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BOOK OF ABSTRACTS

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TUESDAY, 6 OCTOBER

S1.1 Radiation Safety in Crisis Situations

S1.1-1 ON THE HEALTH SIGNIFICANCE OF REFERENCE LEVELS ADOPTED IN RADIOLOGICAL EMERGENCY SITUATIONS: TOWARDS COMPLEMENTARY METRICS?

Author: Quentin Couanau, Yann Billarand | Co-Author: | Speaker: Quentin Couanau

In the event of a nuclear or radiological accident, public authorities may implement protective actions such as sheltering, evacuation, or stable iodine administration. Decisions are generally based on comparing projected radiation doses, estimated in the absence of protective measures, with predefined reference levels expressed in millisieverts. Although projected dose is a well-established radiological protection metric, it does not account for the size of the affected population and therefore provides limited information to decision makers on the overall public health consequences of an accident. This work explores the use of a collective risk metric, expressed as the expected number of excess cancer cases attributable to radiation exposure, as a complement to projected dose in radiological emergency preparedness and response in France.

Two severe nuclear power plant accident scenarios involving core meltdown were considered. In the serious accident scenario, environmental releases are filtered through the containment system, whereas in the major accident scenario, containment failure results in unfiltered releases and substantially higher radiological consequences. Atmospheric dispersion and dose assessments were performed using ASNR emergency assessment tools. The resulting projected doses were used to identify areas exceeding French reference levels for evacuation. These outputs were complemented using Arpagon-Sanitaire, a proof-of-concept tool that combines dose estimates, lifetime excess cancer risk coefficients, and population census data to estimate the number of radiation-induced cancer cases within affected populations.

For the serious accident scenario, projected doses exceeding the evacuation reference level are limited to an area extending approximately 5 km from the nuclear power plant. This area is fully covered by the evacuation measures already planned under the French off-site emergency plan (PPI). In such circumstances, the decision to evacuate can be implemented within the existing preparedness framework.

In contrast, for the major accident scenario, projected doses exceeding the evacuation reference level extend up to approximately 40 km from the site. Within this area, around 45,000 inhabitants reside in communes where evacuation criteria are met, corresponding to an estimated collective health impact of approximately 100-150 excess cancer cases over the lifetime of the exposed population. The affected area extends well beyond the pre-planned evacuation perimeter defined in the PPI, implying that any decision to evacuate the entire population would require the implementation of large-scale, unprepared protective actions. In this context, collective risk estimates provide decision-makers with additional information on the expected health benefits of evacuation, which can be weighed against the logistical challenges and potential adverse consequences associated with large-scale population displacement.

Although still at the proof-of-concept stage, this work demonstrates the potential value of collective risk metrics as a complement to conventional dose-based reference levels in radiological emergency management. Such metrics may enhance risk communication and support more informed decision-making during emergency response planning. Ongoing developments and limitations of the approach are discussed, together with perspectives for future research and operational implementation.

S1.1–2 CITISTRA – A DISTRIBUTED CITIZEN-BASED NETWORK OF MOBILE IONIZING RADIATION DETECTORS: FROM EMERGENCY PREPAREDNESS TO ROUTINE ENVIRONMENTAL MONITORING. PROJECT CONCEPT AND IMPLEMENTATION IN POLAND

Author: Renata Kierepko | Co-Author: Anna Mroziak, Mateusz Krzysiek, Paweł Olko, Agnieszka Szumska, Jan Helebrant, Marie Davidková, Ivana Fojtíková, Pavol Ragan, Zuzana Gonekova | Speaker: Renata Kierepko

The current geopolitical situation, including the armed conflict in Ukraine and in the Middle East involving Iran, has increased concerns regarding the integrity and safety of nuclear facilities located in regions affected by military activities. Consequently, modern societies should be prepared to support governmental agencies legally responsible for emergency response and radiological protection, not only during emergencies but also in peacetime preparedness activities.

The CITISTRA project (Citizen Measurements as a Complementary Radiation Monitoring Strategy in Threats Due to Armed Conflict or Natural Disasters) engages Polish citizens in a structured network of users of mobile ionizing radiation detectors. The project aims to identify the most suitable professional groups capable of performing dose rate measurements during emergency situations, develop measurement procedures, establish tools for data verification and analysis by radiation protection specialists, and provide visualization and dissemination of measurement results within a distributed monitoring network.

The CITISTRA network operates in south-eastern Poland, covering approximately 84,000 km² and including the Silesian, Małopolska, Świętokrzyskie, Podkarpackie, and Lubelskie regions. As part of the project, 200 CzechRad ionizing radiation detectors, designed and manufactured by the National Radiation Protection Institute (SÚRO, Czech Republic), were distributed among representatives of six professional groups: volunteer and professional firefighters, Territorial Defence Force soldiers, employees of Sanitary-Epidemiological Stations, personnel of municipal offices located near the borders with Ukraine and Belarus, and forestry service employees.

The presentation will describe the architecture, operational principles, and results of the network obtained during more than twelve months of operation, including the identification of radiation hot spots. It will also present the results of sociological studies conducted among the Polish population throughout the project, as well as the network's response to the first emergency exercise of its kind, based on the wildfires that occurred in the vicinity of the Chernobyl Nuclear Power Plant in May 2026. In addition, the strengths and weaknesses of the developed system will be discussed, together with the potential for its future implementation in the regions planned for the first two nuclear power plants in Poland.

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S1.1–3 FROM METEOROLOGY TO IMPROVED THRESHOLDS IN NUCLEAR SURVEILLANCE NETWORKS

Author: Rieke Schäfer | Co-Author: Katharina Münster, Anca Melintescu, Andrei Neacsu, Susana Barbosa, Stefan Röttger | Speaker: Stefan Röttger

*Nuclear surveillance networks for radiological protection need to set proper alarm thresholds to avoid false alarms and to simultaneously ensure the registration of genuine incidents, *e.g.* the release of radionuclides from nuclear facilities. However, finding this balance is not straightforward because natural and anthropogenic variations of the environmental radiation may occur in similar orders of magnitude. To trigger alarms only in the case of unusual radiological events, natural fluctuations must either be exceeded or sufficiently well understood to be identified and excluded.*

Within the EURATOM project NuClim, we contribute to the latter approach by developing the RAINGAM (RAINfall-induced GAMma enhancement) model, a process level-based model designed to quantify precipitation-induced enhancements of ambient gamma dose rate above the natural background. The model considers the main processes governing the washout of radon progeny from the atmosphere, including scavenging by cloud droplets and raindrops, cloud-to-ground transport, radioactive decay during transport, and deposition at the earth's surface. Precipitation rate is a key model parameter, influencing cloud water removal, raindrop size distribution, progeny deposition fluxes and, ultimately, gamma dose rate enhancement.

The ambient gamma radiation is measured at the Atmospheric Radiation Measurement (ARM) User Facility, Eastern North Atlantic (ENA) located at Graciosa (Azores, Portugal) using a NaI(Tl) detector. Meteorological observations including precipitation measurements from the same location are used to parameterise and evaluate the RAINGAM model. In addition, a formalism for calculating the ambient gamma dose rate from the detector response data has been developed.

In this contribution, we will present initial results from the comparison of ambient gamma dose rate and precipitation measurement data collected at the ENA station with the RAINGAM model and their integration in the NuClim project. Preliminary investigations show that washout events might lead to an increase of the ambient gamma dose rate compared to the background estimated by the model. The improved quantification of natural ambient gamma dose variability provided by RAINGAM model can support the optimisation of alarm thresholds in surveillance networks, enabling enhanced sensitivity to anthropogenic radiological events while maintaining a low false alarm rate. The resulting improvement in the discrimination between natural and anthropogenic radiation signals contributes to more effective radiological monitoring and emergency preparedness.

S1.1–4 DEVELOPING A RADIATION-PROTECTION STRATEGY CONSIDERING RESIDUAL DOSES

Author: Mario Gaspar Quarenta | Co-Author: Chris Twenhöfel, Teun van Dillen, Astrid Kloosterman | Speaker: Mario Gaspar Quarenta

A protection strategy for nuclear accidents includes effective protective measures, which are justified and optimized, to minimize the harmful effect of radiation on the population in the event of a nuclear power-plant accident. We will present the process of developing a radiation-protection strategy for the Dutch nuclear power plant in Borssele for the urgent phase in a general emergency. Previously, protective measures were solely based on intervention levels for potential doses, without taking into account the effects of countermeasures such as sheltering and iodine prophylaxis. These potential doses were then used to determine protective action zones on a case-by-case basis. For the new strategy, we also consider residual doses, which do include these dose reducing effects, and the corresponding reference levels.

The objective of the study is to predefine planning zones for protective measures, allowing for a more feasible and efficient response. The starting point of defining these planning zones is a statistical approach in applying our atmospheric dispersion and dose model NPK-PUFF. We have simulated approximately 1000 accidental releases with varying weather conditions covering a time

span of 3 years, and using different source terms resulting from the hazard assessment. The analysis of potential and residual radiation-dose distributions as well as input from relevant stakeholders shape the new radiation-protection strategy. Challenges we encountered as well as additional considerations and opportunities that came with the consideration of the residual dose will also be highlighted.

S1.1–5 PROTECTING FORCES DEPLOYED DURING NUCLEAR SECURITY EVENTS: TRUSTED METHODS AND NEW INNOVATION

Author: Emily Alice Kroeger | Co-Author: Julius Vogt, Martin Baron, Eike Gericke, Britta Lange | Speaker: Emily Alice Kroeger

The response to nuclear security events involves preparing for and responding to situations in which radioactive material is out of regulatory control, in particular cases where the material is being used maliciously, for example the threat of the misuse of radioactive material in connection with an unconventional explosive device ("dirty bomb"). Close cooperation between police and radiation protection is required for a successful response to such threats and radiation protection demands an integrated approach considering the perspectives of experts of different fields [1]. If the German authorities responding to an event involving nuclear or radioactive material out of regulatory control require support, the German Federal Office for Radiation Protection (BfS) can provide assistance in the form of personnel, measurement equipment (and other technical equipment) and expert advice.

The main aim of the BfS when supporting the response to nuclear security events is to minimise the radiation exposure of the deployed forces and the public using the ALARA principle during the simultaneous police investigation. Of course, there may be radiation doses already received by members of the public and / or first responders requiring immediate assessment and treatment. For this reason, the topic of medical emergency preparedness is incorporated directly into the BfS unit organising the response of the BfS to nuclear security events. A secondary aim is the prevention of contamination of the environment (including a possible crime scene) with radionuclides. In all responses to nuclear security events, the prevention of the release of radioactive material into the environment, or the containment of existing contamination, is a priority in order to meet these aims.

When called upon to support the response to a nuclear security event, the BfS personnel and equipment is integrated directly into the existing police structures to deliver measurements, technical support and radiation protection advice in real time. This close cooperation and some examples of the technical support will be detailed in this contribution, sharing lessons learned. The use of Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) for measurements and scouting will be presented, along with field reports from recent testing and training. The advantages and disadvantages of the use of unmanned vehicles will be discussed. Future ideas for improving the capability include the real-time transfer of UAV-data into existing data collection structures and the integration of machine learning for the analysis of gamma spectra.

[1] Fit for purpose: German contributions to the new ICRP recommendations, Birschwilks et. al., Radiation and Environmental Biophysics (2026) 65:15-36

S1.1–6 PREDICT: HOW TO IMPROVE SIMULATION MODELS FOR NUCLEAR DETONATION EVENTS

Author: Astrid Kloosterman, Christoph Haller, Elias Pagh Senstius, Erik Berge, Florian Mertes, Heiko Klein, Hendrik Bergsma, Jan Burman, Justin Brown, Lois Huggett, Michiel de Bode, Wolfgang Raskob | Co-Author: | Speaker: Wolfgang Raskob

Objective: PREDICT, a project in the frame of the PIANOFORTE EJP, aims at filling in significant gaps and improving upon current radiological assessment and decision-aiding technological capabilities for nuclear detonation events. Work package 3 is designed to improve simulation models for the assessment of the consequences from these events.

