorber was used. Calibration was performed by ion chamber TM30013 (PTM UNIDOS-E).

It was shown that radiosensitivity and mutability of the lyophilized yeast strains were different and corresponded by their ploidy, i.e. Biocodex was diploid and Puratos was tetraploid. The last of them was more sensitive and probiotic strains were more sensitive than laboratory strain. The frequency of drug^R-mutations was respectively low. Lactobacillus strains L6 was more sensitive to proton irradiation, survival was low and drug^R-mutations induced more efficiently. The growth of both lyophilized lactobacillus strains in MRS broth and in modified MRS with a single carbon source FOS was not affected by proton irradiation. Moreover, L9 strain showed enhanced growth. While the viability in the presence of 10% v/v pancreatin was lower for the both irradiated with 20 Gy strains. Further characterization of the genetic basis of resistance to stress conditions will allow the selection of probiotics for the purpose of long-duration space missions with non-harmful exposures to ionizing radiation.

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Non-linearity investigation of a novel hybrid-dosimetry system according to IEC 62387:2020

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The development of new technologies in dosimetry is aimed towards enhancing the performance and capabilities of radiation dose measurement systems. Examples of such advances include hybrid dosimeters, spectrodosimetry, computational dosimetry etc. One of the objectives of 22NRM07 GuideRadPROS Joint Research Project is to address the need for revision and update of IEC standards to accommodate these technological advances. The scientific work package 4 of this project directly assesses these needs by evaluating new technologies and identifying necessary improvements to ensure compliance with current standards and addresses the potential need for their update, or the need for new standards. Hybrid dosimeters stand out by integrating multiple dosimetry techniques and combining their strengths to overcome their individual limitations. Consequently, hybrid dosimeters deliver improved accuracy and reliability in radiation protection dose measurements, which also makes them suitable for diverse applications in medicine, industry, and research. In relation to that, testing of hybrid dosimeters was conducted in accordance with the guidelines outlined in IEC 62387:2020. One of these tests includes non-linearity assessment which is important for the evaluation of the dosimeter's response across a wide range of radiation doses. This test was conducted in the reference X-ray and gamma-ray radiation fields, established according to ISO 4037:2019. Non-linearity was investigated within a wide range of dose values, corresponding to different exposure situations, including low doses encountered during regular monitoring, and the situations of exposure to high doses of radiation due to accidents. The linearity and accuracy of dose measurements, particularly for lower doses, meet the requirements of the standard and dosimeters demonstrate excellent performance.

Keywords: area monitoring, dosimeter, harmonization, individual monitoring, radiation protection, standardization

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Assessing radiation exposure and room effect in the new lab with a DD neutron generator at STU

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The study presents an extensive simulation analyzing radiation exposure levels in an under-construction laboratory at STU, equipped with a deuterium-deuterium neutron generator. The laboratory's design and radiation shielding requirements are determined based on available premises and their proximity. Due to the complexity of the task, resource-intensive SCALE MONACO Monte Carlo simulations are employed to evaluate ambient dose rates within and near the projected premises. Various approximations concerning source anisotropy, secondary gammas, bremsstrahlung, and source positions are explored. Notably, the facility aims to support precise fast neutron radiography of large industrial components, thus the first estimation of the room effect is carried out.

Sensitivity of neutron energy spectrum to estimate radioactive source term in bio-shield of pressurized water reactor

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Korean government has a program for dismantling/decommissioning of Kori Nuclear Power Unit 1 which was shut down permanently in June 2017 after 40 years of operation. When we consider a practical process such as decontamination, cutting, and radioactive waste management, radiation safety is crucial to protect workers from high level radioactivity. The pervious study showed that the neutron energy spectrum in the outer region of bio-shield is significantly softened. Thermalized neutron can increase a capture cross-section of bio-shield materials. It indicates that sensitivity of neutron energy spectrum should be considered accurately. In this study, the spatial dependency of the neutron energy spectrum is investigated in the bio-shield region of a pressurized water reactor.

The ultimate goal of this study is to optimize spatial discretization in terms of accuracy and efficiency of neutron transport calculations to obtain one-group effective cross-section. Firstly, the sensitivity of neutron energy spectrum is examined as the function of distance from the reactor core. For a case study. the bio-shied is divided into 2, 3, 4, 5 regions of concentric shell in each case. From the calculation results, an optimal number of space differencing in the radial direction is determined.

The previous study calculated the source term inventory for 3 cases of different height from the center of bio-shield. The results are reasonable that the radioactivity of major nuclide in the central region was considerably high due to high flux level. It is also noted that the significant difference is shown between the upper and the lower region, caused by the asymmetric structures in the axial direction. This study examines the sensitivity of neutron energy spectrum considering the height in the axial direction as well as the distance from the reactor core.

The calculation of radioactivity of nuclide includes the terms of multiplying the neuron flux and one-group effective cross-section. It is general that the neuron flux decreases apart from the reactor core. This study also discusses an effect of spatial discretization of neutron flux distribution in the bio-shield region.

Keywords: pressurized power reactor, radioactive source term, effective cross section, neutron energy spectrum, bio-shield

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Consideration of operation history for estimation of radioactivation in pressure vessel of Kori Nuclear Power Unit 1

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Considering dismantling/decommissioning of nuclear reactor, radioactivity calculation is required for nuclear reactor components including baffle, barrel, pressure vessel, bio-shield and so on. Bateman equation for radioactivity calculation is governed by one group effective cross section and neuron flux level. In general method to calculate radioactivity in reactor structure components, standard reactor core is considered of which power distribution are specified as a representative. The previous study examined an effect of a practical history of reactor operation on radioactivity calculation. The radioactivity was calculated for the defected former bolts of the Kori Nuclear Power Plant Unit 1 in Korea considering the actual monthly operation history. The results showed that radioactivity considering operation history is significantly lower than the conventional method.

This study discusses an effect of the actual operation history on the radioactivity calculation for pressure vessel of a pressurized power reactor. Effective cross sections are dependent into neutron energy spectrum. From the previous study to calculate radioactivity in the outer region of rector core, it is noted that the neutron energy spectrum is considerably hard in the region of pressure vessel because the thermal neutrons are absorbed by the fuel material with high abortion cross section in the core region. In this study, the sensitivity of the neutron energy spectrum to the actual operating history is investigated in terms of the effective cross-section and activity of radionuclides in the pressure vessel region.)

Keywords: pressurized power reactor, radioactivity calculation, effective cross section, operation history, pressure vessel

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Dismantling of Theratron Equinox head with Co-60 radioactive source and personal doses assessment

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In this paper are presented some technical aspects from the decommissioning process of a Teletherapy machine model "Theratron Equinox" that contained category one Co-60 radioactive source. This machine was used for several years in "Mother Tereza" University Hospital Centre for radiotherapy purposes. The dismantling process of Theratron Equinox head with Co-60 was carried out by International Atomic Energy Agency (IAEA) experts in collaboration with Institute of Applied Nuclear Physics experts (IANP).

This study includes some technical aspects of dismantling, security, transport and personal doses assessment during the dismantling procedure of teletherapy machine based on the Albanian Laws. The dismantling process of Co-60 source was carried out by removing the teletherapy head which contained the radioactive source of Co-60 from Theratron Equinox machine and the Teletherapy head was used as a container for the source. After dismantling the Teletherapy head was transported to the National Radioactive Waste Storage Facility for temporary storage.

During the dismantling process were used thermo luminescence dosimeters (TLD-s) and Electronic Portable Dosimeters (EPD-s). The personal dosimeters (TLD-s) of the team who participated in the dismantling process showed that radiation doses received were less than 0.10 mSv and ambient dose equivalent H*(d) measured during this process was 0.8 μSv/h. These values showed that the workers dose was obtained without over exposure and the dismantled teletherapy head of Theratron Equinox machine was safe during all the dismantling process.

Determination of activity concentration in different coffee samples consumed in Albania and their radiological risk in the human body

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In this paper, the levels of radioactivity were determined in twenty-one coffee samples consumed in Albania and the annual effective dose was estimated. Coffee is becoming one of the most popular stimulating drinks in many countries in the world. The health benefits of coffee are directly related to the contents of bioactive compounds, accumulation of chemical elements and other micronutrients. The natural and artificial radionuclides in the soil can be taken up by the coffee plant, subsequently, they enter by ingestion into the human body through the consumption of coffee and thus it is important to estimate radiological risk. Gamma-ray spectrometry and an HPGe detector were used to analyze and perform the measurements of coffee samples collected. The results indicated that natural radionuclides of ^{40}K and ^{226}Ra were detected in all selected samples, whereas the presence of ^{232}Th was detected in 12 samples. The artificial radionuclide of ^{137}Cs was present only in three samples at low levels. The average values of activity concentration of ^{40}K and ^{226}Ra were found to be 577.15 ± 25.40 Bq kg^{-1} and 9.52 ± 0.54 Bq kg^{-1}. The highest values of ^{232}Th and ^{137}Cs were found to be 1.55 ± 0.24 Bq kg^{-1} and 0.28 ± 0.07 Bq kg^{-1}, respectively. The average value of the Annual Effective Dose (AED) due to the consumption of coffee was found to be 28.61 μSv y-1. The results of activity concentrations and dose were compared with similar literature and international reference values. The annual effective dose in this study was lower than the average value by UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) reports and the recommended limit of 1 mSv y^{-1} by WHO (World Health Organization) and ICRP (International Commission on Radiological Protection) for adults. Therefore, our results indicated that the use of these types of coffee is safe for consumption with acceptable radiological risk and none of them had any significant radiological impact on the health of the human body.

Keywords: activity concentration, annual effective dose, gamma-ray spectrometry, radionuclide

Gamma spectrometry analysis of natural radioactivity in soil samples from the phosphate area in southern Tunisia and its radiological risk assessment

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Introduction. Human exposure to ionizing radiation from natural sources is an unending, sustained and unavoidable phenomenon on earth. Gamma radiation emitted by natural radioactive materials provides external exposure. When received at a high dose rate, it is known to be associated with elevated cancer risks. Natural radionuclide concentrations are influenced by various activities such as uranium mining and processing; phosphate fertilizer production; or natural gas and oil production. The present study investigates the natural radioactivity levels in soils within a 5 km radius of phosphate mining and processing industries around the phosphate area south Tunisia. Since phosphate industries can influence natural radiation levels in a region, the study aims to assess radiation doses and radiological risks from soil radioactivity in the vicinity of these industries.

Materials and Methods. Thirty-two soil samples were collected in the months of January-April, 2021, within a radius of 5 kilometers of phosphate mines and phosphate industries which cover both agricultural land and uncultivated land. The samples were then prepared following standard procedures described in EMBRAPA and IAEA reports and transferred into appropriate container, sealed for one month to achieve radioactive equilibrium between the radium nuclei and their daughters for gamma spectrometry measurements.

Concentrations of primordial radionuclides were measured by gamma spectrometer using a HPGe detector having 38% relative efficiency and an energy resolution of 2.1 keV at 1.33 MeV.

Results. The overall mean values of ^{40}K, ^{226}Ra, and ^{232}Th concentrations were 264, 27, and 13 Bq kg^{-1}, respectively. The activity of ^{226}Ra is about two times higher than that of ^{232}Th. The ^{232}Th to ^{226}Ra. Activity ratios were further determined in this study in order to give a clear insight into the level of radioactive contamination of the investigated site. When the ratio of the activity values is <1 in soils, it can serve as an indicator of anthropogenic impact. The radionuclide activity values obtained in this study were lower than the worldwide average values reported by the united nation of scientific committee on the effect of atomic radiation (UNSCEAR).

From the radioactivity measurements, radiation hazard indices specified by the UNSCEAR such as radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), absorbed dose rates (D) and outdoor annual effective dose (AED) to the population for outdoor environment were determined. The Ra_{eq} values varied in the range 13.7-133.1 Bq kg^{-1} and were all less than the threshold limit of 370 Bq kg^{-1}. The calculated values of H_{ex} obtained in the present study, ranged from 0.04 to 0.4, which means that they were all lower than unity. For all the four sites, the overall mean value of D of 33.4 nGy h^{-1}, observed in the present study was lower when compared to the worldwide average of 57 nGy h^{-1}, respectively. Estimated overall mean value of AED for outdoor exposure was 40 µSv y^{-1} and it was lower than the average world recommended value of 70 µSv y^{-1} for outdoors. The ELCR mean value for outdoor exposure obtained in the present study was 0.1×10^{-3}, which was lower than the worldwide recommended value for outdoors.

Keywords: phosphate area, radium equivalent, external hazard index, annual effective dose, excess lifetime cancer risk

Assessment of radiological impacts of radionuclides in soil samples of Dajti National Park

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Twenty soil samples were selected in the tourist area of Dajti National Park (DNP) for the determination of radioactivity levels and as a result the assessment of radiological impacts. A gamma ray system with a High Pure Germanium detector (HPGe) for the determination of natural (^{226}Ra, ^{232}Th, ^{40}K) and artificial (^{137}Cs) radionuclides concentration in the soil samples is used. The average activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs were found to be 202.63 ± 4.12 Bq kg^{-1}, 67.95 ± 2.17 Bq kg^{-1}, 255.63 ± 10.15 Bq kg^{-1} and 28.31 ± 1.67 Bq kg^{-1} in soil samples, respectively. Based on the measured activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs different radiological parameters have been estimated to assess the radiological hazard of radioactivity such as total absorbed dose rate (D), the annual effective dose (AED) and excess lifetime cancer risk (ELCR).

The average value of the absorbed dose rate D (nGy h^{-1}) in the air at 1 m above ground level due to gamma radiation of the ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs from soil samples was found to be 146.16 nGy h^{-1}. The average value of annual effective dose (AED) for all soil samples was 179.26 μSv y^{-1}, which is higher than the world average value of 70 μSv y^{-1}. However, comparing the observed annual effective dose with the recommended limit of 1 mSv y^{-1} by the International Commission on Radiological Protection (ICRP) reports for members of the public, it is lower. The average excess lifetime cancer risk (ELCR) value was calculated to be 0.63×10^{-3}. Compared to the World's average of 0.29×10^{-3}, the lifetime cancer risk result is higher almost for all localities. Therefore, the all-average values of radiological hazard were higher than the world average, this implies that gamma radiation from the soil in this zone might increase the radiological risk for the population living or when used as a building material.

Keywords: radiological impacts, HPGe, annual effective dose, ELCR

Development of radiation countermeasures for hematopoietic acute radiation syndrome prophylaxis: Biomarker identification and validation for Animal Rule

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Exposures to ionizing radiation, whether intended or unintended, are currently an undeniable reality that carry potentially catastrophic health consequences. Therefore, medical preparedness and the availability of countermeasures are critical security issues, not only for the individual, but for the nation as a whole. Acute radiation exposure induces apoptosis, which results in the development of an illness termed acute radiation syndrome (ARS). Significant scientific advances have been made toward the development of safe, non-toxic and effective radiation medical countermeasures (MCMs) for ARS. However, to date only four radiomitigators including Neupogen, Neulasta, Leukine, and Nplate have received United States Food and Drug Administration (US FDA) approval for countering hematopoietic-ARS (H-ARS). A MCM that can be administered prior to lethal radiation exposure and that is capable of protecting the population at large remains a significant unmet need and has been recognized as a high priority by the US government. A number of promising MCMs (radioprotectors and radiomitigators) are currently under development. Two radioprotectors, BIO 300 (a novel formulation of genistein - 4',5,7-trihydroxyisoflavone) and gamma-tocotrienol (GT3, a nutraceutical and a component of vitamin E) are noteworthy.

These candidate MCMs under development following the US FDA Animal Rule need to be evaluated and their dose for humans needs to be established based on appropriate biomarkers. Currently, we are investigating various biomarkers for radiation injury and MCM efficacy using various omic platforms including metabolomics/lipidomics, proteomics, transcriptomics, microRNA (miRNA), and the microbiome. Several protein/metabolite biomarkers for GT3 and BIO 300 using irradiated murine and NHP models have been identified and are being further validated in follow-up studies. The effects of BIO 300 on the gut microbiota and metabolome of mice exposed to cobalt-60 γ-radiation were characterized by bacterial 16S rRNA amplicon sequencing and untargeted metabolomics, respectively. Following FDA-approval, these promising agents would be useful at a local, national, or global level after a radiological or nuclear event.

Disclaimer: The opinions or assertions contained herein are the private views of the author and are not necessarily those of the Uniformed Services University of the Health Sciences, or the Department of Defense, USA. The author reports no conflicts of interest.

Occupational exposure of medical professionals – The BECOME (Brain CancEr risk in joint CohOrt of MEdical workers exposed to ionizing radiation in France, South Korea and USA) project

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Ionizing radiation (IR) at high and moderate doses (>100 mGy) is a known risk factor for cancer. At low doses, scientific evidence is growing and a recent joint analysis of three large cohorts of nuclear workers exposed to low-dose radiation for an extended period of time (INWORKS) revealed an increased risk of leukemia and solid tumors.

Medical radiation workers are the largest group occupationally exposed to IR, with an estimated 7.4 million practitioners worldwide. In 2018, nearly 222,000 medical workers in France were monitored for IR exposure. They accounted for 60% of the professionals monitored, but accumulated only 17% of the total occupational dose, with a mean annual effective dose of 0.3 mSv.

However, this low average exposure hides a significant disparity between the majority of medical radiation workers who receive very low doses and a small proportion who are exposed to higher doses, such as interventional radiologists or cardiologists and nuclear medicine workers. Long-term health effects (cancer and non-cancer) associated with exposure to IR by medical workers exposed to fluoroscopy-guided procedures or nuclear medicine procedures have been reported.

The brain, unlike the rest of the body, is unprotected by lead apron during medical procedures, and brain cancer is a specific health concern for medical workers. Few publications have reported increased risk of brain cancer, but no large, well-controlled epidemiological study has ever shown a link in occupational cohorts.

The objective of the BECOME project is to study the risk of mortality from central nervous system (CNS) tumor as a function of exposure to IR in medical radiation workers.

The pooled case-control study will be nested in the French, the Korean and the US cohorts. Among these three cohorts, 257 CNS tumor deaths (193 in the USRT, 40 in the ORICAMs and 24 in the Korean cohorts) have been identified. Five controls will be matched to each case on year of birth, gender, country. The main outcome to be analyzed is death by CNS tumor, including benign tumors. A major challenge is the estimation of the dose received by the brain which can only be assessed from the dosimeters worn on the torso and sometime below the apron. Recorded doses will be converted into doses absorbed to the brain, using conversion coefficients considering thickness of apron and recording practices.

The joint analysis will improve the knowledge in the health risks associated with exposure to protracted or repeated low-dose of IR which are patterns of exposure relevant to the health practitioners and the public. The findings will contribute to improve radiation protection strategies for medical workers and to make the medical professionals more aware of the importance of radiation protection in their professional environment.

Estimation of the cumulative effective dose in patients with cardiovascular disease undergoing multiple radiological procedures in southern Brazil

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Cardiovascular diseases are one of the leading causes of global mortality, as evidenced by death statistics, according to data from the Pan American Health Organization (PAHO). According to the Department of Informatics of the Unified Health System (SUS), these diseases are also among the most common causes of mortality in Brazil. It is estimated that approximately 400 thousand Brazilians lost their lives due to these diseases in 2021 (PAHO, 2023). The diagnosis and treatment of cardiovascular diseases often involve imaging modalities that involve ionizing radiation, such as computed tomography (CT), interventional procedures (RIs), and nuclear medicine (NM). Although these procedures offer benefits to patients, it is essential to continuously monitor and control radiation exposure due to the potential for harmful health effects (Brambilla et al., 2021; Frija et al., 2021; Bosch et al., 2023; Li et al., 2020; Rehani et al., 2020). This study aimed to investigate radiation exposure in patients with cardiovascular diseases undergoing multiple diagnostic and therapeutic procedures at a public hospital in the southern region of Brazil. Quantitative, descriptive, exploratory, and retrospective documentary research was conducted, analysing data on effective doses from examinations and procedures performed on patients with cardiovascular diseases in the years 2022-2023. The sample consisted of 658 examinations and procedures, including CT (n=273), fluoroscopy-guided RI (n=294), and NM (n=91), performed on 379 patients over 18 years of age from January 1, 2022, to January 31, 2023. The analysis revealed a wide variation in the effective doses received, with mean exposure values of 17.68±22.09 mSv for CT, 16.26±25.02 mSv for RI, and 16.65±5.1 mSv for NM. The highest effective dose was found in a female patient who underwent percutaneous transluminal coronary angioplasty (PTCA) and who received 312.02 mSv of exposure in this single procedure. The doses varied considerably among the different modalities, with dose intervals of 125.15 mSv for CT, 311.94 mSv for RI, and 22.42 mSv for NM. Despite differences between and within modalities, there was no significant variation in the mean exposure values. It is hoped that the results of this study will encourage the implementation of a local system for recording and monitoring radiation doses received in such procedures, assisting in the adaptation of work processes and guiding radiation protection programs and professional training.