Methods: In particular WP3 aims at quantifying model uncertainties resulting on one hand from current limited understanding of key model parameters and on the other hand by exploring the consequences of critical weather conditions on the model results such as high precipitation events and weather conditions with changing wind directions and frontal passages. To do so, on the one hand side scenario calculations for historic detonation events from the Nevada test site will be performed and on the other side, parameter variations and statistical analyses will be carried out. Seven models from Denmark, Germany, Norway, Sweden, The Netherlands and United Kingdom participated in PREDICT. Three tasks were set up and work performed in three main areas

- *Model comparison and validation using historic events,*
- *Sensitivity analysis of key model parameters and*
- *Sensitivity analysis for key weather conditions*

Results: This paper will present progress from all the three subtasks, concentrating on the analysis of model parameters and weather conditions. For the latter simulations for specific weather conditions were performed for two sites, Bergen and Emden. For the model parameter sensitivity study, four test cases from the NEVADA test site and one from the Trinity site in New Mexico, were considered. Sensitivity analysis was performed for the cloud geometry, activity heights and particle sizes distributions.

Conclusions: Following the evaluation of the results, recommendations are underway to define robust parameter settings to support model developers in fine tuning of their simulation models for such detonation events.

S1.1–7 CURRENT RESEARCH AND TECHNOLOGICAL STATUS OF TL/OSL RETROSPECTIVE DOSIMETRY AND RADIOLOGICAL CHARACTERIZATION OF CANDIDATE MATERIALS

Author: Byungmin Lee | Co-Author: Chanwoo Park, Jae Seok Kim, Min Seok Park, Min Su Cho | Speaker: Byungmin Lee

Retrospective dosimetry is a key component of radiation emergency preparedness, enabling rapid and accurate dose assessment for individuals who were not monitored with personal dosimeter. Among the available approaches, thermoluminescence (TL) and optically stimulated luminescence (OSL) are widely used for retrospective dosimetry that estimate absorbed dose based on luminescence signals emitted by irradiated materials upon thermal or optical stimulation. To ensure their practical applicability during radiation emergency, there would be a need to evaluate the radiological characteristics of a wide range of candidate materials, including biological and personal belongings.

This study aimed to evaluate the radiological characteristics of candidate materials with high potential for application in radiation emergencies based on a review of recent advances in TL/OSL-based retrospective dosimetry.

A review of the current research revealed that international institutions, such as IRSN in France and BfS in Germany, have actively promoted TL/OSL dosimetry research and standardization utilizing mobile phone components (surface-mount devices, glass), tooth enamel, and dental restorative materials. In South Korea, KAERI has also conducted TL/OSL dosimetry research utilizing mobile phone components and SIM cards.

In this study, TL/OSL-based dosimetry system (Lexsyg Research, Germany) in operation at KIRAMS was used to evaluate the radiological characteristics of materials (chip resistors, display glass, tooth enamel, and dental ceramics). Dose linearity, energy dependence, and signal fading behavior were investigated to assess their suitability for retrospective dosimetry applications. Specifically, the dose-response linearity of all candidate materials was evaluated first, and subsequent assessments for energy dependence and signal fading were conducted for the samples that exhibited clear linearity.

The results showed that chip resistors and display glass exhibited linear dose-responses from doses as low as several tens of mGy, whereas tooth enamel and dental ceramics showed reliable linearity at doses of 1 Gy and above. Based on their clear dose-response linearity at low doses, chip resistors and display glass were further evaluated for energy dependence. For both materials, relatively higher luminescence signals were measured in the low-energy region (< 100 keV) compared with the Cs-137 energy region (662 keV), which was used as the reference radiation field. This behavior is attributed to differences in the mass attenuation coefficients of the materials.

These findings indicate that chip resistors and display glass are promising materials for TL/OSL retrospective dosimetry, provided that energy-dependent signal corrections are applied depending on the radiation field. The radiological characteristics of the candidate materials, evaluated based on the research-status review, can provide useful foundational data for selecting optimal materials and establishing reliable retrospective dosimetry procedures in future radiation emergencies.

S2.1 AI for Monitoring & Dose Management

S2.1-1 MACHINE-LEARNING-SUPPORTED PROBABILISTIC INDOOR RADON MAPPING FOR POPULATION EXPOSURE MONITORING AND DOSE MANAGEMENT IN GERMANY

Author: Eric Petermann | Co-Author: Peter Bossew, Joachim Kemski, Valeria Gruber, Nils Suhr, Bernd Hoffmann | Speaker: Eric Petermann

Background: Radon is a carcinogenic radioactive gas and a major contributor to public exposure from natural sources. Reliable information on indoor radon is essential for monitoring exposure, identifying areas and population groups with increased risk, and supporting proportionate radiation protection actions. However, national radon surveys are often affected by sampling bias, while sample sizes are insufficient for direct high-resolution exposure and dose assessment. We present an machine-learning-supported probabilistic modelling framework for Germany and discuss its relevance for monitoring and dose management.

Methods: We developed a multistage machine-learning approach based on quantile regression forests using environmental, geogenic and building-related predictors to estimate the full probability distribution of indoor radon concentration for each floor level of residential buildings in Germany. A probabilistic Monte Carlo procedure was then used to combine floor-specific predictions with population and building information. This allowed uncertainties from individual predictions to be propagated to aggregated exposure estimates at different spatial scales.

Results: The model estimated an approximately lognormal national indoor radon distribution, with an arithmetic mean of 63 Bq/m³, a geometric mean of 41 Bq/m³ and a 95th percentile of 180 Bq/m³. The estimated exceedance probabilities were 12.5% above 100 Bq/m³, corresponding to about 10.5 million people, and 2.2% above 300 Bq/m³, corresponding to about 1.9 million people. The approach also revealed systematic spatial and building-related differences, including generally lower population-weighted radon concentrations in large cities, partly due to floor-level population distributions.

Conclusions: Machine-Learning-based probabilistic radon mapping can transform monitoring data into high-resolution, uncertainty-aware exposure indicators. Rather than providing only descriptive survey statistics, the framework supports risk-informed prioritisation of measurements, remediation, communication and regulatory follow-up. This is directly relevant to AI for monitoring and dose management because it links environmental radiation measurements, predictive modelling and population-weighted exposure assessment in a transparent decision-support workflow. The work contributes to SDG 3, Good Health and Well-being, by improving prevention of radon-related lung cancer risk, and to SDG 11, Sustainable Cities and Communities, by supporting healthier indoor environments and evidence-based management of environmental radiation risks.

S2.1-2 QUALITY ASSESSMENT AND INTEGRATION OF CITIZEN MEASUREMENTS INTO ENVIRONMENTAL RADIATION MONITORING DURING NUCLEAR EMERGENCIES: ACTIVITIES OF THE CITHARA PROJECT

Author: Paola Fattibene, Sara Della Monaca | Co-Author: Claudio Andenna, Giorgia Stendardo, Jean Marc Bertho, Kathleen Pele, Laura Torrieri Di Tullio, Mohamedamine Benadjaoud, Roberta Valentina Gagliardi, Tiziana Falcone | Speaker: Sara Della Monaca

Citizen-generated radiation monitoring networks emerged following the Fukushima nuclear accident through collaborative platforms such as OpenRadiation and Safecast. These networks have

the potential to complement official Emergency Preparedness and Response (EPR) systems during nuclear emergencies. Unlike institutional monitoring networks, citizen measurements can provide information from locations directly relevant to public protection, such as homes, schools, and workplaces, thereby enhancing the spatial coverage and granularity of environmental radiation monitoring. However, their operational use remains limited by concerns regarding data quality, stemming from detector heterogeneity, variable acquisition conditions, and the absence of standardized measurement protocols.

The European project CITHARA, funded under the PIANOFORTE Partnership, addresses these challenges by developing Artificial Intelligence (AI)-based tools to strengthen EPR capabilities. In particular, Work Package 2, coordinated by the Istituto Superiore di Sanità, focuses on the exploitation of citizen-generated radiation data through AI-driven approaches for data quality assessment, integration with official monitoring networks, and the development of probabilistic methods for environmental radiological modelling.

The activities are based on the OpenRadiation database, which currently contains 1,480,981 measurements collected under real-world conditions using a wide variety of radiation detection devices. Of these, 208,898 correspond to in-flight measurements, which, together with records flagged as wrong measurements or temporary source, are excluded from the environmental analysis, leaving 1,200,058 ground-relevant measurements. An automated data cleaning and harmonization pipeline is under development, including format standardization, geospatial validation, filtering of non-realistic physical values, and identification of measurements performed at ground level. In parallel, exploratory analyses are being conducted to characterize dose-rate distributions, identify anomalous measurements, and evaluate the performance of different detector categories.

Preliminary results highlight substantial sources of variability associated with both measurement conditions and instrumental heterogeneity, confirming the need for advanced methodologies to improve data reliability. Building on these analyses, we will present the data cleaning methodology and the current version of the data cleaning report, which will provide the basis for constructing a probabilistic model of dose-rate variability, accounting for instrumental and environmental sources of heterogeneity. The ultimate goal is to generate a synthetic dataset that can be used in the future as a representative radiological background for nuclear emergency preparedness scenarios.

These developments represent a key step toward the effective integration of citizen-generated radiation measurements into official environmental monitoring systems and radiological modelling frameworks for nuclear emergency management. Such integration may also contribute to strengthening trust, transparency, and collaboration between institutions and citizens.

S2.1–3 MACHINE LEARNING ENHANCED ANALYSIS OF SILICA GLASS JEWELLERY BEADS FOR THERMOLUMINESCENCE DOSIMETRY HEALTH MONITORING.

Author: Lukasz Tomaszewski | Co-Author: Caroline Shenton-Taylor | Speaker: Lukasz Tomaszewski

Thermoluminescence dosimetry (TLD) is used to estimate the absorbed radiation dose received by an individual over a defined period, enabling the monitoring of exposure to ionising radiation. Doped lithium fluoride materials such as LiF:Mg,Ti and LiF:Mg,Cu,P offer stable, sensitive dose response and lower detection limits, supporting accurate dose assessment in radiation monitoring applications. Advances in TLD focus on improved detector materials, enhanced accuracy, automated readout systems, and machine learning (ML) assisted glow curve analysis.

This research explores four machine learning frameworks for advanced TLD analysis for a new dosimeter material, building on previous work that demonstrated the use of micro silica glass jewellery beads as retrospective body and extremity dosimeters. Commonly worn for aesthetic purposes, these beads exhibit stable, linear thermoluminescent (TL) responses across low and high-dose ranges, and are currently in use in radiotherapy. Silica glass bead TL glow curves are incorporated into three ML frameworks: synthetic glow curve generation, glow curve correction, and material classification. These approaches address key challenges in TLD analysis, including generating synthetic data for large dataset ML applications, correcting distorted glow curve responses, and reliable material identification for bead size, colour, dose and readout temperatures. Future work will explore irradiation fading and isotope identification.

A fourth ML framework investigates the relationship between material physics, charge-carrier kinetics, and glow curve modelling through deconvolution. This model is envisaged to predict complex kinetic parameters more rapidly than current methods, improving analysis efficiency. These approaches aim to enhance glow curve interpretation and improve material understanding for the use of silica glass bead dosimeters for individual health monitoring within the nuclear sector.

S2.1–4 ACCREDITED PROJECT: ADVANCEMENT IN COMPUTATIONAL DOSIMETRY FOR COMPLEX RADIATION FIELDS

Author: Daniela Passeri | Co-Author: Filip Vanhavere, Giacomo Manessi, Luana de Freitas Nascimento, Mahmoud Abdelrahman, Marco Caresana, Olivier Van Hoey, Pasquale Lombardo, Sachith Welarathna | Speaker: Daniela Passeri

Complex radiation fields have become one of the new focuses for occupational dosimetry with the increasing applications of high intensity and pulsed beams. Stray fields with strong neutron components, pulsed structure or high energies spectra highlight the limits of traditional occupational dosimetry, including the use of operational quantities and the uncertainties on neutron dose monitoring. This work aims to overcome these limitations by implementing online computational dosimetry within an operational framework, for direct calculation of protection quantities.

The project will combine worker movement tracking and effective dose mapping of the workplace. Four working packages can be identified: radiation field characterization, worker body tracking, method validation and application development. The focus will first be on neutron dosimetry and then it will be possible to include different radiation types.

The radiation field will be mapped using spectral neutron monitors (DIAMON, SP2, Bonner spheres system) for fluence and direction resolution; Monte Carlo (MC) simulations with Geant4 will be performed both as a comparison and integration of the measurements. The goal is to optimize the characterization phase enhancing its applicability to different workplaces. We plan to achieve this including Convolutional Neural Networks trained on the combined dataset of measures and simulations to reduce the time consumption of the field mapping.

The tracking of the worker will be based on the ZED 2i camera and built upon its SDK (Software Development Kit) and the driver OpenCV. Native SDK algorithms for body tracking and object detection will be combined with algorithms for personnel identification, e.g. face identification and body features recognition. The integration of multiple cameras will also be tested for the maximization of field covering and for the resolution of overlapping workers' tracks.

Matching the positions of the tracked body joints and the field parameters in real time will allow the calculation of worker effective dose; personal neutron dosimeters will be used as an assessment of the calculated effective dose through operational quantities.

In this first phase of the project, key findings mainly include the extraction of a depth uncertainty map for the ZED 2i camera. The evaluation of neutron measurement techniques with the detectors mentioned above, including MC simulations, will be carried out for some example workplace fields.

Computational dosimetry can become an effective solution to current limitations of personal dosimeters, despite the challenges for its integration within a real workplace workflow. Thanks to the integration of body tracking and both field measurements and MC Simulations, it could yield higher confidence in results especially for complex radiation fields. The development of a user-friendly dosimetric tool based on a generalizable protocol for dose mapping foreseen in this project could drastically reduce time consumption for dosimetry assessment and facilitate its application to different settings.

S3.1 One Health & Environment

S3.1-1 HUMAN-MOUSE COMPARISON OF RADIATION-RELATED CANCER MORTALITY USING THE TWO-STAGE CLONAL EXPANSION MODEL

Author: Tatsuhiko Imaoka | Co-Author: Keito Asano, Masaru Takabatake | Speaker: Tatsuhiko Imaoka

Objectives/background: Epidemiological studies provide a cornerstone for radiation protection, yet findings from animal experiments are not fully leveraged. Previously, we applied a multistage carcinogenesis model to compare radiation-related cancer mortality between humans and mice, indicating a critical role of species-intrinsic mutation rates in dictating the observed species difference in radiation-related risk. In the present study, we apply a two-stage clonal expansion (TSCE) model to the same datasets to quantitatively identify key parameters driving interspecies differences.

Methods: Data from female B6C3F1 mice (Sasaki 1991) and the Life Span Study of Japanese atomic bomb survivors (Ozasa et al. 2012) were analyzed. A simplified TSCE model assuming radiation-induced cancer initiation was applied. Model parameters were estimated using Poisson regression.

Results: Comparison with nonparametric models showed that the TSCE framework adequately captured the attained-age and age-at-exposure patterns, and in both mice and humans the linear-quadratic model provided a statistically better fit to dose-related trends than the linear model. The introduction of an age-at-exposure modification parameter for radiation-induced initiation had less impact than in the multistage carcinogenesis model. This suggests that age-at-exposure dependence in cancer risk is driven more by differences in the duration of clonal expansion than by strong age dependence of radiation-induced initiation itself. Parameter estimates were generally within biologically plausible ranges. The clonal expansion rate was ~45-fold higher in mice, while a parameter related to cell number and spontaneous mutation rates was ~10⁴-fold higher than in humans. Although absolute radiation-related cancer mortality was substantially higher in mice under representative conditions, relative radiation risk was similar between species because differences in key parameters offset each other.

Conclusions/implications: The TSCE framework provides a mechanistic explanation for interspecies differences in radiation-related cancer risk. These findings improve our understanding of how animal data can be extrapolated to humans and contribute to a biologically grounded basis for radiation protection.

S3.1-2 DEVELOPMENT OF A DOSIMETRIC VOXEL MODEL FOR A MARINE MAMMAL

Author: Elin Wefer | Co-Author: Marc-Oliver Aust, Simon Rombauer, Mauritius Hiller, Pedro Nogueira | Speaker: Elin Wefer

Marine mammals are sentinel species for the health of marine ecosystems, yet current environmental radiation protection frameworks do not address them and all dosimetric calculations up to this point used mathematical models that due to their simplicity introduce great uncertainties in the calculations. To enable inclusion of these taxa in the reference animals and plants (RAPs), we develop a state-of-the-art, anatomically detailed model of a representative cetacean, the harbour porpoise, and derive absorbed fractions (AFs) and organ specific dose conversion factors (DCFs) for both internal and external radiation exposure.

A juvenile harbour porpoise (≈ 21 kg, ≈ 100 cm) was scanned post-mortem with a clinical CT scanner (slice thickness = 1.25 mm, 120 kV). 21 anatomically distinct tissues (e. g. bone, heart, blubber,

lung) were segmented manually in 3D-Doctor (Able Software Corp, USA), exported and converted into a voxel phantom (voxel size $\approx 3.91 \times 3.91 \times 1.25 \text{ mm}^3$) using the software Voxelizer (Human Monitoring Laboratory, Canada). The phantom was imported into the Monte Carlo particle transport code MCNP6 (v3.0). Mono-energetic photon (0.04 - 4 MeV) and electron (0.04 - 4 MeV) sources were placed either uniformly throughout each organ (internal exposure) or the seawater surrounding the animal (external exposure). For each scenario, absorbed energy per emitted particle was tallied for all organs and statistical uncertainties were below 3 % for most of them, only few errors of $\leq 10 - 15 \%$ occurred. Adjustments based on physical principles relating to secondary radiation, weighting factors and various variance reduction techniques were used to improve the statistics. AFs were obtained from the simulation results.

In general, the AFs show usual trends over the used energy ranges, e. g. the self-AFs for internal exposure decrease with increasing energy as more particles are able to leave the source organ. Furthermore, differences in the AF trends of the different tissues are highly dependent on material parameters, such as the density, as well as the size and relative position to the radiation source of the organ.

The developed harbour porpoise voxel model constitutes the first anatomically correct dosimetric tool for marine mammals. Derived DCFs will be incorporated into an open-access lookup table to enable a rapid dose and thereby regulatory risk assessment for accidental radiation release events. These data hold the potential to close a critical gap in environmental radiation protection.

S3.1–3 REFINING THE ADVERSE OUTCOME PATHWAY (AOP) FOR RADON-INDUCED LUNG CANCER: INTEGRATING GENETIC VARIABILITY AND ENVIRONMENTAL CO-EXPOSURES TO IMPROVE RISK CHARACTERIZATION

Author: Klea Hondro | Co-Author: Paul Locke | Speaker: Klea Hondro

Radon is a well-established environmental carcinogen and the second leading cause of lung cancer after tobacco smoking. However, current radon risk assessments rely largely on population-averaged exposure-response models that may not fully account for biological susceptibility or real-world co-exposures. This thesis aimed to refine the Adverse Outcome Pathway (AOP) for radon-induced lung cancer by integrating evidence on genetic variability in DNA repair pathways and the modifying effects of tobacco smoke. The central research question was how host susceptibility and environmental co-exposures influence the biological progression from radon exposure to lung carcinogenesis.

This study used two complementary scoping reviews conducted through PubMed and Embase. The first review evaluated mechanistic, experimental, and epidemiologic evidence linking radon exposure with deficiencies or polymorphisms in DNA repair genes and pathways, including ATM, BRCA1, XRCC1, non-homologous end joining, homologous recombination, and base excision repair. The second review examined evidence on combined exposure to radon and tobacco smoke, including epidemiologic studies, toxicologic models, and mechanistic investigations. Findings from both reviews were mapped onto the existing radon lung cancer AOP to identify key events and relationships influenced by genetic susceptibility and co-exposure conditions.

The findings showed that radon-induced alpha-particle radiation causes complex DNA double-strand breaks in bronchial epithelial cells. When DNA repair capacity is impaired, these lesions are more likely to persist, resulting in genomic instability, chromosomal aberrations, mutation accumulation, and increased lung cancer susceptibility. Human studies further indicated that lung cancer risk can vary among individuals exposed to comparable radon levels, supporting the importance of genetic susceptibility. The review also found that tobacco smoke modifies several

stages of the carcinogenic pathway by increasing oxidative stress, adding additional DNA damage, impairing repair mechanisms, promoting chronic inflammation, and increasing effective radiation dose through altered deposition of radon progeny in the airways. Combined radon and tobacco smoke exposure was consistently associated with substantially greater lung cancer risk than either exposure alone.

The refined AOP positions DNA repair deficiency as a susceptibility-modifying node and tobacco smoke as a multi-stage effector within the radon-induced lung cancer pathway. This enhanced framework improves the biological realism and public health relevance of radon risk characterization. By incorporating both genetic variability and cumulative exposure conditions, the findings support moving beyond uniform population-based models toward more biologically informed approaches for identifying high-risk populations, guiding radon mitigation strategies, and strengthening environmental health protection. This work contributes to more equitable and biologically informed public health decision-making by emphasizing that radon-related lung cancer risk is shaped not only by exposure level, but also by individual susceptibility and cumulative environmental conditions.

S3.1–4 INTERNAL ACCUMULATION AND REPRODUCTIVE TOXICITY OF CHRONIC RADIUM-224 EXPOSURE IN CAENORHABDITIS ELEGANS

Author: Hengyi Zhu | Co-Author: Dag Anders Brede, Simon Mark Jerome, Erica Maremonti, Dag Markus Eide | Speaker: Hengyi Zhu

Objectives / Background: Radium-224 (^{224}Ra) is a naturally occurring alpha-emitting radionuclide of relevance to both environmental radiation exposure and radiopharmaceutical applications. However, the uptake and biological effects of chronic internal exposure to ^{224}Ra and its decay products remain insufficiently understood. This study used *Caenorhabditis elegans* as a model organism to investigate radionuclide accumulation, dose contribution, and toxic mechanisms following prolonged ^{224}Ra exposure.

Methods: Synchronized *C. elegans* larvae were exposed for 65 h in sealed vials containing $^{224}\text{RaCl}_2$ at activity concentrations ranging from 0 to 2107 Bq mL⁻¹. Radionuclide accumulation was quantified, and internal and external dose contributions were estimated using Erica Tool and energy-based dosimetry. Biological effects were assessed through developmental and reproductive endpoints, including somatic growth, brood size, sperm number, and germline apoptosis. Antioxidant activation was evaluated using SOD-1 expression, and transcriptomic analyses were performed to explore potential molecular pathways altered by chronic alpha exposure.

Results: *C. elegans* accumulated up to 3.37% of the total activity of ^{224}Ra and its decay products, corresponding to a volume-based concentration ratio of approximately 210, with uptake increasing in an activity concentration-dependent manner. Despite uncertainty in dosimetry, internal dose accounted for more than 98% of the estimated total dose, with dose rates ranging from 22 to 3531 mGy⁻¹. Developmental delay was observed in all groups, including controls, although all nematodes reached adulthood by 90 h post-L1 and displayed comparable somatic growth. In contrast, reproductive toxicity was observed at the highest concentration, where total brood size and sperm counts decreased by 39.8% and 34.9%, respectively. Germline apoptosis increased by 1.72- and 1.59-fold at 527 and 2107 Bq mL⁻¹, respectively. Antioxidant responses were induced, with significantly elevated SOD-1 expression at the highest concentration and increased intestinal SOD-1 levels from 132 Bq mL⁻¹. Transcriptomic analysis further revealed altered regulation of pathways related to protein phosphorylation and dephosphorylation, dauer formation, germ line function, chromatin organization, and cell division.