Review of different methods used to estimate occupational radiation dose to the lens of the eye in interventional cardiology

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Background. Monitoring operator eye dose in interventional cardiology is essential due to its sensitivity to radiation and the need to comply with dose limits. Nevertheless, determining eye dose remains a challenging task.

Aims. Herein, we review different methods of measurement in interventional cardiology to offer guidelines for practitioners and physicists working on occupational radiation protection of the eye lens

Methods. We have published scientific literature in major databases including Web of Science, Scopus, and PubMed on the subject using the following keywords: eye lens dose measurements in interventional cardiology, Hp(3) in interventional cardiology, estimates of eye lens dose from whole-body dose, and eye lens dose conversion coefficients in cardiology. The identified subjects were analysed based on the predetermined inclusion and exclusion criteria. The selected data were critically reviewed and analysed to determine the best current eye lens dosimetry methods, their advantages and disadvantages, uncertainties in measurements, and practical recommendation

Results. Using these keywords, we identified 360 participants from a major scientific community. After removing duplicates and screening subject titles and abstracts, 30 papers were eligible for inclusion in the review. Methods used for eye lens dose estimates include direct measurement dosimeters based on thermoluminescence dosimeters (TLD) using LiF:Mg,Ti and LiF:Mg,Cu,P TLD crystals or optical luminescence dosimeters (OSL) using Al_2O_3:C and BeO crystals[DOI 10.1088/1361-6498/aab2e4]. Most clinics estimate eye lens dose using conversion coefficients from dose as product (Hp(3)/DLP), conversion coefficients to the personal dose equivalent (Hp(3)/ Hp(10)), and dose equivalent to the skin (Hp (3)/Hp (0.07))[DOI: 10.1093/rpd/nct180].

Conclusions. Different methods used to estimate the operator's eye lens dose in interventional cardiology have been explained. Emphasis is placed on dosimeter suitability and the reported dose conversion coefficient from various available dose information sources. This study is anticipated to provide important guidelines to harmonize eye lens dosimetry interventional cardiology

Keywords: radiation protection, staff dosimetry, eye lens, cataract, personal dose equivalent

Evaluation of dose rate and dose uniformity of radiation field in Cs-137 gamma ray irradiation unit and X-ray irradiation unit

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The purpose of this study was to evaluate and compare the parameters of the strong radiation field produced by two irradiation systems, with gamma rays emitted by the Cs-137 radioactive source and X-rays generated by the X-rays tube. The ionizing radiation has been used to develop new varieties with additional economic value, improved resistance to pests and diseases and high nutritional value. These improvements can be achieved through mutations, which are transmissible changes that occur in the genetic material of living organisms. Plant induced mutation is a method that uses physical radiation to stimulate spontaneous genetic variation in plants to develop new crop varieties. In the frame of sustainable development of agriculture in Albania the Institute of Applied Nuclear Physics (IANP) in cooperation with research departments and institutes, for many years has used the GU-3 irradiation unit with Cs-137 Gamma radiation to induce mutations in plants. The GU-3 irradiator has been installed in 1986 and now its activity is around 7250 Ci. Since 2022 in IANP operates a new system, a non-radioisotopic alternative technologies, the RS-2400Q produced by Rad Source Technologies, which generate an intense X-rays field with equivalent photon energy of 94 keV. To evaluate the dose, dose rate and dose uniformity (DU = Dmin/Dmax *100 %) of the two kinds of irradiators units we chose the TLD-100H, produced by Harshaw with sensitivity up to 10 Gy. The measurements were performed using Harshaw TLD™ 6600 Plus Automated Reader. The experiments were carried out in air, water, wheat seeds and bean seeds. In the case of GU-3 irradiator we used 11 dosimeters to evaluate the set-up dose of 4 Gy, calculated from previous studies. For TLD in air, the dose was 3.25 Gy and dose uniformity was 79%, for TLD immersed in wheat seeds, the dose was 2.50 Gy and dose uniformity was 71% and for TLD immersed in bean seeds, the dose was 2.70 Gy and dose uniformity was 68%. The RS-2400Q irradiator holds six 830 mL canisters for 5L processing volume. Each canister has a diameter of 10.2 cm and the average dose rate in center was 16.47 Gy/min. We used 5 dosimeters to evaluate the dose rate and dose uniformity of 4 Gy set-up irradiation dose. For TLD in air, the dose at canister top / bottom was 5.3/4.3 Gy and dose uniformity was 78%, for TLD in water, the dose at canister top / bottom was 3.8/4.5 Gy and dose uniformity was 63% and for TLD immersed in bean seeds, the dose at canister top / bottom was 3.5/3.5 Gy and dose uniformity was 61%. The results of the study showed that the dose uniformity is almost the same in the case of air for both radiation systems and the dose measured in the irradiated volume is closer to the set-up values for the RS-2400Q system. Further evaluation will continue using GAFChromic films.

Keywords: irradiation, bread wheat, Cs-137, X-rays

Estimating the risk of radiation exposure from ^{210}Po through different pathways

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Humans are subject to exposure to various natural and artificial sources of radioactivity. Certain radioactive isotopes have the potential to enter the human body and induce internal radiation doses through processes such as ingestion, inhalation, and dermal absorption. It is imperative to assess the overall effective dose in order to evaluate the potential health risks associated with radiation exposure. The radiation dose magnitude is intricately associated with both the exposure duration and the radiotoxic characteristics of the radioactive source. According to the classification outlined in the International Atomic Energy Agency (IAEA) publication on radio-toxicity (IAEA TRS No. 15), ^{210}Po is categorized as a highly hazardous radionuclide.

This study focused on the estimation of committed effective dose equivalent (CEDE) resulting from the ingestion of food and total suspended particulates, as well as the inhalation of radioactive airborne particles in arid regions of Kuwait. Analysis was conducted on the presence of ^{210}Po in various food categories (both locally produced and imported), encompassing items such as grains, fruits, vegetables, meats, seafood, and assorted beverages, taking into account dietary patterns prevalent among the population. Furthermore, calculations were performed to determine the levels of ^{210}Po in fine particulate matter (less than 5 μm) present in the atmosphere of residential zones. Additionally, assessments were made regarding the concentration of ^{210}Po in total suspended particles. Utilization of models from the International Commission on Radiological Protection (ICRP) in conjunction with the Residual Radioactivity (ResRAD) software facilitated the computation of the effective dose resulting from ^{210}Po intake, thereby enabling estimation of the associated cancer risk.

Consequently, the predominant source of dose exposure attributable to ^{210}Po intake was identified as food consumption, accounting for approximately 117 μSv/y.

Patient radiation doses and Diagnostic Reference Levels (DRLs) for interventional cardiology procedures in Sudan

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The aim of this study is to assess patient radiation doses during interventional cardiology procedures in Sudan. Dosimetric data and the associated parameters were retrospectively recorded from the DICOM header for 3332 patients in 6 hospitals. The procedures were distributed as: 69 % cardiac angiography (CA), 2 % percutaneous coronary intervention (PCI), 18 % CA+PCI, 9.5 % pacemaker; and 1.4 % percutaneous transluminal mitral commissurotomy (PTMC). Diagnostic reference levels (DRLs) were set in terms of the Kerma area product (PkA) and cumulative air kerma (CAK) as 75 percentile of the hospital median values [Annals of the ICRP, 46(1), pp.1-144.NCRP, 2012.]. For the CA, CA+PCI, PCI, Pacemaker, and PTMC the DRLs in terms of PkA D were 42.6, 118.2, 118.2, 47.4 and 58.5 Gy.cm2, respectively. In terms of CAK, The DRLs were: .575, 2.093, 1.574, 0.406,.906 Gy, respectively. CAK values frequently exceeds the 3 Gy the onset for deterministic effect. Suggested DRls were comparable to those presented in the literature. the proposed DRLs were: The results revealed wide variability in patient doses among individual patients. Monitoring and recording patient dose data can be valuable for quality assurance and patient safety purposes.

The Harmonic (Health effects of cardiac fluoroscopy and modern radiotherapy in paediatrics) project

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The use of ionizing radiation (IR) for medical diagnosis and treatment procedures has had a major impact on the survival of paediatric patients. Although the benefits of these techniques lead to efficient health care, evaluation of potential associated long-term health effects is required. Until recently, most of our understanding of the effects of radiation exposure on children was based on large epidemiological studies where children were included as part of the groups under study (i.e. A-bomb survivors). These studies have recently been supplemented by large cohort studies investigating cancer effects of exposure to IR in childhood and adolescence in computed tomography scanning, showing an increased risk of leukaemia, lymphoma and brain tumors.

Complementary to the computed tomography (CT) studies, the Harmonic project builds the structure and instruments for the medical and scientific communities to evaluate the potentially detrimental effects of medical exposure to IR in children with cancer and cardiac defects, with the potential for advanced patient specific dose reconstructions and biological investigations.

The cardiac component builds the largest European pooled cohort of paediatric patients from Belgium, France, Italy, Germany, Norway, Spain and the UK to investigate, based on a common protocol, cancer risk following exposure to IR and explore the potential effects of conditions predisposing to cancer. The cohort contains approximately 90,000 patients who underwent cardiac fluoroscopy procedures (CFP) during childhood and adolescence. Harmonic develops software tools to allow dose reconstruction in CFP. The project's main outcomes will be leukaemia and lymphoma, which are among the most common paediatric cancers and are known to be linked to radiation exposure. Major efforts are put into estimating organ doses from cardiac procedures. A software tool is under development which will be provided to the scientific and medical community. Doses from other medical examinations (i.e. CT scans) will be estimated for a subgroup of patients.

Overall, the project aims at better understanding biological and health effects of radiation exposure during childhood since the paediatric population is usually considered as more radiosensitive than adults. Clinicians, patients, parents and carers will benefit from improved information on the potential radiation related risks from both radiotherapy and cardiac fluoroscopy. Our actions are expected to lead to improved patient outcome and raise awareness among health care professionals.

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Radiological characterization and risk assessment due to black walnut fruit tincture ingestion

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Black walnut contains a mixture of various pharmacologically active compounds, increasing interest in its products. However, there is little information available in the literature about the content of radionuclides in tinctures of medical plants. Therefore, the purpose of this work is to present the radiological characterization of black walnut fruit tincture and risk assessment due to ingestion.

The black walnuts were collected at location Serbia (43° 55′ 23.4″ N, 21° 22′ 7.2″ E). The tincture was obtained using an ultrasonic assisted extraction method at 40° C for 80 min. The grounded fruit was mixed with ethanol (70 % (v/v)) at solvent-to-solid ratios of 4:1 (v/w). Concentrations of natural radionuclides (^{210}Pb, ^{235}U, ^{238}U, ^{228}Ac and ^{40}K), as well as concentrations of ^{137}Cs as an artificial radionuclide, were analyzed in 200 ml tincture. The sample was measured in close to detector geometry using two coaxial HPGe spectrometers: AMETEK-ORTEC GEM 30-70, with 37 % relative efficiency and 1.7 keV resolution for ^{60}Co at the 1332.5 keV, and Canberra GX5019, with 55 % relative efficiency and 1.9 keV resolution for ^{60}Co at the 1332.5 keV. The sample was packed in the appropriate cylindrical geometry equal to efficiency calibration standards. The annual effective dose (Sv) was calculated using the amount of tincture consumed in a year (kg /y) (it is assumed that 10 ml of black walnut tincture is taken every day), the radionuclide specific concentration in the analyzed sample (Bq/kg) and the effective dose coefficient for ingestion of specific radionuclide for the adult (1.3 10^{-8} Sv/Bq for ^{137}Cs, 6.9 10^{-7} Sv/Bq for ^{210}Pb, 4.7 10^{-11} Sv/Bq for ^{235}U, 4.5 10^{-8} Sv/Bq for ^{238}U, 4.3 $\times 10^{-10}$ Sv/Bq for ^{228}Ac and 6.2 10^{-9} Sv/Bq for ^{40}K).

Obtained radionuclide concentrations for black walnut tincture are: < 0.3 Bq/kg for ^{137}Cs, (5.6 ± 06) Bq/kg for ^{210}Pb, (0.7 ± 0.2) Bq/kg for ^{235}U, (17.2 ± 1.7) Bq/kg for ^{238}U, (0.6 ± 0.1) Bq/kg for ^{228}Ac and (49.3 ± 2.8) Bq/kg for ^{40}K. Individual annual effective doses due to ingestion of black walnut tincture are < 0.013 μSv for ^{137}Cs, (12.5 ± 1.3) μSv for ^{210}Pb, (0.11 ± 0.03) μSv for ^{235}U, (2.5 ± 0.3) μSv for ^{238}U, (0.9 ± 0.2) nSv for ^{228}Ac and (1.0 ± 0.1) μSv for ^{40}K. The total annual effective dose is (16.2 ± 1.7) μSv which is in total considerably lower than the recommended limit of 100 μSv. This limit is reported in Article 8 of the Regulation on limits of radionuclide content in drinking water, foodstuffs, feeding stuff, drugs, items of general use, building materials and other goods to be placed on the market (Official Gazette of the Republic of Serbia, 2018) and does not pose a significant radiological risk for consumers. It indicates that the consumption of black walnut tincture is safe, especially concerning artificial radionuclides.

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Harmonization and standardization in diagnostic radiology quality assurance measurements within 22NRM01 TraMeXi Joint Research Project

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Optimization of the doses delivered to patients from various modalities and diagnostic procedures requires proper calibration of dosimeters and harmonization of measurement protocols. Dosimeters in diagnostic radiology are calibrated and tested mainly for reference radiation conditions described in international standards, such as IEC 61267, but the conditions in which they are used in hospitals might differ considerably from typical calibration conditions at many secondary and primary standard laboratories. Recent developments and updates in medical imaging X-ray systems led to an even wider range of clinically used radiation spectra, in some cases increasing the differences between the clinical and calibration conditions and increasing the probability that the dosimeter calibration will not be appropriate for its use. In general radiography the clinically used radiation beams may not be well represented by the IEC Al-filtered RQR and Cu-filtered RQC radiation qualities due to the wide range of different filtrations available at modern devices. In mammography the situation is particularly difficult due to the various anode/filtration combinations being in use, while the IEC standard defines the reference radiation qualities for the molybdenum/molybdenum anode/filtration setup only (RQR-M series). Besides the need for harmonization of reference radiation conditions in diagnostic radiology, the harmonization of measurements of different quality assurance parameters (air-kerma, X-ray tube voltage, X-ray tube current, half-value layer, total filtration) is also necessary. Quality assurance measurements in the hospitals are usually performed using semiconductor-based X-ray multimeters. These devices have manufacturer specified software corrections to compensate the inherently pronounced energy dependence of the detectors. Users are in most cases not aware of the corrections and calculations performed by the software. Because of this, it is important to test the X-ray multimeters in a wide range of clinically relevant conditions.

To address the issues on the reference radiation fields and X-ray multimeter performance, the joint research project 22NRM01 TraMeXi was developed. The main scientific objectives of this project are the following: comprehensive analysis, review and update of reference radiation qualities based on clinically used and available radiation conditions, performance testing of commercially available dosimeters in both laboratory and clinical settings, harmonization of calibration and measurement procedures and validation of established and updated calibration procedures and capabilities.

Keywords: diagnostic radiology, dosimeter, harmonization, mammography, radiography, standardization, X-ray multimeter

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Harmonization of operational dosimetry quantity measurement in photon dosimetry within 22NRM07 GuideRadPROS Joint Research Project

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There is a large variety of photon dosimeters used in radiation protection for area and individual monitoring in different applications of ionizing radiation. These dosimeters are based on different detector types and include both active dosimeters with real-time dose readout and audial/visual alarm functions and passive/hybrid dosimetry systems. Radiation protection dosimeters used for measurement of the operational dosimetry quantities are calibrated and tested in the ISO 4037:2019 reference X-ray and gamma-ray radiation fields. The methods of testing and limits of variation for dosimeter response due to the effects of different influence quantities are defined in several IEC standards which are related to the specific operational quantity, dosimeter type and application of such dosimeter. Most common radiation-based tests include the influence of photon energy, angle of incidence and dose (rate) on the dosimeter response.

The ISO 4037 standard parts 1-4 were updated in 2019, and many calibration laboratories have difficulties in implementing some of the new requirements. There is also a need for revision and update of IEC and ISO standards with respect to the new and upcoming technologies in radiation protection. ICRU report 95 proposed new operational quantities, which would require significant changes in equipment and standards. However, the scale of these changes is not completely known. The 22NRM07 GuideRadPROS Joint Research Project is addressing these questions in four scientific work packages.

Harmonization in radiation protection is necessary on several levels. Some of the most important topics addressed by the project are harmonized approach to X-ray spectrometry in calibration laboratories, which would improve the uncertainty estimation in dosimeter calibration and test procedures. Analysis of type-testing standards and identification of their inconsistencies would contribute to the harmonization of the test methods and criteria of acceptability for radiation protection dosimeters. This would especially be beneficial for the area monitoring dosimeters, where there are currently several IEC standards pertaining to the same operational dosimetry quantity (ambient dose equivalent), which provide different criteria for similar applications. The harmonization and update of the IEC standards should consider the use of new dosimetry technologies such as spectrodosimetry and computational dosimetry. The project is also looking into the current state of the art of radiation protection measurements, and the implications of the possible adoption of new operational quantities.

Keywords: area monitoring, dosimeter, harmonization, individual monitoring, radiation protection, standardization

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Comparison of survey meters in X- and γ- reference fields and in the field of an unknown source

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The aim of this study was to assess the energy dependence of survey meters, under standard and non-standard radiation conditions, and to discuss different ways of calculating the comparison reference values. Five dosimeters were tested: an ionization chamber (Victoreen 451P), three Geiger-Mueller counters (Automess 6150 AD6, Gamma-scout, DMRZ-M15) and a scintillation detector (Automess 6150 AD-b). First part of the test, under standard radiation conditions, included measurements in ISO 4037:2019 established radiation fields: (1) X-ray radiation quality N-80, (2) X-ray radiation quality N-200, (3) ^{137}Cs radiation field and (4) ^{60}Co radiation field. For these measurements the comparison reference values were calculated using measurements by secondary standards, which have low measurement uncertainty and proper calibration factors for each radiation quality. For the second part of the test, radiation conditions were: (1) scatter radiation from X-ray unit positioned at 1 meter from scatter object, (2) ambient measurements in center of the sealed sources storage room and (3) in contact with ^{60}Co radiotherapy unit shielding. Comparison reference values, for second part of the test, were obtained as average values of the measurements performed by ambient dosimeters. Results (in terms of relative energy response) were analyzed against the limits of deviation for radiation-based influence quantities defined in Standard IEC 60846-1 and National Regulation on Dosimeters.

While all dosimeters exhibited satisfactory responses at high energies, dosimeters based on non-compensated Geiger-Mueller counters displayed significant energy dependence at lower energies. Ionization chamber and scintillation counter demonstrated weak energy dependence, making them suitable for accurate radiation measurements at low photon energies. Notably, measurement uncertainty was not considered but could impact borderline results' compliance with criteria. Findings align with theoretical predictions. The two reference values were similar for high photon energies, where all dosimeters have relatively flat energy dependence. However, in the case of lower energies, the dosimeters based on non-compensated GM-tubes showed significant overresponse, therefore affecting the reference value. Consequently, some dosimeters which behave well when compared with the ionization chamber failed the comparison when the reference value was based on the survey meter measurements.

These results show that it is important to consider the metrological properties of the dosimeters when deciding on the reference value of the comparison. Using weighted mean instead of the simple mean can also reduce the problems, provided that the measurement uncertainty is not underestimated.

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On-site training comparison of air kerma calibration factors within the 19NET03 supportBSS project

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Radiation protection dosimeters are calibrated, tested or verified in reference fields established by calibration laboratories. In case of photon dosimeters, reference fields are established according to the ISO 4037 standard series, which was updated in 2019. Most calibration laboratories already fully or partially adopted the new version of the standard, but several difficulties remained related to X-ray tube high voltage measurements, validation of X-ray reference fields, and measurement uncertainty evaluation, among others. Currently there is a strong need for training related to different aspects of the standard, and also for the comparisons to validate measurement capabilities using the new version of the standard.

The project 19NET03 supportBSS "Support for a European Metrology Network on reliable radiation protection regulation" was selected within the EMPIR support for networks call 2019. One of the objectives of the project is to set up and promote a knowledge-sharing programme for stakeholders, which is realized within Work Package 4. Considering the identified needs, an on-site comparison was organized in Vinca Institute in September 2023. The comparison was performed using one radionuclide reference radiation quality (Cs-137) and one X-ray radiation quality (N-100). Training and workshop were organized together with the comparison.

The comparison was promoted within the project, within the European Metrology Network for Radiation Protection, the Secondary Standards Dosimetry Laboratory network, EURAMET Technical Committee for Ionizing Radiation and other networks. Eight laboratories took part in the comparison, six of them in the official part. Main results and conclusions of the comparison and workshop will be presented.