*Conclusions / Implications: These findings demonstrate substantial internal accumulation and predominantly internal dose delivery during chronic ^{224}Ra exposure in *C. elegans*, resulting in selective reproductive and germline toxicity. The study provides mechanistic insight into the effects of chronic exposure to alpha-emitter and supports the use of *C. elegans* as a relevant model for environmental radiological protection research.*

S3.1–5 LOW NATURAL BACKGROUND RADIATION INDUCES FUNCTIONAL AND TRANSCRIPTOMIC REPROGRAMMING OF HUMAN MESENCHYMAL STROMAL/STEM CELLS

Author: Nicola Alessio, Domenico Aprile, Gianluigi Laporta, Patrizia Morciano, Giovanni Di Bernardo, Umberto Galderisi | Co-Author: | Speaker: Nicola Alessio, Umberto Galderisi

Objectives/Background: Natural background radiation has been a constant environmental factor throughout evolution, yet its contribution to cellular homeostasis and its role as evolutionary driver remains poorly understood. The ECLIPSE project investigates the biological effects of reduced environmental radiation on human bone marrow-derived mesenchymal stromal/stem cells (BM-MSCs), using the unique Low Radiation Environment (LRE) of the Gran Sasso National Laboratory (LNGS) and comparing it with a Reference Radiation Environment (RRE). The study aimed to determine whether chronic exposure to extremely low radiation levels alters cellular physiology and the molecular pathways regulating proliferation, senescence, metabolism, and stress responses.

Methods: BM-MSCs were cultured under RRE and LRE conditions for 7 and 14 days. Cellular responses were assessed through proliferation assays, cell-cycle analysis, Ki67 immunostaining, senescence-associated β -galactosidase staining, apoptosis assays (Annexin V/PI and caspase-3 activation), ROS quantification, antioxidant enzyme expression, DNA damage and repair analyses (γ -H2AX, BER, and NER assays), and evaluation of mitochondrial function and mitophagy. Global transcriptomic profiling was performed by RNA sequencing followed by pathway enrichment (PANTHER, KEGG, Reactome) and network analyses (NetworkAnalyst).

Results: Functional analyses demonstrated that MSCs maintained in LRE exhibited reduced proliferative activity, increased senescence, and impaired antioxidant defenses with elevated oxidative stress, which was counteracted by a switch toward anaerobic glycolysis and altered mitochondrial homeostasis compared with RRE controls. Transcriptomic profiling revealed extensive extracellular matrix remodeling, dysregulation of glycosaminoglycan metabolism, metabolic reprogramming toward glycolysis, suppression of interferon signaling pathways, and the emergence of a platelet-like senescence-associated secretory phenotype. Despite transcriptional upregulation of several cell-cycle regulators, cells displayed impaired S-phase progression, consistent with a non-canonical cell-cycle arrest. Network analysis identified SF3B1, ATM, CDK2, Geminin, and CDK1 as major regulatory hubs underlying the cellular response to low radiation conditions.

Conclusions: These findings indicate that the absence of natural background radiation profoundly affects MSC homeostasis by coordinating functional and transcriptional adaptations involving cell-cycle regulation, metabolism, extracellular matrix organization, and immune signaling. This work provides new evidence supporting the concept that natural environmental radiation contributes to maintaining normal cellular physiology and offers novel insights into adaptive responses relevant to radiation biology, regenerative medicine, and long-term low-radiation environments.

S3.1–6 A DECADE OF RADIOACTIVE CONTAMINATION IN FUKUSHIMA: REPRODUCTIVE ALTERATION IN TREE FROGS ACROSS BIOLOGICAL SCALES

Author: Olivier Armant | Co-Author: André Gilles, Clément Car, Kenji Nanba, Lea Dasque, Sandrine Frelon | Speaker: Olivier Armant

*Organisms chronically exposed to environmental stressors often mount complex, multi-scale responses that shape their long-term viability and evolutionary potential. More than a decade after the Fukushima nuclear accident, we investigated male reproductive traits in the Japanese tree frog (*Dryophytes leopardus*) across a gradient of ionizing radiation exposure. Combining sperm functional analyses, ultrastructural observations, population genetics and testicular transcriptomics, we found that increasing dose rates were associated with reduced sperm density and sperm head abnormalities, including nuclear vacuolization and altered chromatin organization, whereas sperm motility remained unaffected. Transcriptomic analyses revealed coordinated modulation of pathways involved in chromosome segregation, DNA repair, chromatin remodeling and cilium-associated functions, with some of the most sensitive molecular responses occurring at dose rates around $1\text{--}2\ \mu\text{Gy}\cdot\text{h}^{-1}$. Together, these results indicate, for the first time in *Dryophytes japonicus*, persistent molecular and cellular stress responses to chronic IR exposure with potentially adaptive process stabilizing for some functional parameters such as sperm motility.*

Metrology in Radiation Protection Dosimetry

EMN-1 TYPE TESTING OF RADIATION PROTECTION DOSEMETERS IN GERMANY

Author: Hayo Zutz | Co-Author: Oliver Hupe, Steffen Ketelhut | Speaker: Hayo Zutz

In the Federal Republic of Germany, radiation protection dosimeters are subject to the provisions of the Measurement and Verification Act. Consequently, dosimeters employed for legally significant measurements must be type approved. The type-approval is based on type testing by the Physikalisch-Technische Bundesanstalt (PTB) according to their PTB-requirements. The requirements are based upon the established international standards for active and passive dosimeters. Additional provisions have been incorporated into these requirements to ensure compliance with the regulations set out in the Measurement and Calibration Ordinance.

This presentation addresses the following aspects: firstly, the type-testing procedures and the requirements for personal and area dosimeters, as set out in PTB-A 23.2 and PTB-A 23.3; secondly, the legal framework in Germany.

EMN-2 FROM DOSEMETER DEVELOPMENT TO ROUTINE USE – STANDARDS AND UNCERTAINTIES

Author: Rolf Behrens | Co-Author: Oliver Hupe | Speaker: Rolf Behrens

The concept of protection and operational quantities will be explained first. Then, the importance of standardization for the whole dosimeter lifecycle will be outlined:

Reference radiation fields are described in standards issued by [ISO/TC85/SC2 on radiological protection][1]:

- *[ISO 4037][2] for photons,*
- *[ISO 6980][3] for betas and*
- *[ISO 8529][4] for neutrons*

and are used to perform dosimeter type-tests with requirements set in standards mostly issued by [IEC/TC45/SC45B on radiation protection instrumentation][5]:

- *for photons and betas:*
 - o *[IEC 62387][6] for passive personal and environmental dosimetry systems,*
 - o *[IEC 61526][7] for active personal dosimeters,*
 - o *[IEC 60846-1][8] for active ambient dosimeters,*
- *for neutrons:*
 - o *[IEC 61005][9] for active monitors and*
 - o *[ISO 21909][10] for passive personal dosimetry systems,*

these standards address influence quantities such as

- *radiation energy,*
- *angle of incidence,*
- *dose and dose rate,*
- *ambient conditions (temperature etc.),*
- *electromagnetic immunity etc.*

All influence quantities are considered as uncertainty contributions to estimate the overall uncertainty of a dosimeter as described in [IEC TS 62461][11] containing many examples.

The dosimeter's overall performance should be checked regularly by comparison measurements in accordance with [ISO 14146][12] which describes the so-called trumpet curves, i.e., the allowed response limits depending on the dose. Its updated version as of 2024 also covers comparison measurements from the European Radiation Dosimetry Group (EURADOS).

[1]: <https://www.iso.org/committee/50280.html>

[2]: <https://www.iso.org/standard/66872.html>

[3]: <https://www.iso.org/standard/87213.html>

[4]: <https://www.iso.org/standard/80060.html>

[5]:

https://www.iec.ch/dyn/www/f?p=103:7:5151864128581:::FSP_ORG_ID,FSP_LANG_ID:1360,25

[6]: <https://webstore.iec.ch/en/publication/60118>

[7]: <https://webstore.iec.ch/en/publication/66825>

[8]: <https://webstore.iec.ch/en/publication/3682>

[9]: <https://webstore.iec.ch/en/publication/4257>

[10]: <https://www.iso.org/standard/78756.html>

[11]: <https://webstore.iec.ch/en/publication/7065>

[12]: <https://www.iso.org/standard/85249.html>

EMN-3 DEMONSTRATING COMPLIANCE WITH LEGAL METROLOGY REQUIREMENTS THROUGH RISK ASSESSMENT

Author: Marko Esche | Co-Author: Felix Reichmuth, Martin Nischwitz | Speaker: Marko Esche

According to German national legislation, personal dosimetry services shall use certified dosimeters compliant with the Measurement and Calibration Act. These services use complex infrastructure and rely preliminarily on passive sensors as well as organizational measures to protect and secure the measurement process. Since current national legislation is copied directly from the European Measuring Instruments Directive 2014/32/EU (MID), it is more suitable for fully integrated measuring instruments. Therefore, demonstrating compliance with technical requirements as laid down in the established WELMEC Guide 7.2:2025 “Software” is especially challenging. Currently, this Guide acts as a harmonized technical interpretation of software and IT aspects of the MID. In 2022, the European Legal Metrology Cooperation (WELMEC) decided to establish new procedures for assessment of complex measuring systems based on ISO 28005, ISO 18045 and ISO 15408. The resulting new WELMEC Guides 7.2:2026 and 7.6:2026 aim to solve this challenge by introducing a risk-based approach to software examination which can cover organizational as well as technical protection and securing means. In this contribution, an exemplary application of the risk-based approach to a generic setup of a personal dosimetry service is conducted and potential problems with the new approach are discussed. Additionally, a comparison with the previously used Guide 7.2:2025 is conducted. Finally, recommendations for amending the existing legal framework are made. The examined generic setup for a personal dosimetry service consists of passive probes distributed by the service which are later on collected and read out using a certified, fully protected and secured reader which produces initial raw data sets. Subsequently, these data are evaluated in an openly accessible and modifiable server application, with the resulting personal dose values being stored in a separate database server together with the original raw data sets and needed calibration parameters. To exempt server application and database from conformity assessment, an additional certified validation tool is made available to market surveillance and inspection bodies. The analysis shows how such a tool can serve as a trust anchor for the entirety of the measurement process when combined with additional organizational protection measures. Compared to the established approach from WELMEC Guide 7.2:2025, the risk-based software examination manages to provide much clearer and reliable results which leave less room for interpretation. Meanwhile, national legislation

should be amended to extend the concept of fully integrated measuring instruments to more flexible measurement systems.

EMN-4 THE UK SYSTEM FOR LEGAL PERSONAL DOSIMETRY

Author: Eftychia Kouroukla, Kerry Olssen, Nicky Gibbens, Rick Tanner | Co-Author: | Speaker: Rick Tanner

UKHSA runs both the UK's largest secondary standard suite of calibration laboratories and operates the UK's largest personal dosimetry service. UKHSA is a key contributor to ISO and IEC standards via membership of the British Standards Institute, with strong input to standards for metrology and dosimeter/instrument performance. Our calibration laboratories have traceability to National Standards at the UK National Physical Laboratory (NPL) and the Physikalisch-Technische Bundesanstalt (PTB). UKHSA calibration laboratories are also accredited to ISO 17025 via the United Kingdom Accreditation Service (UKAS).

The Personal Dosimetry Service (PDS) provide Dose Assessment, Dose Record Keeping & Coordination, and Accident Dosimetry services, approved and regulated by the British Health and Safety Executive (HSE). Dose Assessment is performed using passive dosimeters; whole body, eye and extremity TLDs for measuring exposure from beta/gamma radiations and PADC dosimeters for whole body neutron dosimetry. As an Approved Dosimetry Service, PDS operates in full compliance with the Ionising Radiations Regulations 2017 (IRR17) and the Health and Safety Executive's Requirements for the Approval of Dosimetry Services (RADS). Compliance with the RADS is determined through a combination of technical competence and performance requirements. In practice, this is demonstrated through conformity to ISO/IEC 17025 for the quality management system, performance testing of dosimeters in accordance with relevant standards (IEC 62387 for passive TLDs and ISO 21909 for PADC), participation in HSE Performance Tests and Intercomparison exercises, and successful HSE reassessments.

For additional quality assurance, the UKHSA Radiation Metrology group perform independent "dummy customer" tests for all dosimeters types issued by PDS, giving unknown exposures. These are checked against ISO 14146 for performance against the tighter $0.8 \leq R \leq 1.25$ limits, if the reference conditions are used for the exposure, or the trumpet curve for other directions and energies.

Together, these practices form the legal framework for personal dosimetry in the UK and enable the valid assessment of doses for classified workers.

FLASH TALKS - TUESDAY

TFT-01 DIGITAL SIMULATION TOOL FOR ASSESSING THE RESILIENCE OF RADIOLOGICAL EMERGENCY PREPAREDNESS, RESPONSE AND RECOVERY SYSTEMS DURING WARTIME.

Author: Thomas Makumbi | Co-Author: | Speaker: Thomas Makumbi

Assessing the resilience of Emergency Preparedness, Response and Recovery (EPR&R) systems for radiological emergencies under wartime conditions is increasingly important for protecting populations in unstable and hostile environments. Recent armed conflicts have demonstrated the vulnerability of nuclear and radiological facilities and the critical infrastructure supporting emergency management. Existing research and international guidance primarily address peacetime emergencies and provide limited consideration of the operational challenges associated with armed conflict. Wartime conditions can significantly degrade EPR&R capabilities through infrastructure damage, communication disruptions, restricted access to affected areas, shortages of trained personnel and equipment, reduced healthcare capacity, population displacement, and limitations in radiation monitoring and exposure assessment. This study presents a digital framework for evaluating community-level resilience and identifying preparedness measures that strengthen radiological EPR&R systems under wartime conditions. The framework is demonstrated through a hypothetical scenario involving a missile strike on an operational nuclear reactor near Kharkiv, Ukraine. Two complementary simulation tools are integrated. The FRAmework for Analyzing systeMic risks and Exploring Sustainable Solutions (FRAMESS), an agent- and network-based modelling platform, represents war-specific conditions including infrastructure damage, mobility constraints, landmine contamination, and behavioral adaptation. Java Real-time Online DecisiOn Support system (JRODOS), a radiological decision-support system, provides atmospheric dispersion, contamination, and dose assessments based on source-term and meteorological data. JRODOS outputs are incorporated into FRAMESS to simulate civilian decision-making, protective actions, emergency management interventions, and system-wide performance under both peacetime and wartime conditions. The integrated framework enables the analysis of complex interdependencies and cascading failures affecting radiological emergency management during armed conflict. Comparative simulations demonstrate how wartime disruptions can substantially reduce the effectiveness of protective actions and emergency response functions. System resilience is quantified using aggregated indicators capturing health impacts, population well-being, and preparedness costs. The approach also provides a platform for testing alternative preparedness measures and evaluating their effectiveness under varying conflict conditions. The proposed framework offers a novel capability for assessing and improving the resilience of radiological EPR&R systems in conflict-affected environments. By combining radiological consequence modelling with agent-based behavioral simulation, it supports evidence-based preparedness planning and decision-making. Future work will integrate deep reinforcement learning and multi-criteria decision analysis (MCDA) to identify optimal preparedness strategies.

TFT-02 RADIOLOGICAL INCIDENT SCENARIOS IN THE TITAN 3 TRAINING PROGRAMME

Author: Billy Murphy, David Megson-Smith, Ewan Woodbridge, Josh Saunders, Liwia Kocela, Thomas Scott, Tom Bennett, Yannick Verbelen | Co-Author: | Speaker: Yannick Verbelen

Ionising radiation continues to find more applications in the modern world, in industrial, scientific, and medical fields. Applications of fission products that are abundant, such as Sr-90 in radiothermal generators (RTGs) or Cs-137 in thickness and density gauges, are attractive because of their reliability and cost-effectiveness. However, as radioactive materials find more applications and the number of radiation sources increases, so does the likeliness of accidents. Despite best efforts, orphaned radiation sources do appear regularly where they are not expected, in

exceptional cases leading to radiation injuries and death. The 19 GBq Cs-137 source lost in Western Australia early 2023 illustrates why building up nuclear/radiological (RN) incident response capabilities is essential to manage incidents effectively and safely.

The University of Bristol (UK) has been at the forefront of RN threat response training since the launch of the TITAN programme in 2024. This programme, designed by radiation protection experts with expertise in orphan radiation source incidents and radiological accidents, aims to provide RN incident response training to professionals of diverse backgrounds. It combines theory sessions with hands-on exercises where incidents are simulated as realistically as possible, including the use of radiation sources and radiation detectors the way they would be used in the field. This paper presents the training scenarios that were developed for the TITAN 3 programme, which took place February - March 2026 in the UK. The background setting, scenario, mission objectives, props, and radiation sources are presented, alongside a discussion of trainee experiences. Each scenario is constructed such that it is suitable for a team of 5 persons, where teams internally allocate roles. The paper concludes with suggestions for future improvements in equipment and procedures.

TFT-03 DEVELOPMENT OF ADVICE FOR COMMUNICATION ON PROTECTIVE ACTIONS IN NUCLEAR DETONATION SCENARIOS

Author: Christiane Pölzl-Viol, Yevgeniya Tomkiv | Co-Author: Mariana Filipa Fonseca Rodrigues | Speaker: Yevgeniya Tomkiv

Objectives: The increasing risk of nuclear detonation events in the current geopolitical environment presents significant challenges for emergency preparedness and response. Such events differ fundamentally from emergencies originating at nuclear power plants. For nuclear facilities, radiological emergency preparedness and response measures including protective actions and communication with the public are well established and exercised. However, nuclear detonations change the context for protection measures, public response, and thus alters information and communication requirements.

Communication with the public is crucial in the event of a nuclear detonation. The goal of Work Package 4 from PIANOFORTE project PREDICT (funded within the 1st Open Call of the PIANOFORTE EJP, with twelve partners from seven European countries), is to develop effective communication approaches for nuclear detonation scenarios, based on the developed protection strategies and taking into account the unique characteristics of these events.

Methods: To address this gap and to develop informed communication recommendations for this new and complex scenario, an analysis was carried out of existing international communication materials related to radiological emergencies. The aim was to determine the existing state of communication offerings, identify areas of improvement and key aspects important for communication in case of a nuclear detonation. The analysis was conducted using an evaluation framework that served to assess the fulfilment of requirements for effective risk communication.

Additionally, a workshop with relevant stakeholders, such as radiation protection specialists, first responders, social and natural scientists, was held to gather insights from different perspectives and to identify key aspects they consider important in handling protection recommendations that need to be addressed in communication strategies. The focus of the workshop was on developing an overview of the opinions of these stakeholders on how to practically operationalise protective strategies; what will be needed to implement those; which actors should be involved; how and what trade-offs will have to be made.

Results: Currently, the results from the communication material analysis and the stakeholder workshop are being compiled and will be presented at the ERPW. The presentation will highlight

key insights into best practice examples of communication formats and recommendations for communication strategies, as well as the valuable and nuanced inputs gathered during the stakeholder workshop related to communication in case of a nuclear detonation scenario.

Conclusions / Implications: WP 4 in PIANOFORTE PREDICT project ensures the European perspective on protective actions following a nuclear detonation scenario and the communication to the public. Based on the work within WP 4 of PREDICT, the identified protection strategy can be better implemented and communication with key actors, such as first responders and the public, can be improved.

TFT-04 DIETARY INTAKE OF NATURAL RADIONUCLIDES AMONG CHILDREN AND ADOLESCENTS IN GERMANY

Author: Michaela Achatz | *Co-Author:* Anna Jäger, Christian Jung, Jens Fohlmeister, Peggy Hofmann | *Speaker:* Michaela Achatz

Objective: From 2016 to 2021, the German Federal Institute for Risk Assessment (BfR) conducted Germany's first Total Diet Study, the BfR MEAL Study ("meals for exposure assessments and analysis of foods"). Within this study, 356 MEAL foods were investigated for more than 300 potentially beneficial or harmful substances. As a satellite study, naturally occurring radionuclides in foods of the German diet were investigated by the Federal Office for Radiation Protection (BfS) to assess dietary radiation exposure. The study contributes to the UN Sustainable Development Goal 3 (SDG 3: Good Health and Well-Being) by improving the scientific basis for the protection of public health, particularly for sensitive population groups such as children and adolescents.

Methods: More than 200 food samples from major food groups, including vegetables, fruits, cereals, meat, fish, and dairy products, were analyzed. The radionuclides Lead-210, Uranium-234, Uranium-238, Radium-226, and Radium-228 were determined after drying, ashing, microwave digestion, and radioanalytical measurements according to Hofmann et al. (2024). For dose assessment, age-dependent food consumption data and ingestion dose coefficients were applied for five age groups defined by the German Radiation Protection Ordinance: infants (<1 year), toddlers (1-2 years), children (2-7 years and 7-12 years), and adolescents (12-17 years). In addition, Po-210 assessment was included using conservative assumptions because of its relevance for ingestion dose.

Results: Activity concentrations of natural radionuclides were generally low compared with international data compilations, with Radium-228 and Radium-226 dominating most measured activity concentrations (Hofmann et al., 2025). Estimated effective doses for children and adolescents remained low compared to the total radiation exposure caused by natural sources assuming an average of 2.1 mSv/a. Nevertheless, doses in younger age groups were generally higher than those reported for adults (Achatz et al., 2026), because of higher age-specific dose coefficients and greater food intake relative to body weight compared with adults. Polonium-210 and Radium-228 were identified as major contributors to the overall ingestion dose.

Conclusion: The results provide an important basis for evaluating dietary exposure to natural radionuclides in sensitive age groups of the German population. By extending previous adult assessments to children and adolescents, the study enables a more comprehensive dose assessment for the overall population and supports evidence-based radiation protection measures in line with SDG 3: Good Health and Well-Being.

References:

Achatz et al., 2026. Comparative dose assessment of natural radionuclides in food consumed by adults in Germany J. Environ. Radioact. in prep.

Hofmann et al., 2025. Levels of naturally occurring radionuclides in foods from the first German total diet study. Sci. Total Environ. 965, 178653.

Hofmann et al., 2024. The first German total diet study: Analytical techniques to identify natural radionuclides in food samples. J Radioanal Nucl Ch 333, 2449-2460.

TFT-05 BRIDGING RADIATION PROTECTION AND LIFE CYCLE ASSESSMENT: INTEGRATING NORM INTO HOLISTIC SUSTAINABILITY ASSESSMENT

Author: Boguslaw Michalik | Co-Author: Dorottya Jakab, Federica Leonardi, Gennaro Venoso, Giorgia Stendardo, Jelena Mrdakovic Popic, Rosabianca Trevisi, Anna Śliwińska | Speaker: Boguslaw Michalik

Objectives / Background: Naturally Occurring Radioactive Material (NORM) is increasingly recognized as a relevant source of exposure across a wide range of industrial sectors. However, its integration into Life Cycle Assessment (LCA) and, in particular, Life Cycle Impact Assessment (LCIA), remains limited to specific cases and methodologically inconsistent. While overall radiological impact assessment within LCA has significantly evolved, existing approaches are largely tailored to anthropogenic radionuclides and nuclear fuel cycle systems. In addition, conventional LCA methodologies do not adequately capture interactions between radiological and non-radiological stressors, despite their combined relevance for risk and hazard characterization especially in NORM contexts. Therefore, these methods are not directly applicable to NORM-related industrial processes unless a specific case is considered.

Methods: The LCA4NORM project develops an operational framework based on: (i) decomposition of industrial processes into basic activities and associated exposure pathways, (ii) creation of a dedicated NORM Life Cycle Inventory database connecting full NOR characterization with possible associated contaminants via specific industrial processes, (iii) definition of Unit Exposure Scenarios (UES) enabling standardized and flexible exposure modelling, and (iv) development of process- and product-specific life cycle exposure models based of UES spatial and temporal combination. The approach incorporates radionuclide-specific behavior, environmental transport, and differentiation between occupational, public, and ecological receptors. A key innovation of the approach is simplification of complex exposure situation modelling and the explicit consideration of interactions between ionizing radiation and co-occurring chemical and physical stressors at the level of hazard formation, allowing for the evaluation of synergistic and antagonistic effects beyond conventional midpoint and endpoint aggregation.

Results: The proposed framework addresses identified key methodological gaps, including oversimplified exposure assumptions, insufficient representation of occupational and environmental exposure pathways, limited consideration of site/process-specific conditions, and a lack of consistency in handling radionuclide decay chains and time-dependent equilibria. It enables consistent derivation of characterization factors for NORM-related releases and supports modelling of combined radiological and non-radiological stressors regardless of particular NORM exposure scenarios. Initial applications demonstrate improved transparency, flexibility, and representativeness compared with existing LCIA approaches.