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Application of FRAM software in gamma spectrometry for nuclear material characterization

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Gamma spectrometry serves as a valuable non-destructive method for the characterization of nuclear materials. While routine gamma spectrometry laboratories primarily focus on analyzing environmental samples, i.e. Naturally Occurring Radioactive Materials (NORM), the utilization of the FRAM software in such settings is limited. However, the commercial potential of the FRAM software is realized in laboratories specialized in the analysis of nuclear materials. There are other available commercial software solutions that are used for the analysis of nuclear material such as the MGA++ and MGAU packages. They present very convenient and easy-to-use alternatives because the entire isotopic analysis of uranium and plutonium is reduced to just a few steps. On the other hand, the mentioned features are at the same time their disadvantage, since MGA++ and MGAU represent a kind of a black box, that is, they do not provide the users with the flexibility to influence the course of the analysis in any way. FRAM software makes this possible by allowing users to tailor the analysis to the specific requirements of a given measurement. This is achieved by a different selection or by creating a completely new set of parameters that defines the type of detector as well as the suitable energy region for analysis, then the shape (type) of the efficiency function, the selection of photopeaks used for energy, shape and efficiency calibrations as well as many other options within the software itself. This advantage allows the users to achieve a higher control level over the analysis process.

In this paper, testing of the FRAM software by processing gamma spectra of various standard reference nuclear materials [publications.jrc.ec.europa.eu/repository/handle/JRC124107] is presented. The agreement between mass fractions provided by the FRAM software with the reference values of mass fractions for specific radioisotopes has been analyzed. For these purposes, spectra of certified standard uranium and plutonium materials were used. These spectra were obtained at the Joint Research Centre-Institute for Transuranium Elements (ITU) in Karlsruhe as part of collaborative efforts aimed at developing non-destructive methods for measuring nuclear materials. All results calculated by the FRAM software are in good agreement with the reference values.

Neutron irradiations to improve nuclear data in support of nuclear forensics

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Fundamental nuclear data such as branching ratios and fission yields are important to nuclear forensics and related fields. Pacific Northwest National Laboratory (PNNL) has been working on improving fundamental nuclear data by leveraging access to several research nuclear reactors, critical assemblies, neutron generators. To accomplish this, multiple irradiations targeting improvement of gamma emission branching ratios and fission yields have been performed. One example is the determination of branching ratios for Cadmium-115m. Cadmium-115m has been produced through repeated irradiation of isotopically enriched Cadmium-114 and natural Indium. Branching ratios derived from these experiments were confirmed with production from natural cadmium from thermal irradiation. Several thermal and non-thermal neutron irradiations of HEU have been used to improve the Cs-136 fission yield uncertainty from the reported values in ENDF the databases. Irradiations of different fissile and fissionable materials with 14-MeV neutrons and neutron fluences shaped by the use of shielded containers have allowed evaluation of fission yields using modern techniques. This communication will explore these experiments and others performed by PNNL and our collaborators that have resulted in improvements to nuclear data.

The role of quantities and units in the communication of CBRN risk to the public with special emphases on N and R components

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Providing clear and understandable information about the protection against the potential danger of CBRN (chemical, biological, radiological and nuclear) agents intended for the population is very important since the cooperation of the rescue units with the public plays an important role. The same situation also includes any other emergencies, including terrorist attacks, where the response should also be initiated as soon as possible to prevent panic or chaos, which may negatively affect the efficiency of protection measures. A deliberate attack involving CBRN material can potentially *cause substantial fear among the public*.

A CBRN attack is one of the most challenging incidents that emergency services will ever deal with and will attract a high level of public and media interest within a very short space of time. Responding to the demand for information while simultaneously ensuring public safety and dealing effectively with the incident can place considerable demands on rescue workers. During the first hours of a CBRN emergency, police services are usually the lead responders. Therefore, it is their duty to ensure the public is adequately informed and protected from harm. They must be able to deliver and disseminate accurate information quickly and effectively in order to save the lives of those affected or who may become affected.

There is quite a big difference in quantifying the hazards due to chemical and biological agents on one side and radiological and nuclear on the other. While in the case of N and R constituents, there have been introduced a number of quantities (maybe too many) to assess the risk from both stochastic and deterministic effects of CBRN, in the case of C and B materials, there has not so far been developed such a comprehensive system to categorize the level of danger.

Typically, major incidents are localized, but this situation can potentially spread contamination over a broad area. Traditional communication planning heavily depends on mass media, primarily broadcast media. Despite its significance, individuals susceptible to this incident may lack access to television and radio broadcasts. Consequently, communication advisers must explore alternative channels such as social media and direct communication methods.

The paper aims to consolidate information for the public to prevent chaos, panic and misunderstanding during the CBRN emergency, taking into account some experience from the protection against ionizing radiation emitted by radiological and nuclear substances.

Advancing nuclear safeguards: Automated fission track analysis via synthetic model generation and image analysis tools – Analysis for nuclear forensics using U-Net model

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The Fission Track Analysis (FTA) method is a cornerstone in nuclear and safeguard investigations. This presentation unveils a pioneering approach that focuses on the automation of FTA through advanced image processing algorithms applied to microscope images. As a critical prelude to our research and development endeavors, our research group has successfully developed an application capable of generating synthetic models of fission tracks.

Leveraging trajectory data from the fission products trajectory database, created through GEANT4 simulations, we generate synthetic models of fission tracks. This synthetic bank of images closely resembles light microscope images, providing a controlled and versatile dataset for R&D processes for developing robust image analysis tools. These tools aim to automate the identification of fission track clusters without human intervention, representing a significant leap toward the elimination of manual methods.

The preliminary software for image processing demonstrates its efficacy in detecting fission track clusters. Notably, the software logs all fission sites by X-Y coordinates, providing a comprehensive record for analysis. Furthermore, the software calculates the number of tracks, enhancing the efficiency of data interpretation.

The automation of Fission Track Analysis not only streamlines the identification process but also serves as a proactive measure to reduce the likelihood of human errors inherent in manual procedures. This is paramount for enhancing the accuracy and reliability of nuclear investigations.

We emphasize the seamless integration of GEANT4 simulations into our methodology, ensuring a foundation rooted in accurate trajectory data. This integration bolsters the authenticity and applicability of our synthetic models.

This presentation underscores the pivotal role of synthetic model generation and image analysis tools in automating Fission Track Analysis for nuclear safeguards. Our research strides towards a future where human intervention is minimized, thereby fortifying the precision and efficiency of nuclear investigations.

This software can produce a large database that can serve as the data set for AI software. The AI software can classify some types of fission-track clusters. The fission-track clusters are imposed on a background photo taken by a light microscope.

This study introduces a novel methodology for the detection and classification of star shapes in microscopic images, employing state-of-the-art deep learning techniques for segmentation and classification. The U-Net model, a fully convolutional network, was utilized to carry out the segmentation of various star-like patterns in both single-class and multi-class scenarios.

The use of the behaviour of radioactive material for the prediction of the movement of other CBRN components in urban areas

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The paper aims to assess the behaviour of other CBRN (chemical, biological, radiological and nuclear) components based on the models and analysis developed for observing the movement of radioactive materials released in a rural area. The movement of such materials depends on many factors, such as the direction and intensity of wind, other parameters of other meteorological conditions, and the properties of the chemical and physical substances released. An important role also plays the relief of the terrain in the location, especially structure and the height of buildings and the presence of other barriers in the spot, including trees and fences, which may, to a certain extent, affect the movement of the contaminated cloud.

The paper summarizes and analyses the latest situation in assessing the risk and exposure of affected persons to CBRN materials. Applying the results from the movement of radioactive plumes can also be beneficial in predicting the behaviour of chemical and biological agents. Special attention has been paid to the survey of available IAEA modellings and simulations of radioactive substances to predict the movement of other CBRN components. Such information may immensely contribute to optimizing the protection against CBRN based on the reliable knowledge of the distribution of these dangerous materials and their movement in the location of their releases.

In addition, the presentation also briefly discusses some specific aspects of the total biological impacts of CBRN as a whole in comparing their stochastic and deterministic effects on persons contaminated.

Changes in the concentration of volatile organic compounds in foods as indicators of chemical transformations after irradiation

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Food irradiation is used to extend food shelf life and guarantee microbiological safety. However, biomacromolecules in foodstuff, such as lipids and proteins, undergo oxidation as a result of radical processes, what affects the organoleptic characteristics of products. Volatile organic molecules, formed as a result of their radical peroxidation, can be used as indicators of oxidative and microbial-enzymatic processes occurring in products after irradiation. At the same time, it is necessary to understand the fundamental physicochemical and biochemical processes occurring in the product after irradiation, leading to the formation of specific VOCs.

To explain the behavior of the concentrations of volatile organic compounds in food products from the radiation dose, measured immediately after radiation processing, a series of model studies were carried out on the irradiation of standard samples of volatile organic compounds.

The irradiation of the standard samples (alcohols, aldehydes and ketones) was carried out on a continuous 1 MeV electron accelerator UELR-1-25-T-001 (SINP MSU, Russia) with a beam current varying in the range from 50 nA to 500 nA. After irradiation, the concentrations of volatile compounds were determined using a gas chromatography-mass spectrometer Shimadzu GCMS-QP2010 Ultra (Shimadzu, Japan).

It has been established that standard compounds decompose into other volatile compounds under the influence of ionizing radiation. Since food products differ in the composition of proteins, lipids and carbohydrates, and, consequently, in the concentration of VOCs formed as a result of the oxidation of biomacromolecules, to assess the effect of the concentration of compounds on the nature of their decomposition into other compounds depending on the irradiation dose, standard samples of volatile compounds were irradiated in two different concentrations – 1 mg/ml and 50 mg/ml. Also, standard samples of VOCs were irradiated by accelerated electrons in the same doses at different dose rates – 1 Gy/s and 10 Gy/s.

The initial concentration influences the amount of compounds formed from irradiated standard samples. Depending on the radiation dose and dose rates, a threshold of produced is observed for compounds formed from irradiated standard samples.

Based on the results of the study, a mathematical model was developed that describes the dependence of the concentrations of standard volatile compounds and VOCs identified in food products on the radiation dose.

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Effect of ionizing radiation on germination, yield and diseases of wheat in laboratory and field conditions

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Wheat is one of the most important cereal crops in agriculture. Increasing the quality and yield of wheat grains remains one of the priority goals for food security. The aim of the study was to find effective doses of radiation treatment for wheat variety Novosibirskaya 29 with natural contamination of phytopathogenic fungi, ensuring growth stimulation of the crop and its protection from diseases.

Irradiation was performed using a continuous-action linear electron accelerator *UELR-1-25-T001* with an energy of 1 MeV and an X-ray apparatus *1BPV23-100* with an *RAD-100* X-ray tube and a molybdenum anode. The research was conducted both in laboratory and field conditions. During laboratory experiments, seeds were irradiated with X-ray and electron radiation at doses ranging from 4 to 150 Gy and then planted on nutrient medium in Petri dishes. Seed germination on the 7th day and the degree of their contamination with phytopathogenic fungi were evaluated. In field experiments, seeds were irradiated with doses ranging from 5 to 30 Gy and grown in experimental fields in the forest-steppe zone. Germination, crop yield, and the degree of disease infection were assessed. To understand the dose distribution in seeds, irradiation modeling was performed using GEANT4 software.

During laboratory experiments, the most effective dose for treatment with accelerated electrons was found to be 20 Gy, which increased seed germination by 63% and reduced the amount of phytopathogenic fungi on seeds by 20%. This efficiency was confirmed in field studies, where irradiation at this dose increased germination and crop yield by 11% and 5%, respectively, and reduced the incidence of *Septoria nodorum* by 56% compared to control values. No effective doses for treatment with X-ray radiation were found during laboratory experiments. However, in field studies, irradiation with X-rays at a dose of 15 Gy did not affect germination but increased crop yield by 37% and reduced *Septoria nodorum* incidence by 24% compared to control values. Doses of 5 and 10 Gy are also of interest because treatment at these doses with both types of radiation did not reduce the disease incidence of the crop, but increased its yield. Yield was increased by 34-38% when irradiated with an electron beam and by 48% when irradiated with X-rays.

The results are consistent with the literature, indicating that doses ranging from 5 to 20 Gy contribute to increased plant germination rates, shorten the vegetative period, and reduce the risk of fungal and bacterial diseases spreading from the soil. The dose distributions obtained in irradiation modeling for X-rays and accelerated electron beam were different, which could be the reason for the difference in effective radiation treatment doses for the two types of radiation.

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Effect of irradiation on the productivity and phytosanitary condition of potatoes

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Introduction. Adaptation of methods of crop protection and growth stimulation under climate change conditions is an important task for the agronomic sector of the industry [https://www.iaea.org/topics/food-security-and-climate-change (accessed 28 February 2024)]. Radiation treatment is a universal method that allows both stimulating and inhibiting the growth of plants and phytopathogens. This paper studies the effect of ionizing radiation on productivity and phytosanitary condition of potato crop.

Materials and Methods. In the study, potato tubers of the Violet variety with natural infection by the fungus *Rhizoctonia solani* were irradiated with accelerated low-energy electrons and X-rays at doses from 5 to 30 Gy. Irradiation was performed using a continuous-action linear electron accelerator UELR-1-25-T001 with an energy of 1 MeV and an X-ray apparatus 1BPV23-100 with an RAD-100 X-ray tube and a molybdenum anode. After irradiation, tubers were planted in the experimental field of SFSCA RAS to analyze their growth and yield. The obtained crop was phytosanitary analyzed for the degree of fungal diseases. Effective tuber treatment doses could be identified based on yield quantity and quality data.

Results. Evaluation of productivity and phytosanitary condition of the crop showed non-linear dependence of crop yield and disease incidence on X-ray and electron radiation doses. Irradiation at all doses reduced the spread of net necrosis on new crop tubers. Accelerated electron irradiation at doses of 15, 20 and 30 Gy increased yield by 35, 18 and 58 %, while irradiation at doses of 10, 25 and 30 Gy was most effective against net necrosis, reducing its spread by 36, 16 and 8 %, respectively. X-ray irradiation at all doses reduced the spread of reticulum necrosis by more than 16 % and decreased crop yield. The lowest yield reduction was observed at irradiation at a dose of 10 Gy and amounted to 10%.

Conclusion. It was obtained that irradiation of potato tubers reduced the degree of infection of its yield by phytopathogenic fungi. X-ray irradiation was more effective in controlling the disease on tubers, but also reduced the crop yield. Its effective irradiation dose was 10 Gy. Irradiation with accelerated electrons with the doses of 15, 25 and 30 Gy increased crop productivity by 35, 18 and 58 %. Effective dose of radiation treatment of seed potatoes for accelerated electrons was 30 Gy.

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Influence of static magnetic field (SMF) of 100mT on hen egg fatty acids profile

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Over the past two decades, significant evidence has been collected about the interaction of static magnetic fields (SMF) with living organisms as well as with the cell and tissue samples. Different effects have been observed based on the cell or tissue type, magnetic field strength, and exposure duration. The aim of our study was to investigate the influence of the static magnetic field on the fatty acid (FA) profile of hen eggs. The eggs were treated for one hour with the highly homogeneous SMF of 100 mT oriented vertically upwards and downwards. The hens were fed with the standard food. Fresh eggs were collected from the hen farm (Panovo, Serbia) and divided into 3 groups: the control group, “up” group exposed to the vertically upward oriented SMF, and “down” group exposed to the vertically downward oriented SMF. The following day the eggs were exposed to the SMF of 100 mT for one hour. The highly homogeneous static magnetic field used for egg exposure was produced with a custom-made electromagnet whose operating parameters were set to produce 100 mT in the center of the 6.6 cm gap between the magnet poles.

After exposure the egg samples were collected and extracted following the standard procedure for the gas-liquid (GC) chromatography preparation of samples. The fatty acid methyl esters were separated by a gas chromatograph equipped with flame ionization detector and the column that was 60 m long with an internal diameter of 0.25 mm, and 0.2 μm film thickness. Samples were injected in a split mode using the split ratio of 1:4, and helium as a gas carrier. The injector and detector temperature were set at 220 and 250°C, respectively. Fatty acids were identified by comparing retention times with those corresponding to the standard mixture and the content of the individual fatty acid in the investigated tissues was expressed as a percentage of the total lipid pool within a sample. Our results show that SMF has changed the percentage of FA in hen eggs. In the “up” group the percentage of palmitoleic acid (PA) was increased when compared to the control group with the statistical significance of $p < 0.05$, whereas the linoleic acid content was decreased in comparison to the control, as was the case with the linolenic acid. In the “down” group the SMF treatment caused a decrease of the palmitoleic, linolenic, and linoleic acids. The percentage of docosahexanoic acid (DHA) was found to be larger in the “up” group than in the control group. Comparison of the linolenic acid values in the two treated groups showed its larger presence in the “up” group than in the “down” group. Our results showed that SMF of 100 mT affects the fatty acid profile of hen eggs and that the influence depends on the direction of SMF. Comparison between the exposed and control groups show that the SMF oriented upwards changed the fatty acid composition and caused statistically significant increase of overall omega 3 fatty acids as well as of DHA and linolenic acid (ALA).

Pre-sowing seed exposure to static magnetic field can improve cabbage yield

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The static magnetic field (SMF) has been shown to influence living organisms, for example, plants, fungi, insects, mice, and rats. It came as no surprise that the effects caused by SMF depend on the intensity of the applied field and exposure duration; however, discovered non-linear dependence on these parameters was not expected. In addition, it was found that the changes caused by SMF depend on the field direction and orientation as well as on the type of organism that is being affected. Numerous studies show that magnetic fields of various types regulate plant functions as well as enhance growth and tolerance to environmental stress. The studies that used SMF for exposure reported increased germination, seedling growth, length and biomass of plants as well as draught and salinity tolerance of different plants. However, majority of the experiments is performed in the laboratory conditions and is not extended farther into the agricultural field. Our goal was to extend the experiment into the agricultural field and investigate if and how the conditions of pre-sowing exposure of cabbage seeds to SMF affect the yield of crops. Prior to sowing, three groups of cabbage seeds (*Brassica oleracea var. capitata*) were treated with highly homogeneous SMF of 50, 100, and 300 mT for one hour. Plant samples from the non-exposed control group and the three treated groups were taken from the agricultural field and analyzed twice: in the transplant stage two months after sowing and in the mature stage 3.5 months after sowing. In the transplant stage plants from the groups exposed to 50 and 100 mT had statistically significant larger weight and number of leaves when compared to the control group. In this phase of plant development, the magnetic field of 100 mT was found to be the most efficient since it produced plant weight increase of 30.7% and 21.5% more leaves compared to the control group, whereas the corresponding increases for the 50 mT exposure were 19.0% and 10.4%, respectively. All the treated groups had much wider root than the control. The increase was 148.4, 211.7, and 129.6% for the group exposed to 50, 100, and 300 mT, respectively. Most likely, this is due to the absence of the cabbage root maggot in the roots of all treated groups contrary to the control group where numerous pests were found in the root systems of all sample plants. In the mature stage the seed treatment with 300 and 100 mT SMF caused statistically significant increase of the plant weight and head weight. In the group exposed to 300 mT the increase of plant and head weight was 22.7 and 24.8%, respectively, whereas for the 100 mT exposure the corresponding increases were 16.9 and 18.3%, respectively. Consequently, the pre-sowing 1h exposure of cabbage seeds to 300 mT was found to be the most effective of the three studied SMF treatments, since it can produce 24.8% larger cabbage yield compared to the non-treated control.

Exploring the color modifications in biopolymers induced by dual processing with ionizing radiation and cold plasma

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Ionizing radiation and cold plasma have emerged as promising non-thermal, environmentally friendly techniques for modifying biopolymer properties. Recent research focuses on dual modification, combining different modification methods to enhance the physicochemical and functional features of biopolymers while optimizing performance. Assessing color parameters can support the understanding of changes in biopolymer properties, optimizing processing conditions, and meeting consumer preferences. This study explores the impact of dual processing on the color attributes of starch as a biopolymer. The experimental setup involved subjecting starch samples to single and dual processing with an electron beam and cold plasma, varying the processing sequences. Spectrophotocolorimetric analysis quantified color changes using CIELAB and CIELCH colorimetric systems. Dual processing significantly altered starch color parameters, primarily based on irradiation dose. Dual-processed samples exhibited perceptible color changes, though less than electron beam processing alone at the same irradiation dose, as indicated by the total color difference. This research contributes to the advancement of sustainable materials science by providing insights into the color alterations induced by ionizing radiation and cold plasma processing in starch.