Conclusions / Implications: The framework provides a robust and practical basis for integrating NORM into LCA and for improving the consistency of radiation risk assessment in industrial contexts. By aligning LCA with radiation protection principles and enabling multi-stressor assessment, it supports better decision-making by industry and regulators and contributes to a more holistic evaluation of sustainability. Integration with existing LCA systems is currently under

consideration. Full integration as a new impact category is the preferred option, unless technically infeasible.

TFT-06 NON-CANCER EFFECTS OF IONIZING RADIATION AND THE DETRIMENT – ARE WE STILL ON THE RIGHT WAY? RECONSIDERING HEREDITARY EFFECTS AND CARDIOVASCULAR DISEASES IN RADIATION PROTECTION.

Author: Jan Christian Kaiser, Markus Eidemüller, Omid Azimzadeh, Peter Scholz-Kreisel, Simone Mörtl | Co-Author: | Speaker: Peter Scholz-Kreisel

Objectives/Background: Radiation detriment as a risk metric is a central concept of the system of radiological low dose protection and currently incorporates cancer and hereditary effects, while cardiovascular diseases (CVD) remain excluded. Since the publication of ICRP 103, substantial advances have been made in radiation epidemiology, molecular biology, and risk assessment. This work evaluates whether current scientific evidence supports the continued inclusion of hereditary effects and the potential incorporation of cardiovascular diseases into future detriment calculations.

Methods: A narrative review was conducted using recent epidemiological, experimental, and mechanistic evidence relevant to hereditary effects and cardiovascular diseases. Current detriment methodology was critically assessed with respect to biological plausibility, risk quantification, uncertainty, and applicability to radiation protection.

Results: Current estimates of hereditary detriment used for detriment calculation are largely based on the doubling-dose approach derived from animal studies and supported by multiple correction factors. Although experimental evidence demonstrates transgenerational radiation effects in model organisms, epidemiological studies in humans, including descendants of atomic bomb survivors, Chornobyl cleanup workers, and nuclear test veterans, provide little consistent evidence for measurable health effects in offspring. Recent whole-genome sequencing studies suggest that radiation-associated hereditary signatures may occur, but at very low frequencies. Consequently, no robust human-based risk model is currently available for detriment calculations.

In contrast, evidence for radiation-associated cardiovascular diseases has strengthened considerably. Meta-analyses of occupational and environmental cohorts indicate positive dose-response relationships, particularly for cerebrovascular disease, even at low doses. Mechanistic studies demonstrate biologically plausible pathways involving endothelial dysfunction, inflammation, vascular remodeling, and premature cardiovascular ageing. However, substantial uncertainties remain regarding low-dose risk estimates, dose-rate effects, latency, confounding and endpoint definition.

Conclusions/Implications: The scientific basis for including hereditary effects in detriment calculations appears increasingly weak, whereas evidence for cardiovascular diseases at low doses has become progressively stronger. Future revisions of radiation detriment should consider removing hereditary effects as a quantified endpoint while maintaining intergenerational protection as an ethical and sustainability principle. Conversely, cardiovascular diseases warrant serious consideration for inclusion in detriment calculations, provided remaining uncertainties can be adequately addressed. This reassessment would improve the scientific consistency and credibility of the radiological protection system.

TFT-07 OCCUPATIONAL RADON EXPOSURE IN ROMANIA: A COMPREHENSIVE STUDY USING PASSIVE AND ACTIVE SENSORS

Author: Denisa Valentina Negreanu | Co-Author: Alexandru Nicolin-Zaczek, Bogdan Zorila, Margareta Cherestes, Maria-Alexandra Nacu, Ruxandra Sapoi | Speaker: Denisa Valentina Negreanu

Objectives: Occupational radon exposure represents a critical factor in indoor air quality management and radiological protection. Following the implementation of European Council Directive 2013/59/Euratom, there is an increasing need for robust, data-driven assessments to ensure compliance at workplaces. This study aims to evaluate radon levels in diverse Romanian work environments, bridging the gap between long-term compliance monitoring and real-time exposure dynamics.

Methods: The research employs a dual-layer monitoring approach using data provided by Dositracker S.R.L.. A macro-scale assessment was conducted across over 2,500 measurement points (offices, industrial sites, and public buildings) using CR-39 passive detectors to establish annual average concentrations. This was complemented by a micro-scale analysis of over 30 representative environments monitored with active IoT sensors (Airthings), providing high-resolution hourly data for radon, temperature, and humidity. The passive monitoring followed standard protocols with exposure periods ranging from three to twelve months to account for seasonal variations, while the active devices were strategically placed at breathing zone levels to ensure representative sampling of inhaled air. This methodology allows for a cross-validation of integrated long-term results with transient concentration dynamics.

Results: The analysis of the 2,500 passive detectors provided a statistically significant map of radon distribution, identifying specific building characteristics and regions with a higher probability of exceeding the reference level of 300 Bq/m³. However, active monitoring revealed that annual averages often mask significant concentration peaks. In many cases, radon accumulates during non-occupancy hours (overnight), reaching maximum levels exactly at the start of the working day. A strong correlation was identified between thermal gradients and radon entry (stack effect), highlighting the influence of building physics on gas accumulation. The data showed that in poorly ventilated industrial spaces, the peak concentrations during early morning hours could be up to four times higher than the daily average, significantly impacting the calculated effective dose for employees. Conversely, public buildings with modern HVAC systems exhibited more stable profiles but faced challenges regarding energy consumption versus radon dilution.

Conclusions: This study highlights that a singular monitoring approach is often insufficient for a complete radiological risk assessment. By integrating large-scale passive dosimetry with active sensing, we propose an optimized radiological protection protocol. These results provide a scientific basis for "Smart Ventilation" strategies, which effectively reduce the dose for employees while maintaining energy efficiency in occupational spaces. Ultimately, this research serves as a pilot model for the National Radon Action Plan, demonstrating how digitalization and real-time monitoring can transform traditional radiological protection into a dynamic, preventive management system.

TFT-08 RADON AT WORKPLACES: WHAT WE EXPECTED AND WHAT TEN YEARS OF IMPLEMENTATION TAUGHT US

Author: Ivana Fojtíková, Kateřina Navrátilová Rovenská | Co-Author: Marcela Berčíková, Michal Jankovec, Ivana Ženatá | Speaker: Kateřina Navrátilová Rovenská

Background: The transposition of Directive 2013/59/Euratom (EU BSS) introduced, among other obligations, a new requirement to identify and monitor workplaces located on the ground floor or

basement level in radon priority areas (RPAs) - a category distinct from workplaces such as caves or groundwater treatment facilities, which had been subject to monitoring requirements in the Czech Republic already prior to implementation of the EU BSS. This contribution focuses specifically on the workplaces located at RPAs. In the Czech Republic, workplace monitoring begins with a one-year measurement using passive track-etch detectors. Results are compared against the reference level of 300 Bq/m³. Where this level is exceeded, radiation protection optimisation is required, potentially resulting in organisational or technical remediation measures.

Methods: In autumn 2016, prior to the entry into force of the new Atomic law implementing the EU BSS, a nationwide mixed-method survey, a quantitative online questionnaire and qualitative in-depth interviews, was conducted to map workplace operators' awareness, attitudes, and barriers to compliance. Programme experience from 2017-2026 was drawn from operational data including participation rates, measurement results, and operator response behaviour.

Results: After the new requirements were implemented, the number of workplaces monitored ranged from a few to the lower tens per year. Through the gradual implementation of recommendations from the research conducted, this number increased to the hundreds of workplaces measured per year (carrot and stick - you have to measure, but you get the measurements for free). Research conducted on several different questions has shown the importance of properly established communication. This was also confirmed in real-world practice. Receiving measurement results alone not always triggered action; direct personal communication was often found to be essential - operators needed to understand not only what the results meant, but also what exactly was expected of them and what concrete steps were available to address their situation. The concept of optimisation - while central to radiation protection - had little practical meaning for most of the operators. In addition to the above, it turned out that contrary to initial expectations, the market of qualified specialists and contractors for technical radon remediation as well as licensed providers of measurement did not develop sufficiently, primarily due to the small scale of demand.

Conclusions: It turned out that the newly introduced requirement would not be implemented on its own. Effective and sustainable workplace radon monitoring programme requires simple actionable and affordable rules: operators need to know what to measure, when to act, and how to do it - and the means to do so must be readily available. Without sufficient measurement and remediation capacity in place, operators will have no realistic chance of achieving compliance with regulations. Last but not least, enforcement of regulations is also important: experience shows that without ongoing compliance checks, the willingness to reduce radon levels gradually declines.

TFT-09 DOSE RECONSTRUCTION FOR THE INTERNATIONAL POOLED ANALYSIS OF URANIUM PROCESSING WORKERS (iPAUW) STUDY: HARMONIZATION AND RESULTS

Author: Estelle Davesne | *Co-Author:* F. Trompier, L. Alleaume, M. Bellamy, David Broggio, D. Chambers, V. Deffner, G. Drouet, N. Fenske, A. Giussani, A. P. Golden, D. Gregoratto, R. Haylock, C. Hinksman, A. Ho, S. Howard, T. Knight, R. Lane, O. Laurent, E. Samson, T. Smith, V. Spielmann, R. | *Speaker:* Estelle Davesne

Objectives / Background: The international Pooled Analysis of Uranium Workers project (iPAUW) is the first pooled analysis for uranium processing workers based on 6 cohorts from 5 different countries. Its main aim is to assess the long-term health risks of external gamma radiation, long-lived radionuclides, radon, and radon decay products (RDP) among this specific group of workers. Joint analyses of data provided by different cohorts need consistent dose reconstruction, i.e., the assessed doses for two individuals from two different cohorts should be similar if their exposures are similar. Since some parameters in the dose assessment (e.g., duration of exposure, treatment

of data reported as “below detection/reporting level”) were agreed upon based on interpretations and decisions rather than scientific evidence, review, and harmonization of the radiation dosimetry among individual cohorts is warranted.

This work aimed to develop the most suitable protocol to assess and harmonize doses from exposures to external gamma radiation, long-lived radionuclides, radon, and RDP for the cohorts of the iPAUW project, considering the current state of knowledge and available data. This harmonization is critical for conducting pooled risk analyses within iPAUW.

Methods: A harmonized dosimetric protocol was built by consensus among the dosimetry group of the iPAUW project. Dedicated tools were developed to derive dose conversion factors for external exposure depending on geometry, energy spectrum and dosimeter technologies. The two codes used to calculate internal dose from bioassay measurements were compared to ensure quality of the results.

Results: Based on the review results and available data the iPAUW Dosimetry group issued an harmonized protocol to assess doses from external gamma radiation, long-lived radionuclides, radon, and RDP. The two codes for internal dosimetry give similar results. Due to differences in exposure patterns (e.g. exposure to RDP or not, to radium or not...), dose levels are very different among cohorts.

Conclusion: Dose estimates were calculated for six cohorts applying the protocol. Due to the standardized dosimetry, the individual cohorts can now be directly compared and their unique dose profiles identified. The dose estimates will now be used as input data for the joint analyses of health effects in the joint iPAUW cohort.

TFT-10 BONE MARROW EXTRACELLULAR VESICLES OF DISTINCT CELLULAR ORIGINS MAY DIFFERENTIALLY MEDIATE RADIATION DAMAGE

Author: Martina Forgács | Co-Author: Balázs Gyebrovski, Katalin Lumniczky | Speaker: Martina Forgács

Background: Ionizing radiation (IR)-induced genomic instability and altered immune system homeostasis play a key role in the development of malignant processes within the bone marrow (BM). Hematopoietic stem and progenitor cells (HSPCs) are essential for normal hematopoiesis; however, these cells also belong to the most radiosensitive subpopulations within the BM. IR-induced persistent DNA damage may facilitate long-term pathological alterations in the BM. Extracellular vesicles (EVs) play a crucial role in intercellular communication, particularly in mediating radiation-induced bystander effects. We have previously demonstrated in vivo that BM-derived EVs from irradiated mice initiate a radiation-induced bystander effect (RIBE) in non-irradiated mice.