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HiSPANoS fast neutron irradiation facility at CNA: Capabilities and first applications

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HiSPANoS is a neutron beam facility hosted at the Centro Nacional de Aceleradores (CNA) in Sevilla, Spain, open to external users via Transnational Access through the EC projects EUROlabs, OFFERR and APRENDE. The facility, driven by a 3 MV tandem accelerator, delivers both continuous and pulsed beams of epithermal and fast neutrons. In the case of fast neutrons, monoenergetic beams (2.5 to 6 MeV) are produced via d-D reactions at a rate of 1e6 n/sr/uC, while broad energy beams from Be(d,n) and Li(d,n) reactions are more prolific, with 1e10 n/sr/uC up to 10 or 20 MeV, respectively.

Recently, several experiments have been carried out via irradiation with fast neutrons from the Be(d,n) reaction. For instance, irradiations seeking for radioisotope production, neutron imaging and biological mutagenesis, have been carried out in early 2024. These recent examples will be presented and discussed, along with the prospects for more intense neutron beams and the possibilities of combined fast and thermal (through moderation) continuous neutron irradiation.

Initial approaches for establishing of the fast neutron radiography with PADC material

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The neutron radiography is a non-destructive testing method. As well as the radiography using X-rays, neutron radiography is based on the particle attenuation in matter. After passing through the object of inspection, the particle beam is recorded using the appropriate radiation detector, such as film-based detectors, or scintillators. The fast neutron radiography technique offers an opportunity to retrieve information about bulk materials, or large components, whose defects could not be reliably displayed by either X-rays, or thermal neutrons.

The fast neutron generator, based on the DD reaction will be installed at the Center of Nuclear Technology and Applications (CeNTA) of the Faculty of Electrical Engineering and Information Technology of STU in Bratislava (FEI STU) in the following months. Among others, the performance of the precise fast neutron radiography of large industrial components is one of the intended uses of this facility. Besides the usage of traditional methods of imaging, other options are being explored.

The solid-state nuclear track detectors of poly-allyl diglycol carbonate (PADC) represent a passive method of reliable ion and fast neutron detection. The principle is based on the creation of a latent track along the path of the incident particle, in the nm scale. The subsequent etching leads to the magnification of the latent track on the order of μm. Additional layers of radiators (such as polyethylene or boron) are often used to enhance the detection efficiency.

This work represents the design procedure, leading to the ability to display of the analyzed subject using PADC material. For the highest possible precision, several aspects had to be considered. The design of coupling of the PADC with the appropriate material was proposed, which depends on the parameters of the used fast neutron source. The polyethylene was selected, leading to the detection of protons from the elastic scattering on the hydrogen nuclei. This selection was made based on the parallel research performed at STU. The determination of the neutron source and the associated proton fluence had to be specified to achieve sufficient irradiation time to imaging precision ratio. The setting of the etching time was performed to achieve the best possible focus of the resultant image. The final step of the design was focused on the retrieving of the image from the PADC plate. The flatbed scanner was proposed, based on the experiments described in (doi.org/10.1016/j.nima.2014.07.061). The sub-steps as well as the procedure were experimentally verified.

Assessing SFR subassembly depletion via variational analysis with the SCALE code system

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An integral aspect of advancing Sodium-cooled Fast Reactor (SFR) technology involves the evaluation of new and untested concepts by the means of simulation to determine its crucial parameters. These reactor-physics computations utilize deterministic and stochastic methods integrated into various code systems such as SCALE, SERPENT, and ERANOS. However, ensuring the accuracy and reliability of these simulations poses a challenge due to sensitivity to different data and the inherent propagation of uncertainties, particularly as safety considerations are paramount in the development of the new generation of reactors. Consequently, the performance of individual codes and nuclear data libraries must be assessed through benchmarking exercises. Benchmarks serve to compare results obtained from selected code systems either against experimental reference data or results from different code systems.

Many benchmarks within the nuclear engineering domain emphasize the neutronic behavior of a reactor's core. This paper seeks to assess the performance of deterministic and Monte Carlo codes for neutronic and depletion calculations through the representation of a single subassembly typical of a Sodium-cooled Fast Reactor (SFR). Key modeling parameters are outlined, and a comprehensive variation analysis of these parameters is undertaken utilizing the SCALE code system. Reactivity parameters and isotopic concentrations are examined, and the ensuing results are compared with those obtained from the Nuclear Energy Agency's ERANOS benchmark of SFR representative subassembly for comparative evaluation.

Response of 400nm RADFET to a photon beam

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This work presents the preliminary tests performed with RADFET devices, which purpose is to be able to detect a radiation event on the environment. To do so, a large volume device is needed, for that the main device characteristics are a thick (400 nm) SiO2 gate oxide and with a channel dimension of 10 um of length and 500um width. We have manufactured it at Institute of Microelectronics of Barcelona (IMB-CNM-CSIC) clean room, located in Barcelona (Spain).

Methods and Materials. The tests were carried out at the San Cecilio Clinical University Hospital, with a photon field generated with a linear accelerator LINAC Elekta Infinity (Elekta Solutions AB, Stockholm, Sweden), placed at "Hospital Universitario Clínico San Cecilio" (Granada, Spain). The device was irradiated with 6MV photon beam under a build-up layer (1.5 cm of solid water) to achieve the electronic equilibrium. The top of the build-up layer was located at the isocentre of the source into an irradiation field of 10x10 cm2.

The source voltage of the RADFET was measured continuously by the reader unit, developed by our research [Sensors and Actuators A 247 (2016) 269–276]. To increase the linearity and sensitivity an external bias voltage can be applied by the reader. Using two JFETs (Q-SD and Q-GS) the transistor is switched in three different states:

- - Storage period: All JFETs in ON, thus all terminals of the pMOS are connected.
- - Sensing period (Irradiation): JFET Q-GD is CUT-OFF disconnecting the gate and the drain, and Q-SD is ON connecting the source and the drain. Therefore, the source, drain and bulk are grounded, and the gate is biased, in our case at 5V during 2s.
- - Readout period: JFET Q-GD is ON, and Q-SD is CUT-OFF. Thus, the source and bulk; and drain and gate are connected, and the transistor is in saturation regime. Then, the transistor is supplied at 10 μA and the source voltage is recorded.

The irradiation runs were planned in shots of 2 minutes providing a dose of 4 Gy per run, leaving a rest period of 4 minutes between them to study the possible effect of the recovery of the transistor threshold voltage (short-term fading). The source voltage was registered every 5s.

Results and Conclusions. Three shots of 4 Gy were provided to the device under test, obtaining a good linearity (R^2 = 0.999) and an averaged sensitivity of (57.7± 0.8) mV/Gy, that is a promising result to continue with the characterization of these RADFETs as radiation sensors.

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Neutron and gamma sensitivity for a SPND using Monte Carlo simulation

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The behaviour of materials under neutron irradiation conditions similar to those expected in the future nuclear fusion power reactors is unknown. The aim of the International Fusion Irradiation Facility-DEMO Oriented NEutron Source (IFMIF-DONES) is to test materials under equivalent nuclear fusion irradiation conditions. The neutron source in that facility will be produced with a 40 MeV and 125 mA deuteron beam impinging on a thick lithium jet to produce a striping reaction $D^+ + {}^{6,7}Li$.

Self-Powered Neutron Detectors (SPNDs) are a key diagnostic to be used in the IFMIF-DONES High Flux Text Module (HFTM). They are robust, and have tiny size, and can give an online signal, very important to control and analyze in real time the beam. This work presents a simulation study about SPNDs with different Monte Carlo codes. The goal of this work is to analyze its behaviour under different neutron and gamma sources and the variability in the response of the detector changing the emitter material.

A comprehensive characterization of gas detectors in response to X-rays

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In radiation-related projects, monitoring is crucial to ensure safety conditions and to obtain precise measurements of radiation flux for both research and operational purposes. A wide variety of detectors are commonly employed for this type of diagnostics, including ionization chambers and fission chambers.

In this work, we study one model of each of these detectors: the micro-ionization chamber model CRGR10/C5B/UG2, and the micro-fission chamber model CFUR43/C5B-U8/UG2, with U-238 as the fissile material. Both models are manufactured by Photonis (Merignac, France) and are filled with argon gas at a pressure of 5 bar. Irradiations were conducted at the Biomedical Research Center of the University of Granada (CIBM, Granada, Spain), with an X-ray source. The voltage of the X-ray tube was maintained at 150 kV. The current varied between 0.5 and 22.5 mA depending on the test.

The detector signals were acquired with a Keysight B2985B electrometer. It has a minimum resolution of 0.01 fA and a voltage up to 1000 V can be applied to the devices. A control software was used to remotely control the electrometer from a computer. The devices were positioned at 224.75 mm from the tube window and fixed to a 3-D printed holder previously using plastic clamps.

Tests were conducted to obtain the optimal bias voltage for these devices and their sensitivity. The chambers operated in the plateau region in the whole range from 50 to 200 V, with a slope lower than 0.1%/V. The sensitivity obtained was of 0.1879±0.0015 $nA_{chamber}/mA_{tube}$ with the chamber CRGR10/C5B/UG2, and 0.2329±0.0015 $nA_{chamber}/mA_{tube}$ with the CFUR43/C5B-U8/UG2 model. The bias voltage was set at 150 V. Further studies are expected to be conducted, potentially involving other radiation sources, and studying more samples and other types of detectors.

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Development of deuterium-deuterium compact neutron source

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In the present work, we will present the status of the deuterium-deuterium (D-D) neutron source that is being developed in collaboration between the University of Granada and the University of the Basque Country.

Our neutron source consists of an ion source which accelerates the beam towards a deuterated target. The ion source is used to generate a deuteron beam by ionizing deuterium and extracting the deuterons created. The ionization is achieved by radiating the cylindrical Electron Cyclotron Resonance (ERC) plasma chamber with a 2.4 GHz signal. This signal is generated by a 1300 W magnetron and transmitted towards the plasma chamber by WR340 waveguides. The RF system consists of the mentioned magnetron, whose power can be adjusted, a circulator and a load to control undesired reflected signals, directional couplers to monitor the RF levels and a tuner to adapt the waveguide geometry to the variable plasma chamber impedance. Moreover, the plasma chamber works in vacuum conditions, so a cylindrical alumina RF window is used to keep the vacuum status from the ambient pressure condition inside the W340.

Once the plasma is generated, the deuterons are extracted from the plasma chamber using a Pierce electrode geometry and three other electrostatic lenses. These lenses are fixed to different negative potentials depending on the type of beam that is required. The beam is accelerated towards an oxygen-free high conductivity (OFHC) copper target disk with a deuterated titanium mesh fixed to -100 kV. The collision between the deuteron beam and the deuterium deposited on the titanium mesh generates the desired neutron radiation.

There are several applications of D-D neutron sources across scientific and industrial domains. Its neutron emission is produced in the fast neutron range (above 2.5 MeV) and finds use in neutron radiography, providing a non-destructive imaging technique useful in inspecting materials. Additionally, D-D neutron sources play a crucial role in neutron activation analysis, aiding in elemental identification and quantification in various samples with application to fission and fusion nuclear technologies. In case of University of Granada and its deep relation with IFMIF-DONES neutron source, it is worthy to mention that we plan to carry out experiments for determining the cross-sections of relevant isotopes in the studies of IFMIF-DONES to a better simulation of the behaviour of such material under high neutron flux irradiation. Moreover, the radioisotopes production for nuclear medicine is also contemplated as an application for our neutron source.

Spectrometry of cosmic-ray neutrons with HENSA++: Commissioning and project status

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Neutrons are produced continuously as a secondary radiation from cosmic-ray interactions in the upper atmosphere of our planet. The characterization of such secondary neutrons is connected with different fields such as environmental radioactivity [DOI: 10.1093/rpd/nch232] and the physics of cosmic-rays and space weather [DOI: 10.1023/A:1026567706183].

The High Efficiency Neutron Spectrometry Array (HENSA) is a collaboration focused on the design and development of high efficiency neutron spectrometers [Tarifeño-Saldivia, A., "The HENSA project" (2020). https://www.hensaproject.org/]. The latest version of this project, HENSA++, is intended for high efficiency measurements of cosmic-ray neutrons, focusing on space weather and environmental dosimetry applications. The operation of HENSA++ is based on the same principle as the Bonner Spheres Spectrometers (BSS) [DOI: 10.1016/S0168-9002(01)01379-1]. A topological modification of the detector geometry has enabled to improve the detection efficiency between 5 and 10 times over the standard BSS [4]. The current version of HENSA++ is composed of an array of sixteen He-3 tubes, each one embedded in different materials including high density polyethylene moderators, cadmium shieldings and lead neutron converters. This setup allows for spectral sensitivity from thermal up to GeV's neutrons and provides near real-time measurements of the neutron spectrum on a time scale of tens of minutes up to few hours, thus enabling possible applications in space weather as a neutron monitor with spectral sensitivity.

In the present work, the details about the design and optimization of HENSA++ and the commissioning of the spectrometer for cosmic-ray neutron measurements are presented. Additionally, the challenges for the reconstruction of wide energy range spectra (thermal up to 1 GeV) from neutron spectrometer measurements are discussed.

BLUME: A blanket functional materials module for the Helium Cooled Pebble Bed breeding blanket in IFMIF-DONES

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Within the EUROfusion DEMO programme, the Helium Cooled Pebble Bed (HCPB) and Water Cooled Lithium Lead (WCLL) breeding blankets (BBs) are the two driver blanket candidates for the European DEMO. The HCPB BB utilizes pressurized helium as a coolant, lithium-containing ceramics in the form of a pebble bed as the tritium breeder, titanium beryllide in the form of a block as the neutron multiplier, and Eurofer97 as the structural material. The current HCPB breeding blanket is based on a fuel-breeder pin concept, wherein the lithium ceramic pebble bed is enclosed within a steel pin, and outside the steel pin is the titanium beryllide block. The tritium breeder and neutron multiplier materials are referred to as the functional materials of HCPB BB. Several studies, both in the design and experimental phases, have been conducted on the functional materials to test single-effect phenomena, including thermal cycling behavior, tritium release properties, and crush characteristics.

To test the multiple-effects phenomena of the functional materials under DEMO-relevant conditions, a fusion-like neutron source with sufficient irradiation volume and a relevant neutron spectrum and flux are required. IFMIF-DONES, the International Fusion Materials Irradiation Facility – DEMO Oriented NEutron Source, serves as a facility for the testing and qualification of materials intended for use in future fusion power plants. The Test Cell of IFMIF-DONES can offer a unique opportunity to test multiple-effects phenomena occurring in the breeder zone of the HCPB BB. This can be achieved through a relevant mockup with conditions closely resembling those in a fusion DEMO. This specific mockup for this purpose is called BLUME (BLanket fUnctional Materials modulE). This work presents the system requirements, test goals, preliminary design, and analyses of BLUME.

The monitoring and assessment of electromagnetic fields near one or more base stations for telecommunication systems

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In modern times, the use of mobile phones as one of the primary communication devices has been accompanied by the ever-growing interest of the public and researchers in the potential emergence of adverse effects on human health, which may be caused by exposure to electromagnetic fields associated with these devices. The improvement of service and the increase in cellular operators have led to the rise in the number of base stations primarily located in residential areas. Monitoring and assessing the electromagnetic field near one or more base stations, especially in populated centers, is of great interest.

The aim of this study is to monitor and assess high-frequency electromagnetic fields near one or more base stations for telecommunication systems, located mainly near residential centers in several urban areas of Tirana. This involves measuring the physical quantities of the field (electric field intensity E) using the SRM-3006 (Selective Radiation Meter) for electromagnetic fields up to 6 GHz. Additionally, the measured values will be compared with the permissible exposure levels for the population, as defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The methodology for measuring the physical quantities of the electromagnetic field has been implemented following a standardized procedure based on European recommendations for multiple base stations, particularly applied in cases where there is more than one transmission station in a specific area.

Arborescence in low voltage aluminum electric cable using images generated by X-ray microtomography and COMSOL Multiphysics

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In this work, the thermal effects generated by the passage of electric current were calculated. An analysis of dissipated power and impedance, using Maxwell's equations as base, was carried out in different lengths of cables with aluminum conductor, with the three-phase electrical system, with a frequency of 60Hz and with an electrical phase difference of 120º between the phases and the voltage amplitudes between the two bands: 127 V and 220 V. The use of computational tools is developing every day to make it possible to model physical processes that occur in subvolumes of different samples. In this case, these are electrical power cables with an aluminum core that were characterized using advanced 3D imaging techniques, which are increasingly common. The objective of this work was to evaluate the effect of current pulses, which generally occurs in transients, on the proliferation of voids in the insulating layer of electrical cables. The microCT system was used and the Avizo program to quantify and generate the STereoLithography (STL) files of the aluminum electrical cable before and after the electrical current pulses. The software Avizo was used to transform a 3D tomographic image derived from the X-ray microcomputed tomography (microCT) technique of an electrical cable sample with an Al core multiplexed with a voltage of up to 1 KV, with insulation and solid cover composed of ethylene propylene rubber (EPR) and polyvinyl chloride (PVC), respectively. The Comsol Multiphysics software, which uses the Finite Element Method (FEM), was applied with the information provided by the X-ray microtomography technique to better describe the electromagnetic phenomena in a power cable.

The results showed that the phenomenon of electrical arborescence occurred and the increase in voids in the insulating layer, caused by current pulses due to the increase in temperature inside the conductor. Furthermore, it was observed that current pulses increase the internal volume, causing changes and generating small imperfections in the insulating layer, as was possible to verify in the results of this work. One of the consequences was the phenomenon of electrical arborescence.

Transmission and attenuation of the millimeter-wave OAM beams through the layers of tissue

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The orbital angular momentum (OAM) waves, from microwave and millimeter waves to optical frequencies have lately been recognized as one of the key technological enablers of high-data-rate wireless communications. Given their planned use in short-distance line-of-sight (LoS) application scenarios in B5G / 6G wireless communications, such as immersive extended reality (IXR) or wearable antennas / monitoring devices within the body-area networks (doi: 10.1007/978-3-030-72777-2_6; doi: 10.1109/ISWTA55313.2022.9942785), it is important to study the interaction of OAM waves with tissue. Moreover, the OAM waves have been proposed for medical imaging and diagnosis, deep-tissue imaging, biosensing, and communication with medical implants (doi: 10.1038/s41598-021-82033-6; doi: 10.1364/JOSAA.34.002046). Our previous study addressed the amounts of EM energy which can be delivered to the tissue surface, in terms of the Poynting vector obtained under the various specified conditions (doi: 10.1016/j.apradiso.2024.111261). There, biomedical applicator designs aiming at localized tissue treatments or tissue ablation by OAM beams were proposed.

In this work, we consider different OAM beam parameters and different properties of tissue layers, aiming at the detailed analysis of the effects of propagation of OAM waves through the biological tissue. The investigation is carried out utilizing full-wave numerical simulations of OAM EM fields. Attention is particularly directed to the attenuation of different OAM modes during propagation with various initial vortex angles, possible decrease in OAM mode quality, and amounts of energy delivered to the tissue layers. The results could guide the design of components utilizing mutually orthogonal OAM modes for biomedical or communication purposes.

Simulation of magnetic field exposure from built-in transformers: Possible methods for reducing exposure

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The presence of built-in transformers in residential buildings raises concerns among people about the possible effects related to exposure to electric and magnetic fields. Furthermore, the IARC classifies extremely low frequency magnetic fields as possibly carcinogenic to humans (Group 2B). This classification was made based on limited evidence of an association between the power frequency magnetic field and childhood leukemia. Several epidemiological studies consider exposure to a 0.4 μT magnetic field as a cut-off point for childhood leukemia. These values are much lower than reference levels of Council Recommendation 1999/519/EC, as well as ICNIRP Guidelines. In Bulgaria, there is no national legislation that sets exposure limits for extremely low frequencies for the general public. Results from our previous studies in apartments situated next to and above built-in transformers show values up to 1.5 μT. The aim of the paper is to investigate by simulation the magnetic field levels emitted by a built-in transformer under different loads and compare them to the registered measurements. We investigate how different configurations of the built-in transformer will affect the values in the exposed premises and determine the methods for reducing the magnetic field. It considered various shielding options by simulating and what are the possibilities of decreasing the levels below the threshold of 0.4 μT.

Pilot study on electromagnetic fields generated by battery electric vehicles

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In recent years, there has been a rise in the use of fully electric and hybrid vehicles. The Electric Vehicles Industrial Cluster in Bulgaria released statistics showing that the number of registered electric and hybrid vehicles increased by more than 100% in the previous year. However, users of this type of vehicle are concerned about potential negative effects related to exposure to electromagnetic fields (EMF). It is well known that the low-frequency magnetic field was classified by the International Agency for Research on Cancer (IARC) as a possible carcinogen class 2B. Despite this, there is no national legislation in our country to protect the general public from exposure to electric and magnetic fields with frequencies below 100 kHz. The International Commission on Non-ionizing Radiation Protection (ICNIRP) has recommended limits for protecting humans exposed to electromagnetic fields.