Methods: HSPCs were isolated from 6-7 week-old male C57BL/6 mice. Total BM cells were harvested from the femur, tibia, humerus, and pelvic bones. Lineage-negative cells were separated via magnetic depletion, followed by the sorting of LSK (Lin⁻, c-kit⁺, Sca-1⁺) and LK (Lin⁻, c-kit⁺, Sca-1⁻) stem and progenitor cells. LSK and LK cells were then treated in vitro with either 0.1 Gy or 2 Gy of X-rays, or with EVs isolated from irradiated (0.1 Gy or 2 Gy) or non-irradiated total BM cells, or from C57BL/6 mesenchymal stem cells (MSCs). Phenotypic changes and γH2AX levels—indicative of DNA double-strand breaks—were measured within specific stem and progenitor subpopulations 24 and 48 hours post-treatment using flow cytometry.

Results: At 24 and 48 hours post-irradiation, an elevated level of γH2AX was observed in several stem and progenitor subpopulations. Among the most primitive stem cells, the multipotent

progenitors (MPPs) displayed the highest radiosensitivity. Within the lineage-committed progenitors, the myeloid lineage progenitors—specifically common myeloid progenitors (CMPs) and immature granulocyte-monocyte progenitors (GMPs)—showed the highest radiosensitivity. Treatment with both total BM- and MSC-derived EVs also increased γ H2AX levels within the subpopulations. However, compared to total BM EVs, MSC-derived EVs increased the proportion of γ H2AX+ cells to a substantially greater extent. Furthermore, there was a minor difference in the extent of the changes after EV treatment from control or irradiated donors.

Implications: Our results suggest that both low- and high-dose IR can induce DNA damage in HSPCs, although their responses to the treatment vary across specific subpopulations. Furthermore, BM EV pools are highly heterogeneous; EVs originating from different cellular subpopulations may exert distinct effects on HSPCs, indicating that different BM subpopulations transmit distinct biological information.

Funding: This work has received funding from the Euratom research and training programme 2022-2027 in the framework of PIANOFORTE under grant agreement No 101061037

POSTER SESSION - TUESDAY

PTU-01 REDUCING UNCERTAINTY IN PRIMARY RADON-222 STANDARDISATION USING DEFINED SOLID-ANGLE ALPHA SPECTROMETRY

Author: Behnam Khanbabaee | Co-Author: Stefan Röttger | Speaker: Behnam Khanbabaee

Radon-222 is one of the most significant contributors to natural radiation exposure and plays an important role in radiation protection, environmental monitoring, and regulatory compliance. Reliable calibration of radon measurement systems therefore requires highly accurate and traceable primary activity standards maintained by National Metrology Institutes (NMIs). Defined solid-angle (DSA) alpha spectrometry is a primary method for the absolute activity determination of Radon-222, in which radon is cryogenically deposited onto a metallic surface and the emitted alpha particles are detected in a well-defined geometry. The measurement accuracy is governed by the geometry factor, which depends critically on the source-diaphragm distance. Previous investigations identified this distance as one of the dominant contributors to the total measurement uncertainty.

This work presents thermo-mechanical modelling performed as part of the ongoing upgrade of the PTB primary Radon-222 standard. Coupled heat-transfer and structural finite-element simulations using COMSOL Multiphysics® were carried out to analyse the temperature distribution and thermally induced deformation of the cryogenic source assembly during cooldown from room temperature to approximately 6 K. The source assembly consists of the metallic radon deposition surface connected to the cryocooler by a nickel support rod. The influence of the source assembly geometry on the source-diaphragm distance and its associated uncertainty was systematically investigated. In addition, the radial temperature distribution across the deposition surface and its influence on the radial distribution of the condensed radon source, and consequently on the geometry factor, were analysed.

The simulations show that thermo-mechanical deformation represents the dominant contribution to the uncertainty of the source-diaphragm distance under cryogenic operating conditions. Depending on the source assembly geometry, axial displacements of up to approximately 0.28 mm were obtained. The length of the nickel support rod was identified as the key design parameter controlling thermo-mechanical deformation, and a nearly linear relationship between rod length and axial displacement was observed. Furthermore, the calculated radial temperature distribution indicates that the operating temperature influences the size of the condensed radon source and therefore contributes to the uncertainty of the geometry factor.

The presented approach establishes a consistent framework linking thermo-mechanical modelling, source assembly design, thermal behaviour, and uncertainty evaluation. It provides a practical basis for reducing uncertainty contributions in DSA-based primary Radon-222 standardisation and represents an important step towards reducing the combined measurement uncertainty to the 0.1% level through optimisation of the measurement geometry.

PTU-02 ASSESSMENT OF CHROMOSOME AND CHROMATID ABERRATIONS AFTER CRYOPRESERVATION OF WHOLE BLOOD SAMPLES FROM PROSTATE CANCER PATIENTS

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Background: Mass-casualty radiological events require triage systems for the affected population. Categorization into clinically relevant groups such as unexposed and individuals developing either a low degree haematological acute radiation syndrome (HARS) or high HARS degree can support the triage. The dicentric chromosome assay (DCA) is well established regarding biological dosimetry and is currently studied for its applicability to clinical outcome identification of potential victims. The DCA is time-consuming and currently in most laboratories it is only viable using fresh blood samples. In emergency situations, the large number of victims could cause the collapse of the health infrastructure, so an increase in the capacity and time of analysis from laboratories is key. The cryopreservation of whole blood samples has been proposed to extend the viability of samples weeks or months after the exposure and enable transport to distant laboratories. In the present study, we used whole blood samples from prostate cancer (PCa) patients collected before and during radiotherapy (RT). The aim of this study is to simulate a real exposure scenario, to evaluate whether cryopreservation affects the dicentric chromosome (DC) yield or any other parameter that may influence dose estimation.

Methods: Samples from ten patients diagnosed with prostate adenocarcinoma undergoing RT were collected. Each patient underwent two blood extractions: one before the start of RT and one near the end of the treatment (between fractions nr. 17 and 21 out of 28 or 29). Whole blood was cryopreserved using a mixture of 20% DMSO and 80% FCS and stored in 2 ml cryovials at -80°C freezer. Both fresh and cryopreserved blood cultures were performed following standard protocols. Chromosome and chromatid-type aberrations were recorded. Dose estimation was performed with BiodoseTools software. A morphological score was developed to evaluate the morphology of metaphases and the structure of chromosomes. Mitotic index (MI) and morphology were evaluated on all the samples from three patients. Results for the remaining patients are still pending.

Results: No notable changes were observed in metaphase morphology or mitotic index between fresh and cryopreserved cultures, although high inter-patient variability was detected. No significant differences were observed in the number of dicentric chromosomes between fresh and cryopreserved cultures, in both pre- and post-exposure samples. However, the number of chromatid breaks was significantly higher in cryopreserved cultures. The estimated doses obtained with both types of cultures were comparable and showed no differences.

Conclusions: Cryopreservation of whole blood samples is an accurate approach for dose estimation in emergency response situations. However, it seems to provoke chromatid-type aberrations, mostly chromatid breaks, even though these do not interfere with dose estimation. This method has been proven to be applicable to cytogenetic assays in biodosimetry and offers great potential for triage applications in mass casualty accidents.

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PTU-03 ARTIFICIAL INTELLIGENCE IN BIOLOGICAL DOSIMETRY: VALIDATION OF A DEEP-NEURONAL NETWORK WORKFLOW FOR FULLY AUTOMATED ANALYSIS OF DICENTRIC CHROMOSOMES

Author: Martin Bucher | Co-Author: Andreas Brown, Siegfried Hänselmann, Jayne Moquet, Stephen Barnard, Ursula Oestreicher, David Endesfelder | Speaker: Martin Bucher

Objectives/Background: Artificial intelligence has recently found its way into biological dosimetry. The aim of this study was to validate an initial version of a deep neural network (DNN) workflow

that had been implemented in an existing, commercially available analysis platform for the detection of dicentric and polycentric chromosomes in microscopy images.

Methods: Fine tuning of thresholds for the class score parameter defining the aberration classes was performed based on a 60Co dataset. As a result, a fully-automated calibration curve was established using the DNN workflow. This was compared to manual and semi-automated scoring to evaluate the performance and enable parameter optimisation. Finally, the fine-tuned workflow was used to establish calibration curves on independent X-ray test datasets from two different laboratories, in order to test the usability in biological dosimetry by performing dose estimation on fully automatically scored test samples in both full and triage scoring modes.

Results: The implementation of these thresholds brought DNN scoring closer to manual scoring for low doses by reducing the number of false-positive dicentrics, while balancing the influence of false-negative detections, especially for higher doses. Although slightly higher, the DNN achieved an acceptable yield of dicentrics for the control samples. A comparison of the calibration curves showed that the DNN curve was between the curves for manual and semi-automatic scoring. Furthermore, DNN curves based on two independent test datasets from different laboratories showed very good agreement, with dose estimations matching the reference doses for all 13 test samples (0-5.1 Gy) precisely, even with triage scoring.

Conclusion: This workflow enables the establishment of calibration curves for different radiation qualities and successfully performs dose estimations. It could enhance the capacity of individual biological dosimetry laboratories to handle large sample sizes in the event of large-scale radiological or nuclear incidents and thus contributes to improving existing semi-automated scoring modes.

PTU-04 MODELLING RADIATION RISK TRANSFER BETWEEN POPULATIONS AND ITS RELEVANCE FOR LIFETIME RISK

Author: Markus Eidemüller, Jan Christian Kaiser, Alexander Ulanowski | *Co-Author:* | *Speaker:* Markus Eidemüller

Objectives: The current radiation protection system relies on health risk estimates derived from large radioepidemiological cohorts such as the Life Span Study of atomic bomb survivors. These estimates must be applied to target populations that differ in geographical, historical, ethnic, social and medical characteristics. This process, known as risk transfer, remains poorly understood. The present work clarifies its conceptual basis and presents a systematic general framework for transferring inferred risks between populations.

Methods: Commonly, transfer of radiation risks uses estimates of the excess relative risk (ERR) and excess absolute risk (EAR) obtained from radioepidemiological cohorts. For this, an ERR model is conventionally used to transfer risk multiplicatively to the target population, while an EAR model is used for additive transfer. A final risk value is produced as a weighted mean of the two models, with weights reflecting believed importance of either transfer path. For many cancer sites, equal weights of 50% / 50% are assigned, while for a few these weights are judged unequal. However, conceptually this method conflates two independent notions: the type of risk model used to fit the cohort data and the modality of risk transfer to other populations. Here we present a more general approach that treats these as two independent steps in the risk assessment process. First, a model or models with good and parsimonious description of the cohort radiation risk should be developed, together with a description of the underlying spontaneous disease rates. Using these spontaneous rates, radiation risk can then be transferred to the target population through a representative plausible combination of multiplicative and additive transfer modes, independently of the type of risk model.

Results: The proposed approach was developed and systematically applied in several software tools (ProZES, PASSOS, CONFIDENCE) for assessment of the assigned share or lifetime radiation risks. This approach appears particularly helpful in situations that challenge the conventional method, for example, in situations where the ERR and EAR models yield markedly different risk estimates or when the parameter uncertainties in one of the models become very large. Moreover, the explicit consideration of spontaneous disease rates provides better control of the associated uncertainties when disease rates differ substantially between the cohort and the target population, as is the case for stomach or breast cancers in Japanese and Western populations, or when baseline rates in either population are influenced by medical screening, preventive or curing actions. Example calculations of lifetime risks for stomach and colon cancers will be presented to illustrate differences between both approaches.

Conclusions: An approach to cross-population transfer of radiation risk is presented that is based on conceptual independence of risk model type and population transfer mode. This approach can be applied to any type of radiation risk model, including ERR/EAR- and biologically-based models. It provides a complementary route for radiation risk assessment that can be especially valuable in situations that are challenging for the conventional approach.

PTU-05 BIOLOGICAL DOSIMETRY OF CHRONIC OCCUPATIONAL RADIATION EXPOSURE USING THE DICENTRIC ASSAY AND A BAYESIAN FRAMEWORK

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Background / Objectives: In cases of suspected overexposure of individuals, who have already been chronically exposed to low doses of ionizing radiation in the workplace, cytogenetic biodosimetry may be useful. This requires estimation of the excess of chromosome damage above the expected background level associated with a known cumulative radiation dose. However, such “reverse” biodosimetry remains methodologically challenging. The aim of the present study was to demonstrate the applicability of the dicentric assay, combined with advanced data interpretation, for radiation biodosimetry in chronically exposed medical staff.