The focus of the study is to perform pilot measurements of the static magnetic field, the low-frequency electric and magnetic fields, and the radiofrequency fields generated by battery electric vehicles (BEVs) and to explore the complex exposure conditions for the driver and passengers. For the purpose of the study, we examine some of the commonly purchased models of BEVs for personal use in Bulgaria.

The study aims to develop a methodology that would provide data for further evaluation of EMF exposure in light of international safety standards. A primary measurement protocol was developed based on the studied specificity of the EMF distribution in the confined space of BEVs and the obtained measurement results.

The results from primary measurements and pilot exposure assessment comply with ICNIRP guidelines and Council Recommendation 1999/519/EC. However, there is a need for further investigation and more measurement data of EMF generated by BEVs considering the long-term exposure of the users and the complex EMF fields that occur in the limited space of BEVs.

Neutron activation analysis in long-term studies of the elemental ratios in marine mussels for the assessment of ecological features of coastal zones

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The content of 24 elements (Na, Mg, Al, Cl, K, Ca, Sc, V, Ti, Cr, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Sb, I, Cs, Th, U) in shells and soft tissues of mussels, collected in the area from Namibia to Mozambique in the period 2013-2019 was determined using neutron activation analysis. Both, soft tissues and shells could be used as good bioindicators of contamination with chemical elements. To reveal the influence of low saline waters, special lithogenic structure of the coast and wastewater discharges the mussel collected in the Black Sea and Saldanha Bay were added to the consideration.

According to the Spearman correlation analysis in shells high correlation between Sc, Fe, Co, Rb, Cs, Th (>0.6) indicate their terrigenous origin and possible accumulation from the suspended sediments. It is interesting to note that there was no correlation between mentioned elements and elements with similar origin such as Al, V, Ti, Cr, Ni, Sb, U. The same analysis demonstrated higher correlation between terrigenous elements (Al, Sc, V, Cr, Mn, Fe, Co, Ni, Sb, Cs, Th) in soft tissues.

It was found that the length of mussels was not interlinked with the levels of elements in soft tissue, except of the anticorrelation obtained for Mg (R = - 0.59), Ca (R = - 0.59) and Sr (R = - 0.6). Since these elements are used for shells construction, mussels with the relatively large shells contain lower levels of Mg, Ca and Sr. It was also found that the sex, season or site of sampling did not correlate with the level of any element in soft tissues and shells.

The linear discriminant analysis was used for the determinations of specificity of mussels' groups. The ratio of elements in soft tissue and shells (ST/S ratios) is a useful indicator of temporary deposition rates of elements intake from soft tissue to shells. Such elements as Na, Mg, Al, Cl, K, Sc, Cr, Mn, Fe, Ni, Zn, As, Se, Br, Sr, I, Th, U revealed low depositional levels in general with the several exceptions. In the case of wastewater discharges ST/S ratios of such element as As in mussels were above 1, indicated the ability to deposit the unfavorable substances in shells. The Ca, V, Co, Rb, Sb, Cs revealed high depositional levels (ST/S > 1), which showed the low necessity of such elements in soft tissues of mussel organisms.

The wide range of considering water areas was important to the analysis of local temporal influence of natural and anthropogenic factors.

Biogeochemical aspects of selected elemental content in *Ilex paraguayensis* S.H from Eastern Paraguay II by X-ray fluorescence

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Yerba mate, *Ilex paraguayensis*, is a plant used in infusions/macerations as a "reviver"/energy and mineral supplier beverage from historical times by the ancient originary inhabitants of Paraguay, to these days, almost worldwide; in regard to the mineral content of Ilex from Paraguay few studies are known, some of them by EDXRF. In this work, selected non-metallic, as well as some alkaline and alkaline earth elements contents in yerba mate from eastern Paraguay were studied by EDXRF techniques in order to determine their eventual correlation as well as provenance. The analysis of complex spectra was performed by the AXIL software and the quantitative analysis by the QAES software. The samples indicate that *Ilex paraguayensis* present in the aerial parts an important contents enrichment of S Cl Br some of them considered essentials. On the other hand, except K & Rb, the other cations are well below the line of reference when normalized to UC values. K is an essential element for plant development and is considered as a macronutrient; the absorbed Rb transferred to the shoots is very small in concentration, much lower than potassium; besides K plays a prominent rol in the "reviver" property of beverages.

Determination of initial electron beam profile in the 15MV Siemens Primus medical linear accelerator by GATE/GEANT4 simulation toolkit

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In this work, we determine the parameters of the initial electron beam for the Siemens Primus radiotherapy linear accelerator (LINAC), which operates at 15MV, employing the GATE/GEANT4 simulation toolkit. We explore beam parameters such as energy, position, and emission angle through a comparative analysis of the absorbed Percentage Depth Dose (PDD) and Off Center Ratio (OCR) distributions within a water phantom, comparing simulation outcomes with empirical measurement data. This empirical data, derived from the Siemens Primus LINAC operating at 15MV. The comparative analysis reveals a close concordance between the simulated and measured distributions of PDD and OCR, indicating that the initial electron beam profile can be accurately determined.

Thickness optimization of granular phosphor scintillators for use in low activity ionizing radiation spectrometers: The Gd_2O_2S:Tb theoretical paradigm

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Introduction. Ionizing radiation energy characterization is used in various applications. These include a) medical imaging like Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET), where the radiation count measurements of specific radioisotopes are used as part of the image production, b) quantitative X-ray breast imaging where the transmitted radiation spectral components can be used to selectively determine the breast composition, c) environmental radiation measurements to determine the type and activity of deposited radioisotopes and d) security applications. Besides the need of a robust electronic acquisition arrangement, the detector material type where the initial radiation absorption occurs is important. It should have high density to enhance radiation absorption and high secondary carriers yield so as to assure the maximum signal throughput to the electronics. Gd_2O_2S:Tb scintillator is a granular phosphor, with a decay time of 600 μs, that has been extensively studied as an X-ray imaging detector. Its application may vary from mammography to linear accelerator electronic portal imaging systems. Its high density 7.44 g/cm^3 allows the efficient radiation absorption, while its relatively high intrinsic conversion efficiency (i.e., optical photon energy generation per absorbed radiation energy) may allow the detection of very low activity radioisotopes.

Materials and Methods. The PENELOPE based MC software package PenEasy (J. Sempau et. al., Med. Phys. 38, 5887-5895, 2011) was used. A simple geometry of a narrow cone beam with a cross section of 0.00053 cm^2 at 100 cm distance was assumed. The beam was considered to impinge on a Gd_2O_2S:Tb scintillator. The Gd2O2S:Tb thicknesses were allowed to vary from 0.02 cm to 2 cm. The photon energy varied from 20 keV to 2 MeV, in order to study a broad radioisotope emission energy range. The optical photons escaping towards the Gd2O2S:Tb output was calculated by an analytical formula that takes into account the absorbed radiation, the optical photons generation and the optical photons propagation attributes.

Results. The uncertainty of the simulation was below 5%. It was found that the thicker the scintillator the higher the energy absorbed that contributes to an emitted signal. However, when the optical photon propagation characteristics were additionally considered it was found that for scintillator thicknesses above 1 cm, radiation energies below 141 keV did not produce an output signal due to the reabsorption of the optical photons in the scintillator. The signal produced by energies above 667 keV was better differentiated. Thicknesses between 0.02 cm and 0.05 cm delivered optical photons in the scintillator output for all the energies examined.

Conclusion. Gd_2O_2S:Tb may be used as a low activity radiation detector in a spectrometer, provided its thickness is optimized.

The application of AI-based techniques for early detection of Breast Cancer (BC)

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Breast cancer is a type of tumor that occurs in breast tissue. It continues to remain one of the most prevalent and life-threatening diseases globally, becoming the second leading cause of cancer-related deaths among women. Breast cancer begins when malignant and cancerous cells begin to grow from the breast cells. Self-tests and periodic clinical examinations help in early diagnosis and significantly improve survival chances. Early diagnosis of breast cancer, when it is small and has not spread, can make the disease easier to treat, thus increasing the patient's chances of survival. Due to the medical importance of breast cancer examinations, CAD (Computer-Aided Detection) methods have been developed to detect anomalies such as calcifications, masses, architectural distortions, and bilateral asymmetry. Micro calcifications are nothing but tiny mineral deposits within the breast tissue. They look similar to small white colored spots. They may or may not be caused by cancer. This is one reason why breast cancer detection is difficult with mammogram because the mammogram results vary greatly depending on the patient's age, breast density, and the type of lesion present. Breast density can lead to differences in the contrast of malignant regions and can lead to incorrect conclusions.

Our study describes an AI approach of adaptive median filter which performs spatial processing to determine which pixels in an image have been affected by noise. To detect, a tumor at different stages we use neural network with different learning techniques to get GMM segmentation. The ANN model is based on convolutional neural networks (CNN) and as input data we have selected 260 mammogram images classifying them into three categories; normal mammogram, mammogram with benign and mammogram with cancer. After training process, we used a CNN model named ResNet50 to compare the results. Due to the low processing capacity, we have chosen a small dataset. Our results show that a CNN model with 3*3 convolutional layer performed better compared with GMM segmentation.

Keywords: breast cancer, GMM, CAD, CNN, mammogram, lesions, images, AI, early diagnosis

Profiles of absorbed dose for the 18 MV energy radiation beam

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The use of ionizing radiation for clinical purposes has been known for decades. In the treatment of patients with tumors through radiotherapy, precision in delivering the radiation dose is of particular importance. In this case, we will develop an assessment of the absorbed dose for the radiation beam with an energy of 18 MV produced by the Elekta accelerator. The assessment of the radiation dose will be carried out for different field sizes at various depths within a water phantom, then absorbed dose profiles will be constructed for these cases. The absorbed dose profiles will be analyzed to obtain comprehensive information regarding the distribution of absorbed dose for clinical use in tumor treatment. The data obtained from the creation of absorbed dose profiles will serve for an accurate assessment of absorbed dose distribution, utilizing this data to increase the accuracy of radiation dose delivery during radiotherapy treatment. In tumor treatments using radiotherapy, the protection of healthy organs and precise treatment of the tumor mass are crucial. Building absorbed dose profiles beforehand provides the opportunity for an accurate assessment of dose distribution, aiming to use the acquired data in exchange for the treatment of a tumor using radiotherapy.

Cancer risk evaluation for high-dose chest CT examination during the Covid-19 pandemic

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High-dose chest CT exams were performed significantly more frequently during the Covid-19 pandemic in order to diagnose and treat patients. While critical for patient care, there are concerns about the potential increase in cancer risk linked with this ionizing radiation exposure. Based on the radiation dose, age, sex, and organ exposure, this study examines the cancer risk linked to high-dose thorax CT during the pandemic in Albania. This study is to evaluate the possible cancer risk associated with high-dose CT exams of the thorax for Covid patient. As a method for calculating the incidence of cancer linked to radiation exposure, the idea of Lifetime Attributable Risk (LAR) is investigated through data collection from Covid 19 patient for the period 2020-2022. The study's methodology includes a thorough analysis on radiation exposure from CT scans, with a particular emphasis on the risks associated with cancer from thorax imaging techniques. The cancer risks significantly increased linearly with radiation dose of CT scans, with the highest risks for doses greater than 50 mSv. The lifetime attributable risk (LAR) of cancer for adults following CT scans was inordinately increased. This study also looks into how the Covid-19 pandemic has affected the need for and frequency of thoracic CT scans, considering the increasing use of imaging in the diagnosis and monitoring of respiratory diseases during this global health emergency. The results of this study emphasize how crucial it is to weigh the possible long-term hazards of radiation-induced cancer against the diagnostic advantages of high-dose thoracic CT scans. Using the patient's age, sex, and effective dose value, the risk factors from BEIR VII tables for more than 2000 patients, analyzing other complex factors that contribute to the risk of cancer, we found there is a low cancer risk estimation considering as an important factor the age of patients.

Keywords: CT scans, high dose, exposure, cancer risk, BEIR VII, effective dose

Effect of constant magnetic field on methemoglobinemia erythrocytes

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The effects of *in vitro* treatment with constant magnetic field (CMF) are investigated on methemoglobinemia erythrocytes which is certainly biomedicine important. The chemical agents during physical activity lead to the formation of methemoglobin in the human blood with damage consequences. Methemoglobinemia can be caused by the action of oxidizing agents, amide- and nitro-derivatives of benzene, aniline, hydrazine and its derivatives, nitric oxide, sodium or potassium nitrite [*Bulletin of Siberian Medicine*, 2006; 5(1): 32-37]. The biophysical mechanisms of erythrocyte damage under the influence of agents causing methemoglobinemia have not been studied in detail. The electrokinetic and light scattering properties of human methemoglobinemia erythrocytes are unknown. The electrophoretic mobility of the erythrocytes as a model system is determined after exposition with *in vitro* influence CMF (0.1 – 2.0 T). The report of methemoglobinemia erythrocytes from a patient poisoning of an unknown case is presented, which are characterized by an increased amount of methemoglobin of 9.1% in the blood. Characteristic peaks of hemoglobin M at their spectrophotometric determination are not observed. The erythrocyte preparation procedure is described in detail [*Frontiers in Chemistry*, 2023; 11, 1197210]. Methemoglobinemia erythrocytes in phosphate buffered saline possess negative surface electrical charge at physiological pH of 7.4. Electrophoretic mobility measurements are carried out using microscopic (visual) microelectrophoresis with an OPTON Cytopherometer (Feintechnik Ges., Germany).

We report the generation with CMF (0.5 – 2.0 T) increase in absolute values of electrophoretic mobility, zeta potential and surface charge of erythrocytes. This property is due to a strong increase in electrostatic repulsive forces between cells suspended in an isotonic solution, pH 7.4. The CMF altered significantly the electrokinetic (zeta) potential which is accompanied by an increase in light scattering (90^o, λ=480 nm) of the cells. Due to the enhancement of the electrokinetic potential under the influence of CMF from 0.5 - 1.0 T by approximately 3 mV, a time dependence of the effect of CMF on cells was found. Methemoglobinemia erythrocytes are exposed 1, 5, 10 and 15 minutes under the CMF influence with doses of 0.5 and 1.0 T. The time-dependent CMF treatments decrease electrophoretic mobility, zeta potential and surface electrical charge of cells at doses of 0.5 T (1 min), as well as at 1.0 T (5 min). The electrostatic free energy of erythrocytes is also calculated in order to determine the suitable thermodynamic reactions upon CMF exposure.

The presented results provide a biophysical aspect of surface charge and volume changes in erythrocyte membranes with methemoglobinemia. Thus, a deeper understanding of the action of constant magnetic field on membrane level at erythrocyte membrane with methemoglobia is presented.

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Bilateral comparisons in the field of testing using thermoluminescent detectors in terms of absorbed dose to water for radiation therapy level audits – a practical guide to the statistical analysis of the results

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The Secondary Standards Dosimetry Laboratory (SSDL) in Poland has been accredited by the Polish Centre for Accreditation for the conformity with the ISO/IEC 17025 standard since April 2014. In the scope of accreditation No. AB 1499 there is testing of thermoluminescent detectors in terms of absorbed dose to water, by thermoluminescent dosimetry method. As an accredited laboratory Polish SSDL has to fulfill the requirement concerning monitoring the validity of the tests undertaken. We decided that this monitoring included participation in bilateral comparisons between the Polish SSDL and Dosimetry Laboratory of the International Atomic Energy Agency (IAEA).

The aim of this study is to present a practical guide to the statistical analysis of the results of bilateral comparisons that can be useful in routine activity of the testing laboratories in the above-mentioned area in order to check if results are stable in specified limits.

We analyzed the results of bilateral comparisons conducted annually over the period 2004-2023. These comparisons were conducted according to a procedure established by the IAEA and consisted of comparing the TLD dose reported by Polish SSDL (D_{SSDL}) with the dose value reported by the IAEA (D_{IAEA}).

According to the requirements of the ISO/IEC 17025 standard, statistical techniques were applied to the reviewing of obtained results, namely to analyze the association between the D_{SSDL}/D_{IAEA} value in a given year (variable Y) and number of years since 2004 (variable X). First, the Shapiro-Wilk test was used to assess the normality of distributions of investigated variables. Then, the appropriate correlation coefficient (in this case: Pearson's correlation) was used to analyze the association between the D_{SSDL}/D_{IAEA} value in a given year and number of years since 2004. The p value of < 0.05 was considered statistically significant. The interpretation of strength of correlation was based on the guidelines for biostatistics. Finally, p value calculated for each statistical technique was compared to the p value which was considered statistically significant because only for statistically significant p value the results of applied test may be valid and then interpretation and inference may be reliable.

Results of the Pearson correlation indicates that there is a non-significant very poor negative relationship between X and Y, ($r(19) = -0.18$, $p = 0.44$). These results are in line with our expectations, as the time elapsed between the first and last participation of the Polish SSDL in bilateral comparisons should not significantly affect the outcome of these comparisons - to ensure the validity of the results issued by the Polish SSDL to radiation therapy centers in Poland.

The presented statistical analysis of the results of bilateral comparisons can be useful in the routine activities of accredited testing laboratories performing not only tests of the thermoluminescent detectors in terms of absorbed dose to water.

Monitoring the validity of calibration results – examples of activities performed by an accredited laboratory

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Monitoring the validity of calibration results is one of the requirements of the ISO/IEC 17025:2017 standard entitled "General requirements for the competence of testing and calibration laboratories". This requirement presented in section 7.7.1 of the aforementioned standard is essential in any calibration field, but especially in the calibration of ionization chambers used by medical physicists during dosimetry measurements for radiation therapy centres.

In this work, we will present the examples of activities performed by the Secondary Standards Dosimetry Laboratory (SSDL) in Warsaw in Poland to meet requirement concerning monitoring the validity of our results. Our laboratory has been accredited by the Polish Centre of Accreditation and has accreditation No. AP 155 since May 2014. In particular, we will discuss those aspects of the procedure we have developed that relate to so-called in-house projects, i.e. those that are carried out on the premises of our laboratory. Among these activities are:

1. intermediate checks:

    a) on the working standard dosimeter - on each day the customer's dosimeter is calibrated using the working standard dosimeter;

    b) on a reference dosimeter - during calibration of the working standard dosimeter;

2. visual check of the equipment which is not a measuring instrument (i.e., measuring bench, water phantom, ionization chamber holder, etc.) - before each use;

3. comparison values of the calibration coefficient determined during calibration of the customer's dosimeter with calibration coefficient used routinely by user (i.e., the one determined during the previous calibration) – if data is available;

4. monitoring of atmospheric conditions (ambient temperature, relative humidity, atmospheric pressure) on calibration days;

5. calibration of the same calibration object performed by different members of the SSDL staff in accordance with the currently valid calibration instruction being within the scope of accreditation No. AP 155;

6. metrological control of an additional measuring equipment (i.e. thermometers, barometers, hygrometers) with the frequency established in the current edition of the procedure we have developed.

In addition, we will highlight the most important aspects of these activities, such as the establishment of acceptance criteria. Finally, we will give some results of monitoring the validity of calibration results and analyze these results according to the dispositions established in our procedure.

We believe that the practical examples of activities performed by an accredited laboratory presented in this work can be useful to other calibration laboratories to meet requirement concerning monitoring the validity of calibration results and, with minor modifications, can undoubtedly be applied to many areas of calibration.

SSDL in Poland – experience in performing dosimetry audits

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Dosimetry audits in radiotherapy aim to ensure safe radiotherapy for the patient and to improve the quality of radiotherapy. It is an independent external dosimetry audit that is part of the radiotherapy quality assurance process. It makes it possible to check: correctness of beam calibration on the therapy instrument, correctness of geometric reproducibility of planned therapy beams, correctness of data entered into the TPS, precision of calculated dose distributions.

There are four levels of auditing. Level I involves checking the calibration of the accelerator for photon and electron beams under reference conditions. This audit indirectly allows checking the competence of the dosimetry teams. In addition, there is level Ib, where the purpose of the audit is to check the off-axis dose determination. Here thermoluminescence detectors (TL) or an ionisation chamber are most commonly used. Such audits have been performed in Poland annually since 1991. The measure of the outcome is the delta parameter, which is the percentage difference between the dose declared by the participants in the audit and the dose read out at the Secondary Standards Dosimetry Laboratory (SSDL) taking into account a number of corrections.

Level II of the audit is a comparison of the results of calculations made using the treatment planning system and measurements. Calculations and measurements are performed in a phantom designed specifically for the audit. TL detectors and film detectors are used to record the dose. Level II audits check: the accuracy of MLC leaf positioning, small-field performance, system calculations for different material densities. They are mostly carried out by mail order. In 2020, SSDL conducted this level II audit at 13 centres using a phantom containing defined PTV and OAR volumes.

Level III audits include comprehensive dosimetry for advanced IMRT and stereotactic techniques and radiosurgery. These audits are performed using anthropomorphic phantoms and calculations performed in the treatment planning system. Thus, not only the operation and calibration of the therapeutic device is checked, but also the preparation of the treatment planning system for clinical applications. Level III audits are usually carried out on an exit basis. In 2021, SSDL conducted such an audit using the SHANE phantom provided by the IAEA. The audit was performed for 8 centres. It took place in two stages, in the first stage the audited centre had to perform several tasks, so that in the second stage the auditors would come to the audited centre and, together with local physicists, perform measurements in the hospital.

Regular dosimetry audits have contributed to raising the standards of radiotherapy in Poland. In order to meet expectations and the invariably dynamic development of treatment techniques in radiotherapy, SSDL is working on developing new types of customised audits, e.g. for brachytherapy, in addition to routine Level I audits.

TLD postal dosimetry audit in Poland – 2023 results

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Ensuring safe radiation therapy is an important task for medical physicists. At the national level, it is carried out, among other things, by conducting dosimetry audits. The importance of dosimetry audits in radiotherapy is set very clearly by the IAEA in its publication HUMAN HEALTH SERIES No. 31: "Accuracy Requirements and Uncertainties in Radiotherapy." In the aforementioned publication, a recommendation is given that for each new radiotherapy machine, an independent dosimetry audit should be conducted before irradiating patients. In addition, regular audits should be performed remotely or on-site at the audited facility.

The aim of these audits conducted to radiotherapy centres is to assure proper calibration of radiotherapy beams, to avoid mistreatment of cancer patients, and prevent radiation accidents. Polish Secondary Standards Dosimetry Laboratory (SSDL) offers dose measurement in water, for which it is accredited by the Polish Centre for Accreditation for compliance with the ISO/IEC 17025 standard (accreditation No. AB 1499). SSDL in Warsaw is the only laboratory in Poland performing postal TLD dose audit.

In 2023, 43 radiotherapy centres located in Poland participated in this audit. Total number of audited radiation beams was 145, including 138 photon beams and 7 electron beams. Thermoluminescent dosimeters (TLD) of Li-F MT-F type were mailed to each participant. The participants were instructed to irradiate three TL detectors for each beam with a dose of 2.0 Gy in reference conditions. After irradiation the detectors were sent back to the SSDL. At the same time, set of reference detectors was irradiated with known doses at the SSDL. All detectors were read out at the SSDL with a Fimel PCL 3 TLD reader. The delta parameter was defined as the quotient of the difference between dose value reported by the participant and dose value estimated by the SSDL to the dose value estimated by the SSDL. The delta parameter was calculated as a percentage value.

The biggest difference found between the dose estimated by the SSDL and the dose declared by the participant was 4.1%. The average delta value for all beams was 0.32%. The uncertainty of audit methods was 3.4%.

Dosimetry audits performed in radiotherapy:

a) allow confirmation of the dosimetric and geometric parameters;

b) are crucial to quality management programs in radiotherapy, since the accuracy of dosimetry in radiotherapy is essential to achieve the intended goal of treatment with high-energy ionizing radiation with minimal risk of error in clinical work;

c) play an important role in detecting gross deviations from standards, especially in identifying dosimetric systematic errors.

Assessing the long-term stability of $N_{D,w}$ calibration coefficient for Farmer-type ionization chambers in radiotherapy

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Modern highly specialized radiotherapy techniques require precision and certainty that the dose delivered to the target volume is consistent with the planned dose for that volume. Ensuring confidence in the accurate delivery of planned treatment can be achieved through highly skilled and experienced professionals who adhere to established procedures and use properly calibrated equipment.

Even the best and most advanced dosimetry equipment, such as an electrometer and ionization chamber, runs the risk of malfunction, which can compromise the reliability of measurements. Therefore, regular calibration of dosimetry equipment by an independent laboratory is essential. This service is provided by the Secondary Standards Dosimetry Laboratory (SSDL), operated by the Department of Medical Physics at the Maria Sklodowska-Curie National Research Institute of Oncology. This laboratory is a member of the Secondary Standards Dosimetry Laboratory Network, established by the International Atomic Energy Agency and the World Health Organization. The Polish SSDL fully complies with ISO/IEC 17025 standard and has been accredited by the Polish Centre for Accreditation since May 28, 2014 (accreditation certificate number AP 155).

Calibration of medical linear accelerators involves determining the absorbed dose to water or delivered to the patient during treatment sessions, measured in Gray (Gy) units, as well as the monitor units (MU) used as a reference scale for the linear accelerators. Proper calibration is crucial to maintain consistency between the planned and delivered dose of radiation. The measurement procedures and reference conditions are outlined in the International Code of Practice published by the International Atomic Energy Agency (IAEA).

Dosimetry equipment calibration involves comparing the measured dose using a reference setup with a calibrated setup provided by the user. The dose measurement is performed using gamma rays generated through the decay of ^{60}Co. Both measurements are carried out under identical geometric and atmospheric conditions. Any influence from variable atmospheric pressure and temperature is taken into account when calculating the measured dose for each setup. The normalization factor, $N_{D,w}$, is determined as the ratio of the dose measured by the reference setup to the calibrated setup.

Based on the experience of the Polish SSDL, the stability of the $N_{D,w}$ coefficient has been analyzed. This study focuses on Farmer-type ionization chambers, which are widely used in dosimetric measurements in radiotherapy.

Experience of the calibration laboratory during the implementation of a new working standard for the calibration of electrometers with ionization chambers for teleradiotherapy

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In 2023, two UNIDOS Romeo electrometers of type TM10053, together with two ionization chambers of type TM30013, were implemented at the Secondary Standards Dosimetry Laboratory in Poland as working standards for calibration of electrometers with ionization chambers for teleradiotherapy in a Co-60 gamma ray beam, in terms of the absorbed dose to water. Our laboratory has been accredited in the aforementioned field of calibration by the Polish Centre for Accreditation for the conformity with the ISO/IEC 17025 standard "General requirements for the competence of testing and calibration laboratories" since May 2014 (accreditation No. AP 155).

In this work, we will share our experience during the implementation of one of the aforementioned working standards. As part of this implementation, all the activities required by our laboratory's management system in accordance with the relevant requirements of the ISO/IEC 17025:2017 standard were carried out. These activities included, among others:

a) calibration of the working standard against the reference standard in a Co-60 gamma ray beam in terms of the absorbed dose to water ranging from 0.15 Gy to 3.3 Gy;

b) evaluation of measurement uncertainty for CMC expressed as the expanded uncertainty having a coverage probability of approximately 95 %;

c) development of a method for evaluating measurement uncertainty for calibration of customer's electrometers with ionisation chambers when they are calibrated against a new working standard;

d) validation of the software, i.e. the spreadsheet used when determining the calibration factor of the customer's electrometers with ionisation chambers when they are calibrated against a new working standard.

There was no need to modify the scope of accreditation No. AP 155. The value of measurement uncertainty for CMC for the new working standard was the same as the one determined for the other standards in our laboratory and included in the scope of accreditation No. AP 155.

The aspects of implementing a new working standard for calibrations of electrometers with ionization chambers for teleradiotherapy may be helpful for other calibration laboratories that plan to join the process of obtaining accreditation in a similar field of calibration for compliance with the requirements of the ISO/IEC 17025:2017 standard.

Computer aided target volume delineation for postoperative radiation therapy in brain glioma patients with the use of the hybrid Artificial Intelligence model

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Radiotherapy is an important element of multimodal glioma treatment [doi:10.3390/cancers14215377, doi:10.3389/fonc.2023.1274587]. Proper target volume delineation after first step of treatment, which is surgery, is essential. Automating this process would significantly reduce the time investment required by radiation oncologists. Having provided pre-made contours, radiation oncologists would only need to make necessary adjustments, rather than starting from scratch. Current development in computer-aided brain cancer contouring is focused on U-net (particularly nnU-net [doi:10.1038/s41592-020-01008-z]) machine learning (ML) architecture. Most of the models are trained on available training sets, the BraTS [https://www.med.upenn.edu/cbica/brats/] is especially worth mentioning. While the results on testing sets are promising, medical centres often struggle to implement these methods as they would require modifications to function with clinics' pipeline.

This paper presents the development of a hybrid contouring system. This system uses a proven ML solution combined with the authors' algorithm (named Interactive Contouring Algorithm, ICA). The system's architecture also allows us to take advantage of Syntactic Pattern Recognition (SPR) methods as a source of additional information. So far, we have developed a system that allows contour generation and extensive output adjustment. ICA is applied to detect differences in image brightness between the brain hemispheres on selected series. Binarization is then applied to discrepant locations for contour extraction. Finally, the contour is compared to the output of a U-net model. The contours are displayed on the source MRI image, allowing the user to choose which outputs to use.

The system's output was evaluated by an experienced physician and deemed to produce high-quality results. ICA was found to be particularly effective on series with a small number of slices and where the distance between slices is not uniform. The current system development can already support clinics' contouring workflow. However, we aim to enhance the output by implementing SPR methods. These methods perform well on structured data, such as ECG [doi:10.1016/0031-3203(86)90056-7], ultrasound data [doi:10.1016/j.patrec.2020.02.023], and other medical image data. In our case, SPR can serve to determine if a contoured glioma/tumor bed is near a fragile or important structure and to enhance contours generated by both the authors' algorithm and machine learning model using SPR.

Since a contouring approach suitable for one workflow may not be optimal for others, users are able to adjust the parameters of ICA and choose between ML and algorithm output. Parameters enable the modification of binarization thresholds, sensitivity of the discrepancy search algorithm, and control of contouring accuracy. The system is being developed in collaboration with radiological experts to ensure accurate evaluation of results and early identification of any shortcomings.

Automated cropping and alignment of ACR and CBR mammography phantom images

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The assessment of breast phantom image is one of the tests proposed by mammography quality assurance guidelines worldwide. The mammography phantoms specified by American College of Radiology (ACR) and Brazilian College of Radiology and Imaging Diagnosis (CBR) emulate structures of the breast and are used to assess the equipment imaging performance. The visual evaluation of phantom images is a subjective process and suffers from inter and intra-reviewer variation, in addition to being time-demanding, therefore the process can benefit from automation by computer tools. Aiming to prepare images to later full automation of the assessment process and to decrease storage size, this work develops a software to crop and align the wax insert area (useful area) of radiographic images of ACR and CBR phantoms.

To develop and test the software, a total of 610 ACR and 866 CBR phantom images were used, from several DR, CR and screen-film mammography units. The Python programming language and the OpenCV library were used to code the automation software. Numerous tests were carried out to decide the best choices of techniques, parameters and restrictions for the correct automatic cropping of the wax insert area.

To decide which interpolation method to use in the image alignment, an experiment was carried out to check the degradation of a test image after several consecutive rotations, using some interpolation options available in the OpenCV library (Lanczos over 8x8, bicubic, bilinear and nearest neighbor). Furthermore, tests were carried out with images artificially rotated between -10° to 10° to verify the correct detection of the area of interest in this range.

The steps taken by the software to crop and align the insert wax region of the phantom image are:

(1) pre-processing for highlighting: equalization, blur, adaptive threshold and morphological opening;
(2) segmentation of the wax insert area based on the search for contours and adjustment of minimum area rectangles with restrictions;
(3) image rotation for horizontal alignment of the segmented area;
(4) cropping of the segmented area.

Among the interpolation methods tested, it could be seen that the image degradation by the Lanczos was the lowest and, therefore, it was the chosen method for the developed software. The experiment with images artificially rotated between -10° to 10° showed that the software was able to correctly crop and align the insert wax area of the ACR and CBR phantom images in that misalignment range.

The test with the big set of images showed that from 610 ACR images, 6 were incorrectly cropped and 3 did not have the wax insert area found by the software, and from 866 CBR images, 16 were incorrectly cropped and 11 did not have the wax insert area found.

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Comparison between three metrics of breast density

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Introduction. Breast density, defined as the percentage of glandular tissue present in the breast, has been shown to be a risk factor in the development of breast cancer when found in large proportions. This occurs due to the decreased sensitivity that mammography exams are subject to when the breast has high density. To assess important factors in breast density variation, measurement methods are used. However, an obstacle that exists among research on breast density is the different methods of measuring this magnitude. Currently, quantitative metrics are considered methods with greater reproducibility when compared to qualitative methods. Numerous software programs are used for these calculations; moreover, the metrics can also consider breast volume, just the breast area, and even a specific region of the breast. The objective of this study is to evaluate three quantitative metrics of breast density calculated by the VolparaDensity software.

Materials and Methods. Mammographic images in cranio-caudal projection format, in DICOM and raw data, were collected from 963 patients undergoing routine breast cancer screening at two medical institutions in Brazil. These images were analyzed using the VolparaDensity software to obtain three metrics of breast density: Breast Volume Density (BVD), Breast Area Density (BAD), and Maximum Volumetric Glandular Tissue Point (MVGTP). BVD and BAD provide measurements of overall breast density, while MVGTP represents a localized measure of breast density. The statisticalsoftware SPSS was utilized to conduct Pearson's correlation test to assess the relationships among the three breast density metrics (BVD, BAD, and MVGTP). This analysis aimed to investigate the interplay and associations between these quantitative measures of breast tissue density, providing insights into their potential clinical relevance and utility in breast cancer risk assessment.

Results. For the breast density metrics, BVD, BAD, and MVGTP had a median of 7.58% ($Q_{25\%}$ = 2.00%; $Q_{75\%}$ = 11.02%), 56.83% ($Q_{25\%}$ = 36.92%; $Q_{75\%}$ = 73.08%), and 1.59 cm^3 ($Q_{25\%}$ = 1.01 cm^3; $Q_{75\%}$ = 1.15 cm^3), respectively. The Pearson correlation coefficient (r) revealed that all three breast density metrics exhibited a strong positive correlation. The highest correlation was observed between the global breast density metrics, BVD and BAD (r = 0.801), followed by BAD and MVGTP (r = 0.683), and lastly BVD with MVGTP (r = 0.649). To advance studies on breast density, it is crucial to establish the best methodologies for measuring this characteristic. Discrepancies among the various methods used to measure breast density may be considered a limitation in this type of study.

Conclusions. The results of this study have demonstrated a positive correlation among the three metrics analyzed. Therefore, it can be considered that in studies using any of these three metrics, it would be possible to obtain consistent results across methodologies. This suggests that BVD, BAD, and MVGTP are promising metrics for assessing breast density.

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Hyperspectral imaging for the detection of basal cell carcinoma using an object-based convolutional neural network approach

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Background. Detecting Basal Cell Carcinoma (BCC) demands precise and effective methods to ensure early intervention and treatment. Hyperspectral imaging (HSI) offers a comprehensive approach by capturing rich spectral data from skin lesions. Integrating Convolutional Neural Networks (CNNs) with HSI presents a compelling solution, leveraging deep learning's capacity to discern intricate patterns within hyperspectral imagery. This study proposes a novel fusion of HSI and CNNs, aiming to enhance BCC detection accuracy and efficiency.

Materials and Methods. Datasets comprising hyperspectral images from 12 patients diagnosed with BCC on limbs, back, face or abdomen were used. Preprocessing steps, including noise reduction, spectral band selection, and data normalization, were employed to optimize dataset quality. The main point of the methodology lies in the development of a specialized CNN architecture tailored explicitly for analyzing hyperspectral data. The proposed CNN model was trained using supervised learning techniques, with annotated BCC regions serving as training data. This facilitated the network's ability to recognize subtle spectral signatures indicative of BCC lesions. Additionally, unsupervised learning approaches, such as self-organizing maps, were utilized to unveil spectral clusters within the dataset. Evaluation metrics such as sensitivity, specificity, were used to assess the performance of the method.

Results. The results of our convolutional neural network (CNN) model showed exceptional performance, with both specificity and sensitivity exceeding 90%. This indicates the robustness of our model in correctly identifying true negative cases, as well as effectively detecting true positive instances with consistency. Such high specificity underscores the model's ability to accurately rule out individuals without the condition under consideration, thus minimizing false positives. Moreover, the consistent sensitivity emphasizes the model's capability to reliably detect true positives, crucial for early diagnosis and intervention.

Conclusion. The fusion of hyperspectral imaging and CNNs presents a promising avenue for enhancing BCC detection capabilities. By harnessing the spectral richness of HSI and the deep learning capabilities of CNNs, this approach offers a potent tool for accurate and timely diagnosis of BCC lesions. The refined CNN architecture demonstrates robust performance in capturing subtle spectral variations characteristic of BCC.

Automated melanoma detection using hyperspectral imaging combined with artificial intelligence

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Background. The overall incidence of cancer and melanoma in particular has increased globally in recent times, although considerable efforts have been made to improve cancer diagnostic capabilities, especially in early stages. Significant progress has been made in recent years in melanoma detection approaches aimed at halting the increase in melanoma incidence and reducing melanoma-related deaths, but there is still a need for new approaches to improve the ability to early detect melanoma. Pursuing to meet this need, this paper proposes a melanoma detection method based on hyperspectral imaging and artificial intelligence. By combining hyperspectral imaging, which provides highly detailed spectral and spatial information, with dedicated data analysis algorithms, information beyond the human vision capability can be obtained and used in melanoma detection.

Materials and Methods. Hyperspectral images of the face of a male patient with a melanoma of the right submandibular region were acquired using a visible/near-infrared pushbroom hyperspectral imaging system. Three hyperspectral data analysis algorithms (Spectral Angle Mapper, Spectral Information Divergence and Spectral Similarity Mapper) exploiting the spectral features of melanoma and non-melanoma (normal skin) pixels in the hyperspectral image were tested and their performances were compared to find the most suitable one for accurate detection of melanoma. The receiver operating characteristic curve and the area under the curve were used to evaluate the performance of the hyperspectral imaging based - melanoma detection method.

Results. The results showed that by combining the hyperspectral imaging with the three different data analysis algorithms, more or less reliable performances in melanoma detection can be obtained. The best performance was obtained for the Spectral Angle Mapper (an area under the curve value of 0.9932). Good results were also recorded for the Spectral Information Divergence algorithm with an AUC value of 0.8313. With such values of the area under the curve, these two algorithms can be considered suitable for the analysis of hyperspectral data and accurate melanoma detection. Unsatisfactory values of the area under the curve (0.2588) resulted after analyzing hyperspectral data with Spectral Similarity Mapper.

Conclusion. In conclusion, hyperspectral imaging could effectively improve the accuracy of automatic melanoma detection, but only if it is combined with appropriate data analysis algorithms. Spectral Angle Mapper and Spectral Information Divergence algorithms could be used for automatic detection of melanoma from hyperspectral images, providing an objective tool without the need for a specialist.

Investigating secondary neutron production in radiotherapy using CR-39 detectors and Monte Carlo simulations

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Photoneutrons are part of the unwanted secondary particles generated in a medical linear accelerator (linac) when high-energy photon beams interact with specific materials within the linac's head. Factors such as the presence of a beryllium filter, flattening filter, and high atomic number (Z) elements in the linac head contribute mainly to photoneutron production. Due to their higher relative biological effectiveness (RBE), even a minor absorbed dose of neutrons can be detrimental. Thus, these photoneutrons can affect shielding requirements in radiation therapy rooms and increase out-of-field radiation dose.

This study focused on both experimental and computational investigations to assess the photoneutron dose equivalent in the treatment room and within a maze of a linac accelerator. The distribution of neutrons (fast and thermal components) and the neutron dose equivalent emitted by a Varian Clinac 18MV accelerator were measured using CR-39 detectors. The linac considered in this study was a Varian Clinac 2100C installed in 2008 at the Hospital Nord Franche-Comté (France) and is under decommissioning. Monte Carlo (MC) modelling of the linac head and the radiotherapy room was performed using the Gate/GEANT4 computer code. The MC simulation of photoneutron production in the linac was carried out using phase space files. These files represent the initial distribution of X-ray photons, electrons, and neutrons in the three linac head components: the target, primary collimator, and flattening filter. Moreover, the secondary collimator and multileaf collimators (MLCs) were also simulated. Furthermore, this study examined parameters influencing the production of secondary neutrons, such as distance from the isocenter, multi-leaf collimator and field size. The results show that the contribution of fast neutrons is more significant than that of thermal neutrons, and this contribution decreases as a function of the distance from the isocenter. The study's findings demonstrate the potential for more effective neutron shielding and optimized treatment planning to enhance radiotherapy safety and effectiveness.

Evaluating the transferability of VMAT plans between dosimetrically matched Varian Clinac iX units for brain and head and neck cancer patients using an end-to-end test

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The transferability of patients between medical linacs has been a long-standing issue in radiotherapy centers with high patient workload. The answer of the medical linacs manufacturers to this issue is dosimetric pairing of different linear accelerators of the same type. However, this matching is performed by adjusting the basic beam parameters, such as percentage depth doses and profiles, leaving the clinical physicist the opportunity to optimize parameters associated with intensity-modulated treatments, such as the size of the second source, the dynamic leaf gap or the transmission of the multileaf collimator.

During the acceptance process of the new Varian Clinac iX s.n. 6116 at the clinic, a dosimetric pairing with an existing one, s.n. 5052, was performed. For the energy of interest, 6 MV photons, the difference in the flat part of the profiles, as well as the percentage depth doses at depths greater than 5 mm, was tuned to less than 1%. The parameters related to the intensity modulated treatments were optimized separately for the two machines.

In order to investigate the viability of VMAT patient transfer between different linacs, an end-to-end test was conducted on both linacs using the, i.e. anthropomorphic head and neck phantom. VMAT treatment plans were created for brain and head and neck tumor sites using the Eclipse treatment planning system version 16.1. The plans were optimized and calculated for the linac 5052 using both the AAA and the Acuros XB algorithms. Then the plans were irradiated on both linacs while using two different detectors, PTW Semiflex 3D chamber and PTW microDiamond at different points. The measured values were intercompared and compared with the calculated ones.

A comparison of the measurement results for each of the two linacs with the corresponding calculated doses for the linac 5052 showed that the differences in delivered doses between the two linacs were mostly less than 2%, and certainly less than 5%, a level that we use as an acceptance criterion.

Given that irradiation gaps are detrimental for the outcome of radiotherapy, it is justified to continue with treatment on matched linac, i.e. the transfer of the VMAT plan from 5052 to 6116 is more beneficial than harmful.

ANGELIKA Phantom: Three-dimensional tool for quality control in gynecologic brachytherapy

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High-dose-rate (HDR) brachytherapy involves treatment planning based on two-dimensional (2D) or three-dimensional (3D) radiographic images of the patient. In order to contribute to the improvement of brachytherapy techniques, this study aims to present a methodology for 3D planning of this therapeutic modality that is also useful for 2D planning and quality control. For this purpose, a three-dimensional simulator, called Angelika, with radiochromic film for dosimetric evaluation was developed and tested. The phantom was made from polylactic acid (PLA) on a Creality K1 3D printer using the FDM printing technique. Dose maps of the phantom volume with radiochromic film were obtained using OmniPro software. The proposed method was tested in brachytherapy scenarios using an Iridium 192 source. The precision of the dose delivery in the irradiated volume was analyzed in the phantom carrying nine pieces of radiochromic film, with a ring applicator and post-loading of the source, considering the prescription of cervical cancer treatment as per routine. The methodology was found to be useful for evaluating 2D and 3D HDR brachytherapy planning. The dose maps obtained with the films were similar to those defined by the computerized treatment planning and delivery system.

New method for range calculation based on empirical models in radiotherapy or proton therapy in liquid water for hemodialysis patients with kidney cancer

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In patients with kidney cancer and/or undergoing hemodialysis, direct ionization and excitation of DNA biomolecular electrons or indirect chemical reaction of free radicals with DNA generally lead to significant biological damage that can result in death.

In this study, we initially focused on comparing the choice between radiotherapy and proton therapy. The preliminary calculation results clearly show the difference in the interaction of energetic photon or proton beams with the softer tissues of the kidney, which contain more than 80% water. Proton collisions with water molecules are estimated based on ionization, excitation, and charge-changing processes. The goal is to model the kidney using a mathematical phantom with real tissue dimensions and compositions using the GEANT 4 platform. Subsequently, a dosimetric comparison between photon and proton irradiation is conducted to identify the most effective technique for delivering minimal doses to organs at risk. We investigated the Bragg-Kleeman rule $R = N \times E\beta$, relating range (R) and incident kinetic energy (E), in the range of 1–300 MeV (DOI: 10.14299/ijser.2017.03.007). The results provide a foundation for estimating the Bragg peak in H_2O + DNA biological matter.

In a second phase, we monitored hemodialysis patients, focusing on albumin protein and body mass index (BMI), critical parameters to monitor (doi.org/10.1016/j.cnd.2022.06.001). In Morocco, this issue is real, and awareness is needed to inform patients about their dietary habits. A preliminary study was conducted on phosphocalcium disorders in hemodialysis patients within a private dialysis center in Casablanca, involving a sample of 68 patients. At the end of this study, 54.41% of patients had well-controlled phosphorus levels according to KDIGO recommendations (doi.org/10.2147/IJNRD.S191156), while 33.83% had hyperphosphatemia, and only 11.76% had hypophosphatemia, with an average of 50.49 mg/l. We identified a significant population with hypocalcemia, and 57.35% were within normal limits for vitamin D, while 40% of patients were deficient.

Based on the presented biological parameters, we emphasize the importance of medical monitoring and early evaluation of phosphocalcium balance and biological status in patients receiving regular irradiation doses. To slow the progression of chronic kidney disease (CKD) and improve the quality of life in these patients, we plan to develop an exploitation sheet based on multiple biological data, including energy and protein intake, as well as salt, phosphorus, and potassium intake, which can lead to dangerous comorbidities.

Keywords: radiotherapy, proton therapy, chronic kidney disease, albumin, calcium, phosphorus, nutrition

Stereotactic radiosurgery treatment plan quality for skull based intracranial tumours

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This work will present a retrospective analysis of plan quality of treatment plans of patients treated for the most common benign tumours, as meningioma, vestibular schwannoma and pituitary adenomas with stereotactic radiosurgery radiotherapy, LINAK based. The dosimetric parameters includes conformity index, dose target coverage.

Ovarian transposition to preserve ovarian function in young patients with cervical cancer undergoing postoperative intensity-modulated radiotherapy – A case series

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Introduction. Total hysterectomy with bilateral adnexectomy and lymphadenectomy is the primary treatment of early cervical cancer. In recent years, the incidence has been increasing in women under 40, and there is a trend of increasing ovarian transpositions.

The Aim. Evaluation of the dose distribution and functionality, in relation to the planning target volume (PTV) and the transposed ovaries position in patients with adjuvant radiotherapy.

Materials and Methods. A series of cervical cancer patients with total hysterectomy with bilateral salpingectomy with ovarian transposition, who were prescribed adjuvant radiotherapy. The status of ovarian function was monitored one year after treatment based on the values of luteinizing and follicle-stimulating hormone at three-month controls. The research was conducted at the Center for Radiation Oncology, University Clinical Centre Kragujevac from May 2021 to January 2024.

Results. Four cervical cancer patients FIGO stage I and II (2018) average age of 35.37 years treated with postoperative intensity-modulated radiotherapy (IMRT) with delineation and preservation of 6 ovaries (average TD 41.25 Gy) and brachytherapy with 3 applications of 600 cGy. Ovaries D_{mean} dose was an average of 13.06 Gy. Hormonal function was maintained by two ovaries from two patients, which were transposed at least 5 cm above the iliac crest, i.e. PTV whose D_{mean} doses were 2.1Gy and 4.3 Gy.

Conclusion. Preservation of ovarian function is related to the dose contribution and their distance from the PTV. Before ovarian transposition, it is necessary to consult a radiation oncologist regarding the target volumes position, because the decision on adjuvant radiotherapy is usually made after surgery.

Keywords: ovarian transposition, cervical cancer, postoperative radiotherapy

Changes in the hormone receptor status of residual breast carcinoma

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Knowing the hormone receptor status of breast cancer is important for treatment options. Alterations in estrogen receptor (ER) and progesterone receptor (PR) from primary to residual carcinoma, before and after chemo and radiotherapy is applied, may lead to changes in treatment decisions. The objective of this study is to evaluate the frequency of hormone receptor (HR) status conversion. From 350 patients diagnosed with breast cancer at the University Hospital Center "Mother Theresa" in Tirana, 33 patients with available biopsy results from both primary and residual sites were included in this study. We investigated the alteration of ER and PR status using Immunohistochemistry (IHC) technique on paraffin embedded tissue blocks during breast cancer progression and evaluated the value of receptor conversion before and after chemo and radiotherapy were applied. Patients were classified as not having receptor change versus any receptor change. Changes in hormone receptor status between the pretreatment and residual disease were observed in up to 45% of patients. This study indicated that hormone receptor status is unstable throughout tumor progression. Most guidelines do not currently recommend routine retesting; however, it should be considered to further test whether changing treatment based on hormone receptor conversion could improve prognosis of recurrent breast cancer.

Keywords: breast cancer, immunohistochemistry, hormonal receptor, therapy

The ^{160}Gd neutron capture reaction for ^{161}Tb production

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The neutron capture reaction cross section of gadolinium isotopes plays an important role in several fields spanning from astrophysics to nuclear technologies for energy and medical applications. In the last case neutron capture reactions on gadolinium are linked to the terbium production. Such an element offers a poker of clinically interesting elements and among these, the β^-/γ emitter terbium-161 is very similar to lutetium-177 in terms of half-life (6.89 d), β^--energy and chemical properties. Moreover, being Tb-161 an emitter of conversion/Auger electrons, a higher Linear Energy Transfer (LET) is expected relative to Lu-177, with a consequently larger therapeutic effect. However, existing nuclear data on the Gd-160 neutron capture reaction leading to Tb-161 production are quite scarce and inconsistent between each other. For this reason, the n_TOF Collaboration has performed a new measurement of the capture cross section of Gd-160 at the CERN neutron Time-Of-Flight facilty that has provided high resolution, high-accuracy data on this important reaction of interest for Nuclear Medicine, in the energy range from thermal to tens of keV. In this talk, the results obtained at the n_TOF facility will be presented.

Application of DFT theoretical chemistry methods for development of new radiopharmaceuticals

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Although a large number of radiopharmaceuticals based on radioactive metals are used in nuclear medicine, there is an increasing need for the development of new radiopharmaceuticals. To bind the radioactive metal and deliver it to the appropriate place, it is necessary to use appropriate ligands. The properties of the resulting complex depend mostly on the properties of the metal itself. In the case of d-transition metals, degenerate electronic states may appear, as a result of which such complexes are subject to Jan-Teller distortion, while in the case of complexes with f-metals there is a very strong spin-orbit coupling, and in the case of heavy p-metals due to the presence of 6s electronic pair pseudo Jan-Teller distortion occurs. Adding to that the fact that metals can be soft or hard acids and that they will form covalent bonds with ligator atoms that are soft or hard bases respectively, this greatly complicates the choice of ligands and the prediction of the structure. Using density functional theory (DFT) with the ZORA relativistic method to properly describe heavy metals, complexes of Y^{3+}, Zr^{4+}, Ga^{3+}, Lu^{3+}, Pb^{2+}, Bi^{3+} with the DOTA chelating ligand were investigated. Using energy decomposition analysis method, it was determined which metals prefer lower or higher coordination numbers, and which factors influence this. In the case of the Pb^{2+} and Bi^{3+} complexes, it was established that the free 6s electron pair has a great influence on the structure of the complex, especially in the case of the Bi^{3+} complex.

Alteration of ^{99m}Tc-tin colloid biodistribution by Juglans nigra leaf extract

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The biodistribution of radiopharmaceuticals employed in diagnostic imaging can be influenced by numerous factors. If not understood, these factors may lead to: (a) poor visualization of the organs and to induce inadequate interpretation of the examination and misdiagnosis or (b) repetition of the examination procedure, resulting in unnecessary irradiation of the patient and medical staff. Despite the widespread use of natural products as food or human medicines, they can affect the bioavailability of radiopharmaceuticals. Therefore, the objective of this study was to examine the influence of a J. nigra leaf extract on the biodistribution of the radiopharmaceutical ^{99m}Tc-tin colloid and on the morphology of certain organs in Wistar rats. ^{99m}Tc-tin colloid is a radiopharmaceutical that has been used as an agent for scintigraphic imaging of the liver.

Leaf extract or 0.9% NaCl was administered by oral gavage to Wistar rats at dose levels of 13.7 mg kg^{-1} body weight day^{-1} for 10 days. On 11th day, the radiopharmaceuticals were injected and the rats were sacrificed. The organs of interest were isolated and radioactivity in each organ was counted. The animals were also subject to a gross necropsy.

The leaf extract at a dose of 13.7 mg kg^{-1} bw did not significantly alter ($p>0.05$) the uptake of ^{99m}Tc-tin colloid in various organs, including the thyroid, brain, spleen, pancreas, small intestine, muscle, bone and blood, heart, liver, kidneys, stomach, and colon. However, a statistically significant decrease ($p<0.05$) in the percentage of applied dose was observed in the lungs. No significant changes ($p>0.05$) were noted in the relative weight of vital organs in the treated groups compared to the control group during necropsy. Macroscopic examinations of the organs from rats treated with the extract did not reveal any changes compared to the control group.

In this study, it was observed that leaf extract decreased the uptake of ^{99m}Tc-tin colloid in the lungs, thereby contributing to the reduction of the radiation dose in the lungs—a non-target organ. However, it had no effect on uptake in the liver, which is considered an organ of interest. This observation leads us to believe that, at the studied concentration, this extract does not interfere with the normal biodistribution of ^{99m}Tc-tin colloid in the organs of Wistar rats.

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Stability tests for ^{99m}Tc-DTPA radiopharmaceuticals

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Applications for marketing authorization in respect of radiopharmaceuticals should be accompanied, as in case of all medicinal products, by the particulars and documents referred to in Directives 65/65EEC and 75/31/EEC as amended and in the Annex of Directive 75/318 EEC as amended. Most radiopharmaceuticals are used for the purpose of medical diagnosis. They contain only small amounts of the active substances with a radionuclide attached to them to allow scintigraphic imaging or measurement of biodistribution. Radiopharmaceuticals have changing composition with time, associated with the radioactive decay. The physical half-life of the radionuclide is often so short (like ^{99m}Tc). In these cases, the final preparation must be done immediately before administration to the patients. For all radiopharmaceuticals, the shelf life of the product as supplied by the manufacturer should be specified and justified, as should a shelf life after reconstitution where applicable, considering radiochemical and radionuclide degradation products.

The aim of this study was determination of stability of ^{99m}Tc-DTPA (Diethylenetriaminepentaacetic acid) radiopharmaceuticals used for brain and kidney scanning. Stability is defined analyzing radiochemical purity of the ^{99m}Tc-DTPA radiopharmaceuticals in different times after reconstitution (labelling of cold DTPA-kit with ^{99m}Tc-eluate) and production (shelf-life of cold DTPA-kit). Chromatographic methods of assaying radiopharmaceuticals are used for determining the radiochemical purity of ^{99m}Tc-DTPA radiopharmaceuticals. The system used was ITLC-SG/Acetone and ITLC-SG/Saline to determine the sum of radiochemical impurities (free and hydrolyzed ^{99m}Tc). In conclusion of many experiments, the results show that ^{99m}Tc DTPA radiopharmaceutical was stabile up to 2 hours after its reconstitution and 1 year after cold kit production.

Tests for determining NK cell activity in laboratory practice

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NK (Natural killer) cells are a special group of peripheral blood lymphocytes that act differently from T lymphocytes and that kill virus-infected cells as well as tumor cells. For testing NK cell function, the classic gold standard assay has been used for a long time, determining the activity towards target tumor cells using radioactive chromium. The test requires prior labeling of cells with radionuclides, most often radioactive chromium 51 due to its short half-life, and then determination of cytotoxicity in cell co-culture between NK cells (as effectors cells) with tumor cells (as target) and finally measurement on a radioactivity using gamma counter. In order to reduce the use of radiation in medicine according to the requirements of public health, as well as the development of new technologies, some new methods have recently been used to replace the radioactive test with other tests. Some of them, such as enzymatic ones, are used by using intracellular enzymes instead of labeling with chromium to measure cytotoxicity, and after certain standardization it was shown that there is a significant correlation between these tests. However, the development of flow cytometry and modern techniques using lasers also enabled the analysis of NK cell activity, but by determining the mediators produced by NK cells. Here, the total cytolytic activity is not determined, but only the secretory components, but the tests can serve when comparing healthy and sick patients if they are applied simultaneously. However, classic tests using radioactivity hat determine the total cytotoxicity of NK cells towards the tumor cell to lyse it with the use of radioactive markers should be the standard assay. According to the findings of this standard test with radionuclides, it should be possible to recalculate the values obtained by other tests in the assessment for each subject with tumors where NK cell activity is determined.

Hormesis effect on advanced cancer patients by Radium Spa in Japan

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The term hormesis is defined as a process in which exposure to a low dose of a chemical agent or environmental factor that is damaging at higher doses induces an adaptive beneficial effect on the cell or organism. To survive and reproduce in harsh competitive environments, organisms and their cellular components have, through evolution, developed molecular mechanisms to adaptively to various hazards or stressors that they encounter. Hormesis is a fundamental principle of biology.

When human cells are cultured under unshielded conditions, heat shock proteins were produced more in shielded cells. All -cause mortality and all-cause cancers were significantly lower for nuclear workers than for nonradiation workers. Low-dose radiation from A-bombs elongated lifespan and reduced cancer mortality relative to unirradiated individuals. Low-dose radiation sometimes stimulated our defense mechanisms and beneficial. Earth has been exposed to ionizing radiation for billions of years. Radioactive substances from the birth of earth are still abundant on the earth. We are exposed to large radiation hits from not only the environment but also from materials inside our body. Breathing is more hazardous than low-dose radiation. Hazards by both respiration and low-dose ionizing radiation are mainly caused by Reactive oxygen species (ROS), but ROS product by respiration overwhelms that by low-dose radiation. ROS quenching systems developed under intensive ionizing radiation conditions for more than billion years before the appearance of oxygen in the air must be readily applied to quench ROS by respiration. Low-dose radiation is sensed by bacteria and gene expression is changed greatly at the transcription level. Humans have the ability to sense crisis and to prepare for defense. Defense systems by various mechanisms (ROS quenching, DNA repair, apoptosis, anticancer immunity etc.) must be associated with hormetic dose-response relationship. Low-dose radiation sometimes stimulated our defense mechanisms and beneficial. Hormesis is a positive effect of radiation famous radium spa in Japan:

1. Tamagawa spa (Miyagi)—Many cancer patients who have been given over by doctors gathers from all over Japan-one final hope for cancer patients.

2. Misasa spa (Tottori)—Standard mortality ratios for cancers of all sites were significantly lower among the inhabitants of both Misasa and the control area than in the whole Japanese population

Low-dose radiation in Radium spa is effective for advanced cancer patients sometimes. Radiation hormesis is considered beneficial and promising for advanced cancer patients.

Gender prediction based on the quantitative analysis of the mastoid process

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Osteoscopy and classic morphometric analysis of the skull can determine gender with an accuracy of 92%. The aim of our study was to determine the degree of accuracy in determining the gender of the skull based on the classic morphometric analysis of the mastoid process.

The research was conducted on a sample of 100 macerated and degreased skulls of known gender and age from the second half of the 20th century, including the population of Bosnia and Herzegovina, which belong to the osteological collection of the Anatomy Department of the Faculty of Medicine, University of Sarajevo. It is a prospectively designed, osteometric study, where 3 diameters of the mastoid process were measured on each skull using a sliding compass (Schubler) on both sides: mastoid length, width and antero-posterior diameter. The size of the mastoid process was calculated according to the given formula.

The antero-posterior diameter of the mastoid process was shown to be a significant predictor for the differentiation of skull gender p=0.0001. If the antero-posterior diameter of the mastoid process increases by 1 mm, the odds ratio (chance ratio) that it is a female skull decreases by 41% in our sample, while in the general population the chance ranges between 50-30%. The size of the mastoid process proved to be a significant predictor for the gender differentiation of the skull p=0.0001. If the size of the mastoid process increases by 1 mm3, the odds ratio (chance ratio) that it is a female skull decreases by 41% in our sample, while in the general population the chance ranges between 50-30%.

Increasing values of length, width, antero-posterior diameter and size of the mastoid process increase the probability that the skull is classified as male. By multivariate binary logistic regression, the antero-posterior diameter of the mastoid process was singled out as statistically significant for the differentiation of skull gender.

Keywords: sexual determination, mastoid process, discriminatory functional analysis, morphometry

Human exposure to heavy metals over the last 100 years

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The primary objective of the presented research was to assess the impact of intense global economic development, over the last 100 years, on the bioaccumulation of heavy metals in the human body. This evaluation was conducted based on the measurement of heavy metals in human hair samples collected 100 years ago in present-day southern Poland. In this study, concentrations of lead (Pb), cadmium (Cd), arsenic (As), zinc (Zn), copper (Cu), iron (Fe), and selenium (Se) were measured in 61 hair samples, 28 of which were obtained from individuals who lived 100 years ago, while the remaining 33 constituted the contemporary control group. The concentrations were determined using a triple quadrupole inductively coupled plasma mass spectrometer (Agilent 8900). To assess the significance of differences in heavy metal content between the individual groups, the non-parametric Mann-Whitney test was used. In the case of As, Pb, Cd, and Fe, the concentrations were significantly higher in individuals who lived 100 years ago compared to those living today. Over this period, the median concentrations were shown to have decreased by 95%, 94%, 85%, and 69% for As, Pb, Cd, and Fe, respectively. No statistically significant differences were observed for Cu, Zn, and Se. The results obtained for Pb, Cd, As, and Fe unequivocally indicate that the population studied from 100 years ago was more exposed to internal contamination with these metals than people currently living.

Comparison of the success of immunization against diphtheria in the Šumadija District before, during and after the COVID-19 pandemic

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Introduction. Diphtheria is an acute respiratory infection caused by the gramme-positive bacillus *Corynebacterium diphteriae*. Diphtheria can manifest with various clinical manifestations ranging from diphtheria of the skin, diphtheria of the eye, nasopharynx, tonsils to severe respiratory tract infections. Due to the strong exotoxin produced by this bacterium, complications can occur in some organs and organ systems (myocarditis, neuritis, paralysis). It is very important to treat patients with antibiotics and diphtheria antitoxin to reduce the effect of the exotoxin produced by this pathogen. As a preventive measure, the vaccine should be administered in childhood from the age of one. A booster vaccination is given at 2, 7 and 14 years of age.

Objective. To determine whether the regular administration of the diphtheria vaccine is carried out according to the mandatory vaccination calendar on the territory of the Šumadija district in Serbia and to compare the results obtained for the period before, during and after the COVID-19 pandemic.

Results and Discussion. Thanks to mandatory vaccination, the morbidity and mortality of children has decreased, and in our country this serious infection has almost disappeared, i.e. eradicated. In many countries in Asia and Africa, there are cases of occurrence and spread of diphtheria during the year.

The study is based on the processing of statistical data for the 2018-2022 period. During the pandemic caused by the Corona virus (COVID-19), there was a standstill in health services and interruptions in health care at the primary health care level. It was also observed that the percentage of vaccinations administered decreased in the calendar years during the pandemic and immediately after COVID-19. For the period from 01.01.2020 to 31.12.2020, a significant decrease in booster vaccination against diphtheria from 98% to 72% among 7-year-olds and from 96% to 86% among 14-year-olds was observed on the territory of Šumadija District compared to 2018, the period before COVID-19.

Conclusion. It is to be feared that the disease, which can assume epidemic proportions due to its easy transmissibility and spread, will re-emerge. Healthcare professionals and the population should continue to be educated about the importance of mandatory vaccination according to the childhood vaccination calendar.

Keywords: diphtheria, vaccination, booster vaccination, medical education, COVID-19

Burnout syndrome among medical staff in the District of Bor

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Introduction. Stress is any abnormal reaction of the human organism that manifests itself in psychological and physical symptoms and behavioral responses that occur as a result of attempts to adapt the organism to a sudden, unpleasant influence. It is assumed that stress is a functional state of disturbed equilibrium of the organism and a short-term psychophysiological state that occurs in response to external and internal factors. Occupational stress is a phenomenon often experienced by professionals in certain professions, including healthcare workers. Burnout is a state of excessive stress and a complex human response to long-term exposure to stress. The signs are similar to stress, but burnout also includes emotional exhaustion and an increasingly negative attitude towards work and even life.

The Research Aims. To determine the current intensity of burnout among healthcare workers.

Research Methodology. A modified questionnaire on burnout among healthcare workers and a questionnaire on socio-demographic data specifically designed for this study were used for the study. Data processing included descriptive statistics and hypothesis tests.

The Results of the Study. The results show that there is no statistically significant difference between the manifestation of stress in the basic group of respondents (emergency medical service) and the control groups (general practice service, pediatric pharmacy). Such a result contradicts many other studies from the literature (American Medical Association, 2023; Medscape, 2015; Molina-Praena et al., 2018). When interpreting the results obtained, we believe that the reason for this could be the size of the sample, as well as the fact that a larger area (Timočka Krajina) was covered. Likely, we would then find a difference in work stress in the EMS and control groups. Burnout syndrome in primary care in Bor is more pronounced than we predicted. We had expected burnout syndrome to be more pronounced in the ambulance service than in the pediatric and general medical service.

Conclusion. The statistically processed results of our study show that healthcare staff in primary care are exposed to an approximate level of stress, regardless of where they work or what function they perform. With combined efforts and support, we can overcome the challenges and create a working environment that promotes our well-being and enjoyment of our daily work.

Keywords: stress, healthcare professionals, burnout, medical professions, work environment

The importance of compulsory vaccination of children in the fight against pertussis after COVID-19

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Introduction. Whooping cough (pertussis) is a contagious respiratory disease caused by *Bordatella pertussis*, a gramme-negative bacterium. It can occur at any age. The clinical picture is diverse, with a wide range of symptoms and severity, especially in newborns, infants and the elderly. Due to the potential complications, a high morbidity and mortality rate of this disease has been recorded in developed and developing countries. The diagnosis is made on the basis of the clinical picture and confirmed by a nasal swab or a nasopharyngeal aspirate, PCR detection or serological tests. Epidemics occur worldwide every 3 to 5 years. Early detection of the disease itself and appropriate and rapid treatment with suitable antibiotics are key to success in controlling the epidemic.

Objective. To determine whether, with the emergence of COVID-19, the rate of vaccinations and booster vaccinations against whooping cough according to the prescribed vaccination calendar on the territory of Šumadija District has decreased compared to previous years before the outbreak of the coronavirus pandemic.

Results and Discussion. Prevention of this disease is childhood vaccination according to the vaccination calendar prescribed in our country. Whooping cough is a notifiable disease in the Republic of Serbia and is recorded in the Report on Infectious Diseases of the Institute of Public Health of Serbia "Dr. Milan Jovanović-Batut". The incidence of diseases in Serbia has steadily decreased since the introduction of compulsory vaccination in the middle of the 20th century. The pertussis vaccine has proven to be an effective and powerful weapon in the fight against whooping cough in all age groups.

The statistical data obtained shows that the vaccination coverage rate in the first year of life was 89% in 2021, compared to 2018 when it was 98% in the first year of life. Booster vaccination in the second year of life was 90% in 2021 compared to 98% in 2018 in the Šumadija District.

According to the latest guidelines for vaccination and taking into account the recurrence and spread rate of this disease, as well as possible complications in certain systems, we should talk about the possibility of supplementary vaccination at some point in life.

Conclusion. Based on the processed data, it can be stated that the response of children to vaccination and booster vaccination has decreased during the COVID-19 pandemic in the Šumadija District. It is necessary to check the vaccination status and thus improve immunity against this disease in order to reduce the possibility of the occurrence and spread of the said disease on an epidemic scale, which is extremely serious in newborns, young children and the elderly.

Keywords: whooping cough, immunization, vaccination calendar, Šumadija District, COVID-19

Verification of the tetanus vaccination status of children after COVID-19 in adults and the elderly after injury

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Introduction. Tetanus is a fatal disease that is widespread in underdeveloped countries. Tetanus occurs after injuries, which are the entry point for infection with *Clostridium tetani*. The bacillus itself secretes a strong and potent exotoxin that causes intoxication of the body, which can be manifested by neuromuscular dysfunction. Tetanospasmin, as a powerful neurotoxin, can lead to a fatal outcome of this disease if adequate protection is not prescribed in time after the injury to prevent further intoxication with this exotoxin. Even greater importance should be attached to neonatal tetanus, which has been more common in rural areas over the last century.

The vaccine is one of the safest and most effective measures in the fight against tetanus, as it provides long-term protection in fully immunised individuals. Surgical treatment and appropriate wound care, as well as the administration of anti-tetanus serum together with the vaccine in the first hours after the injury, lead to 100% protection against this deadly disease.

Objective. To determine whether regular vaccination against tetanus in children in the Šumadija District has been successfully carried out over a five-year period from 2018 to 2022 in order to achieve satisfactory immunity and protection against this disease for a certain period of time.

Results and Discussion. The lowest success rate in immunization against tetanus for the observed five-year period was observed in 2020: 72% for the booster vaccination at the age of seven and 86% for the booster vaccination at the age of fourteen for the area of Šumadija District. Even during the current COVID-19 pandemic in calendar year 2021, a low tetanus vaccination coverage rate is observed compared to the period before the pandemic. Based on statistically processed and summarized data, it can be said that the vaccination coverage rate for 2021 is significantly lower for the first vaccination in the first year of life and is 89%, the booster vaccination in the second year of life is 90% and in the fourteenth year of life 87%.

It is important to pay attention to immunization status and the completeness and regularity of tetanus vaccination. In some developed countries, special attention is paid to the assessment of tetanus vaccination status by reviewing medical records as part of primary health care.

Conclusion. Continuous and improved education of physicians (especially surgeons, anesthesiologists and emergency physicians) about immunization of the childhood population according to the calendar of mandatory vaccinations and the elderly against tetanus in the form of panel discussions, lectures and professional conferences is extremely important. Immunoprophylaxis in children and immunoprophylaxis together with seroprophylaxis and chemoprophylaxis in the elderly are the key to success in the fight against tetanus.

Keywords: tetanus, COVID-19, immunization status, injury, education

Analysis of risk factors for acute radiation toxicity in cervical cancer patients in FIGO IIIC1 and IIIC2 stages treated with definitive chemoradiation

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Introduction. During radiotherapy treatment for cervical cancer, the highest percentage of patients experience some manifestation of acute radiation toxicity. The risk of toxicity increases with the stage of the disease because a greater percentage of the organ at risk volumes are involved in the radiotherapy field. The application of modern high-precision radiotherapy techniques greatly contributed to reducing the intensity of toxicity, but the frequency of toxicity did not decrease significantly.

Aim. The primary aim of this research was the analysis of risk factors for the occurrence of acute radiation toxicity in patients with cervical cancer in FIGO IIIC1 and IIIC2 stages treated with definitive chemoradiation.

Materials and Methods. A cohort case-control study was conducted based on the analysis of potential risk factors for the onset of acute radiation toxicity in cervical cancer patients in FIGO IIIC1 and IIIC2 stages treated with definitive with external beam radiotherapy with simultaneous integrated or sequential boost doses, brachytherapy and chemopotentiation. The patients were retrospectively followed up from January 2020 to January 2024 in a tertiary care hospital.

Results. The study integrated 92 patients with cervical cancer in FIGO IIIC1 and IIIC2 stage, which determined treatment with definitive chemoradiation. Clinically significant manifestations either of acute hematology, genitourinary or gastrointestinal radiation toxicity (CTCAE v.5 grade II and higher) were recorded in 28.3% of patients. Univariate analysis showed statistical significance for the variables related to the number of chemotherapy cycles applied, the height of the boost doses GTVn, total rectal volume and V50 and V30, as well as V45 sigma ($p<0.05$). By multivariate binary logistic regression, the number of chemopotentiation cycles applied, the height of the GTVn boost doses, rectal V50 and V45 of the sigma were the most significant factors in the occurrence of acute radiation toxicity ($p<0.05$).

Conclusion. Acute radiation toxicity in patients with cervical cancer in the IIIC1 and IIIC2 stage treated with highly precise radiotherapy techniques is most closely related to the number of cycles of chemotherapy and the height of the boost dose delivered to the GTVn. Chemopotentiation with cisplatin potentiates both desired and side effects of radiotherapy, and the total dose can potentially have a cumulative effect. In order to reduce the volume of tissue from the risk that is included in the radiotherapy field, patients must be adequately prepared for each radiotherapy fraction by respecting the diet and care regime during radiotherapy.

Key words: cervical cancer, definitive chemoradiation, acute radiation toxicity, risk factors

Effect of new Pt(IV) complexes and co-treatment with resveratrol on the antioxidant capacity of rat erythrocytes

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Chemotherapy's low efficacy and adverse consequences prompted researchers to seek alternatives for novel anticancer drugs. Although they have remarkable anticancer potential, platinum(IV) complexes containing esters of ethylenediamine-N,N′-di-S, and S-(2,2′dibenzyl)acetic acid also cause damage to healthy cells [https://doi.org/10.1002/ddr.21900, https://doi.org/10.1007/s12013-020-00953-y]. This study aims to investigate the impact of new platinum(IV) complexes (C1 and C2) containing ethyl-, and propyl- esters of ethylenediamine-N,N′-di-S,S-(2,2′dibenzyl) acetic acid and co-treatment with resveratrol (Res) on antioxidant capacity of erythrocytes isolated from treated rats. For this purpose, the activities of the following enzymes were measured in the obtained erythrocytes lysates: catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), glutathione reductase (GR), and glutathione-S-transferase (GST), as well as the concentration of reduced glutathione (GSH). Each of the six experimental groups included six Wistar albino female rats that were randomly assigned. The investigated chemicals were intraperitoneally injected as a single dose of Pt(IV) complexes C1 and C2 (10 mg/kg) or Res (25 mg/kg) alone or in combination. All three investigated compounds caused changes in measured parameters. Activities of all measured enzymes were decreased after treatment with complexes but also with resveratrol when compared to control. At the same time, the concentration of GSH was significantly increased compared to the control after specified treatments. Nevertheless, co-treatment raised the activities of CAT and GSH-Px compared to single treatments and reversed them to near-normal values measured in control. Regarding SOD, GR and GST, their activities were additionally lowered after combined treatment than single treatment and control. Further, the concentration of GSH was remarkably increased after combined treatments. The obtained results indicate the ability of novel Pt(IV) complexes to influence antioxidant capacity inducing redox disbalance in erythrocytes. Res also caused similar but slight changes, while co-treatment on the one hand alleviated, as well enhanced the effects of single treatments. Therefore, these findings may contribute to further examination involving the elucidation of the mechanisms of action of investigated compounds.

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Pt(IV) complex with *O,O'*-dibutyl-ethylenediamine-*N,N'*-di-*S,S*-(2,2'-dibenzyl)acetic acid ester induces nephrotoxicity in female rats: Protective effect of resveratrol

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The non-selective effect of chemotherapy drugs frequently results in nephrotoxicity. One of the possible ways of eliminating the accompanying harmful effects of chemotherapy is the creation of new platinum (IV) complexes. In addition, the adjuvant application of chemotherapeutics with derivatives of plant origin, which have pronounced antioxidant and antitumor potential, has proven to be a good strategy in overcoming the aforementioned problems.

This study aims to investigate the effects of newly synthesized Pt(IV) complexes containing butyl-esters of the ethylenediamine-*N,N'*-di-*S,S*-(2,2'-dibenzyl) acetic acid on the kidneys of Wistar albino rats, as well as potential beneficial effects of resveratrol. The goals were achieved by measuring redox status parameters as well as by histopathological detection of morphological changes in kidney tissue.

The tested group of animals were intraperitoneally treated with a single dose of 10 mg/kg b.w. for Pt(IV) complex; 25 mg/kg b.w. for resveratrol; and their combination. The control group was injected only with saline. Applied compounds led to a significant decrease in superoxide anion radical compared to control, alone or in combined treatment, while the concentration of hydrogen peroxide didn't change. As for nitric oxide and lipide peroxide production and superoxide dismutase activity, treatment with complex and combined treatment increased them, while catalase activity was decreased compared to control. In combined acting, resveratrol influenced the normalization of measured parameters compared to control values, but mostly without statistical significance concerning individual treatments. Additionally, the combined treatment resulted in a significant increase in lipid peroxides compared to control and individual treatments.

Regarding histopathological results for both individual treatments, moderate hydrops degeneration, necrosis, atrophy, and desquamation of the tubular epithelium cells were noticed, while other changes were of mild intensity. Apart from a moderately intense interstitial inflammatory infiltrate, the combined treatment primarily produced minor alterations. Based on the obtained results the newly Pt(IV) complex may cause mild nephrotoxicity, and combined treatment with resveratrol could protect kidney tissue, but not significantly. These findings could be helpful for future research aimed at elucidating the mode of action of the investigated compounds.

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New experimental setup for exposure of gas-phase bio-aerosols to small air ions

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The COVID-19 pandemic has once again steered the attention of the public to not only medical but also economic and societal problems, caused by airborne microorganism infections. As one of the means of controlling airborne pathogens, there has been a revived interest in using air ionizers to purify the indoor air in closed spaces. The major benefit of newer corona air ionizers stems from the use of carbon fibres to produce small air ions without the harmful side effect of producing ozone (doi: 10.1080/02786820802339553). In addition to speeding up the natural deposition of particles in the air (doi: 10.1016/j.jaerosci.2023.106199), including the bio-aerosol particles, small air ions have been reported also to produce a biocidal action on airborne microorganisms (doi: 10.1186/1471-2180-7-32, doi: 10.1016/j.jhin.2022.04.004, doi: 10.1128/Spectrum.00651-21). In order to perform a detailed study of the effects of small air ions to the gas-phase bio-aerosol, we have developed a dedicated experimental setup for bio-aerosol exposure, able to provide accurate measurements even with moderate bio-aerosol concentrations.

Here we describe the newly invented air ion exposure setup and its principles of work. We report on the experiments with *Aspergillus fumigatus* and *Mycobacterium gordonae*. We study the effects of air ions of different air ion concentrations, polarity ratios, and exposure times. The increased efficiency of particle deposition as well as the noticed biocidal effects are reported.

Imaging of *Staphylococcus aureus* by AFM and SEM

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Analysis of biological samples is an important and complex endeavor that often times needs the utilization of advanced characterization methods. The aim of the present study is to highlight the advantages but also some of the limitations of using Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) in bacterial research.

AFM and SEM were employed in order to observe morphological modifications of *Staphylococcus aureus* cells induced by different types of decontamination agents. The decontaminations agents used are common substances used in decontamination and disinfection, like: *alcoholic solutions, bis(aminopropyl)laurylamine* (N-(3-aminopropyl)-N-dodecyl-1,3-propanediamine) and *natrium hypochlorite solution*.

Using the two techniques it was possible to observe the induced differences in term of cellular dimensions, topography and roughness compared to the untreated (control) cells. The AFM can reveal high resolution details of the samples with minimal sample preparation while the SEM could offer a larger area scan but at the cost of more complex preparation. Both methods were successfully employed and proved to be complementary in the characterization of the bacterial cultures before and after the applied treatment.

Keywords: *Staphylococcus aureus,* bacterial cells morphology, AFM, SEM

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Combined fNIRS and EEG neuroimaging of the prefrontal lobe: Acquisition and processing protocols

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Functional Near Infrared Spectroscopy (fNIRS) is a relatively novel optical neuroimaging technique used for functional imaging of the brain and its workload assessment under various neuropsychiatric conditions. Electroencephalography (EEG) is a highly applicable method to monitor brain electric dynamics and therefore to study brain functionality. Both of these techniques have been used to analyze cognitive processes of the brain.

The purpose of this study, is to design and apply a data acquisition protocol from the prefrontal lobe, using the two aforementioned techniques, and a data processing protocol to quantitatively compare the signals extracted by the two applied methods. Such methodology would allow to highlight the types of procedures, both experimental and in active medical practice, where fNIRS and EEG can be concurrently operated, in order to achieve cumulatively the EEG's higher temporal resolution and fNIRS' better spatial resolution, considering in parallel its prominent use in special cohorts such as infants and patients with motor impairments accompanying their already existing neurological conditions, as well as its profoundly less costly price compared to EEG's.

For the experimental trials, the fNIRS ETG-4000 model and Enobio NE EEG devices were used. A total number of five human subjects (male and female) were chosen and each underwent a cognitive task protocol five times consecutively using both aforementioned devices and thus collecting fNIRS and EEG data for each and every procedure, subject and trial.

The experimental cognitive tasks performed were the Verbal Fluency Task (VFT) including both of its two modes, the Letter VFT and the Category VFT, applied in a linguistic version that serves the native language of the participating subjects, followed by the Reasoning Task with the use of Raven's Advance Progressive Matrices (Raven's APM).

The results present a certain degree of correlation of the data obtained by the two different neuroimaging techniques, indicating the potential of their combined use. In any case, it is essential that the fNIRS and EEG techniques should get tested out with even more cognitive tasks and experimental trials, in order to have a clearer and more reliable picture concerning their correlation.

Keywords: fNIRS, EEG, prefrontal lobe, cognitive tasks, neuroimaging

In vitro experimental model of reactivated toxoplasmosis through the prism of computational image analysis

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Computational image analysis has recently gained increased importance in medical research and diagnostics. Precisely established tissue and cell properties, resulting from dedicated image analyses, are quantitative, repeatable, and free from subjective judgement bias possible with human observers. We were the first group to apply fractal analysis for the description of structural complexity of *Toxoplasma gondii* tissue cysts, in combination with the morphological and particle analyses (doi.org/10.1371/journal.pone.0234169). The majority of analyzed parameters were stable among cysts, indicating a highly uniform structure and occupancy of the *T. gondii* brain cysts of different age and parasite strains, as well as of those derived from mice of different genetic background.

In this work, we present the results of our most recent investigation in this field. Photographs of the *in vitro* conversion of bradyzoites to tachyzoites simulating reactivated toxoplasmosis (RT) in an immunocompromised host, but also cellular invasion and intracellular proliferation (parasitophorous vacuole, rosettes, etc.), will be obtained in experimental settings with (sulfadiazine and/or acridines/acridones) and without (control group) treatment. High resolution digitalized microscopic images will be analyzed using the ImageJ software. The optimization of the morphological, particle, and fractal analyses to the acquired data, as well as investigation of usefulness of other methods, e.g. texture analysis will be carried out.

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