Methods: Dicentric frequencies were measured in cultured blood lymphocytes from 12 interventional radiologists with 5 to 42 years of professional exposure and 14 unexposed controls. Data analysis included mathematical unfolding of observed aberration yields, a robust linear dose-response coefficient derived from an in vitro low-dose calibration curve for dicentrics, and a Bayesian-type statistical framework for calculating posterior probability densities for “true” aberration yields and corresponding dose estimates.

Results: The mean dicentric frequency in radiologists significantly exceeded the control level, but individual yields showed no dependence on the years of service ($r = 0.268$). After “unfolding”, a strong positive correlation with years of service emerged ($r = 0.843$). “Unfolded” dicentric yields were converted into cumulative dose estimates of 49 - 595 mGy. Bayesian posterior distributions of true aberration yields corresponded to the most probable annual doses ranging from 3.7 to 27.9 mGy. Confidence intervals of annual dose estimates, which are “more probable to be true than non-true”, ranged from 0.8 to 39.3mGy, and their upper limits exceeded 20 mGy in eleven of the twelve cases.

Conclusions / Implications: The proposed approach substantially enhances both the accuracy and interpretability of cytogenetic biodosimetry for chronic radiation exposure. In view of potential radiation incidents, it allows estimation of the expected background aberration frequency for a given exposure duration and/or known monitored dose. The resulting dose estimates can be used

for assessment of radiation-associated health risks and support individualized radiation protection strategies for occupationally exposed professionals.

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PTU-06 AIRBORNE GAMMA SPECTROMETRY IN GERMANY FOR RAPID RADIOLOGICAL MAPPING AND EMERGENCY RESPONSE PREPAREDNESS

Author: Tönjes Koschine | Co-Author: Alexandra Muhr, Birgit Seiler, Christopher Strobl, Michael Thomas, Nicole Klasen | Speaker: Tönjes Koschine

Airborne gamma spectrometry (AGS) is an established tool for rapid radiological assessment following nuclear or radiological incidents. In Germany, AGS is operated jointly by the German Federal Office for Radiation Protection (BfS) and the German Federal Police (Bundespolizei) as part of the national emergency preparedness framework. The objective of this contribution to ERPW 2026 is to present the operational concept, technical capabilities, and practical experience of helicopter-based gamma measurements for large-scale radiological surveys and emergency response.

The German AGS system is installed in EC135 helicopters and combines four sodium iodide detectors for sensitive gamma measurements and radiological mapping with one high-purity germanium detector providing enhanced energy resolution for improved radionuclide identification and quantification. Measurement data are combined with flight parameters such as altitude, speed, and position for near real-time evaluation and visualization. Typical survey flights are performed at approximately 90 m altitude and flying speed of 110 km/h using different paths depending on the operational objective. Radiation protection procedures include continuous dose monitoring, optimized flight planning, altitude adaptation, and restrictions on flights during radioactive plume passage.

The AGS system enables rapid assessment of large contaminated areas while minimizing the exposure of emergency personnel. Approximately 100 km² can be surveyed within about three hours, with preliminary results available shortly after landing. AGS measurements complement stationary monitoring networks and ground-based in-situ measurements by filling spatial gaps and enabling surveys in inaccessible or highly contaminated areas. Operational experience has been gained through regular national and international exercises since the 1990s, including multinational campaigns in France and Switzerland. A major operational deployment was conducted in 2021 during the radiological remapping of the entire Chornobyl exclusion zone.

Airborne gamma spectrometry provides rapid situational awareness and supports evidence-based decision-making during radiological emergencies. The long-standing operational cooperation between BfS and Bundespolizei, combined with regular international exercises, contributes significantly to European emergency preparedness and interoperability. Despite the phase-out of nuclear power generation in Germany, airborne radiological monitoring remains an important capability for population protection and cross-border emergency response in Europe.

PTU-07 CAPACITY AND CAPABILITY OF THE RENEB NETWORK FOR LARGE SCALE RADIOLOGICAL AND NUCLEAR EMERGENCIES

Author: Jayne Moquet, Stephen Barnard | Co-Author: Joan Francesc Barquinero, Martin Bucher, Juan S. Martinez, Matthias Port, Andrzej Wojcik, Ursula Oestreicher | Speaker: Martin Bucher

Objectives / Background: Since 2017, the RENEB network (Running the European Network of Biological and Retrospective Physical Dosimetry) provides rapid, comprehensive and standardized methodology for individual dose estimation and support for the clinical management of radiological and nuclear casualties in the case of large-scale radiological events in Europe and beyond. To ensure the network's operational readiness, the 'Infrastructures' working group within RENEB conducts regular surveys to update partners' contact details and gathers information on the laboratories' emergency capacities and capabilities, as well as on the logistics of sample transport.

Methods: An online survey was developed and sent electronically to RENEB voting members and associate (non-voting) members in 2025. One nominated person on behalf of each institute was asked to complete the survey. The survey consisted of six sections asking for the relevant network information.

Results: Replies were received from 29 institutes, providing a clear picture of the RENEB network's capacity and capability. Most countries have one or two institutes that have the laboratory capacity to perform biological and/or physical dosimetry. The dicentric chromosome assay (DCA) remains the most established assay and the scale of capacity highly depends on the use of semi-automated systems and the number of trained staff available at each institute. The use of methods with high-throughput potential, such as the gene expression method, offers a way to support the prioritization of samples for cytogenetic methods.

Conclusion: The data collected confirms that RENEB is prepared for a large-scale radiological event and can provide key information about operational aspects that will be essential in an emergency situation. Overall, networking fosters collaboration and facilitates knowledge exchange, thereby strengthening the collective response to radiological emergencies.

PTU-08 RADON METROLOGY – AT THE CRADLE OF RADON PROTECTION

Author: Sebastian Feige | Co-Author: | Speaker: Sebastian Feige

Understanding and developing protection against radon exposure starts with the observation of the extent of a damage correlated with exposure condition measurements. Reliable input data from measurements are needed to devise models and establish regulations. Decisions regarding protective measures again count on qualified measurements. In environmental monitoring, accredited laboratories and procedures ensure that results from laboratories adhere to the same quality standards. A focus activity of the BfS (Federal Office for Radiation Protection) Section Radon Metrology is the operation and advancement of its accredited radon calibration laboratory. Its services enable the transfer of measurement quantities, such as radon activity concentration and potential alpha energy concentration, linking measuring devices to a traceability chain. Apart from that, the BfS is conducting own research into radon and radon measurement methods to investigate the characteristics of radon atmosphere and to evaluate the performance of measuring devices.

Implementation of revised radon dose coefficients merit further discussion because of metrological challenges of radon progeny measurements. The radon community is concerned about the reliability of used and available instruments. A critical issue is the traceability and measurement of the unattached fraction of radon progeny, a significant parameter in ICRP's biokinetic-dosimetric

model. Pan-European collaboration is a key in the exchange of knowledge e.g. upon radon scenarios but also helps to strengthen the metrological accessibility to traceability chains. BfS is part of international research collaborations (e.g. RadoNorm, EURAMET MetroRadon) and networks such as EURADOS and the European Metrology Network for Radiation Protection (EMN RP). A most recent activity includes a EURADOS WG 3.3 survey to collect information on existing capabilities and infrastructure related to radon progeny measurements and an international intercomparison exercise, striving for a better understanding of instrument performance and to address needs and gaps for further improvement to manufacturers. Is Thoron of concern or not? Thoron is a bit underestimated in the big shadow of Radon. The lack of traceable Thoron progeny calibration represents a metrological pitfall. BfS has commissioned a new calibration volume with the plan to establish calibration procedures for instruments under accreditation.

The contribution will introduce into the activities and ideas of BfS radon laboratory and will detail findings believed to be relevant in the international context.

PTU-09 HOLISTIC VIEW OF NATURALLY OCCURRING RADIONUCLIDES IN NATURAL GAS INDUSTRY – AN OLD STORY?

Author: Jörg Dilling | Co-Author: Lonneke van Bochove | Speaker: Jörg Dilling

The occurrence of radionuclides in installations of the oil and gas industry is well known for more than a hundred years. In many cases, scales and sludges show elevated concentrations of naturally occurring radionuclides like ^{226}Ra , ^{228}Ra and ^{210}Pb . Another radionuclide of concern is ^{222}Rn with its short and long living daughter nuclides.

Focussing on the natural gas industry, we want to present a holistic view on the appearance of NORM (naturally occurring radioactive material) from cradle to grave. Starting at the production site, following the separation and cleaning procedure and ending up with the transport of natural gas over long distances. We will address solid, liquid and gaseous mass flow and will stress, where natural radionuclides will be of concern. Additionally, we will explain specific issues for some NORM residues before disposing them. Concerning these tasks, the natural gas industry is aware of them and has implemented appropriate radiation protection measures.

Recently, the transport of liquified natural gas over long distances is getting more relevant. Unlike in oil and gas industry, the presence of NOR is much less known in the LNG industry. Therefor the risk and needed protective measures are “new” to the industry. The investigation of recent findings of NOR in LNG regasification units provide a clear view on what happens with ^{222}Rn and ^{210}Pb from the production of natural gas, the liquification to LNG, the transport of LNG to the regasification and physically, there is nothing new, the NOR acts as it always did, the “old story”. This contribution will address the knowledge as well as the lack of knowledge of the fate of $^{222}\text{Radon}$ and ^{210}Pb in LNG.

PTU-10 TRACKING THE FATE OF Po-210 IN A SANDSTONE AQUIFER IN GERMANY

Author: Peggy Hofmann | Co-Author: Frank Wagner, Eric Petermann, Clemens Scholtysik | Speaker: Peggy Hofmann

Polonium-210 (Po-210) is a naturally occurring high-energy alpha emitter characterized by high radiotoxicity, a short half-life (138.4 days), and a comparatively high dose coefficient relative to other natural radionuclides. Due to its strong surface reactivity and affinity for mineral surfaces, Po-210 activity concentrations in water are generally low. Nationwide investigations conducted by

the German Federal Office for Radiation Protection (BfS) reported a median Po-210 activity concentration of 1.4 mBq/l in drinking water. However, elevated activity concentrations exceeding 100 mBq/l were identified in several groundwater monitoring and production wells associated with drinking water facilities in southern Saxony-Anhalt, Germany, with isolated occurrences above 500 mBq/l. Such activity concentrations are of particular relevance in light of the requirements of the EU Council Directive 2013/51/Euratom, which regulate radioactive substances in drinking water and may require mitigation measures.

To improve understanding of the occurrence, origin, and mobilization mechanisms of Po-210 in groundwater systems (aquifers), an extensive hydrogeochemical and radiochemical investigation was conducted in southern Saxony-Anhalt. Water samples from approximately 50 monitoring wells, production wells and associated drinking water facilities, supplemented by rock core investigations, were analyzed for natural radionuclides, major and trace elements, and stable oxygen and hydrogen isotopes. The investigated aquifers comprised stratigraphic units of the Lower, Middle, and Upper Buntsandstein (Lower Triassic), the Lower Muschelkalk (Middle Triassic), and Cenozoic sediments. To understand the relationships between the measured parameters and Po-210 activity concentrations better, statistical approaches including machine learning were applied.

The results indicate that elevated Po-210 activity concentrations are predominantly restricted to the sandstone aquifer of the Middle Buntsandstein. The simultaneous absence of the parent radionuclides lead-210 (Pb-210) and radon-222 (Rn-222) in the groundwater samples, suggested a localized Po-210 mobilization mechanism linked to the aquifer host rock itself. Mineral phases such as clay minerals, iron (oxyhydr)oxides and muscovite are considered as potential hosts for Po-210 and its parent radionuclides. The aquifer environment appears to provide favorable geochemical and microbiological conditions for the coexistence of multiple Po-210 mobilization pathways, including redox-driven mineral transformations and cation exchange processes. Results further suggest that Po-210 predominantly occurs in dissolved form ($<0.1 \mu\text{m}$) as the cationic species Po^{2+} .

From a public health perspective, Po-210 was identified as the dominant contributor to the indicative dose under EU Council Directive 2013/51/Euratom, with activity concentrations in some water samples leading to exceedances of the parametric value of 0.1 mSv/a. Given the lack of comparable regulations for natural radionuclides in many parts of the world, identifying and characterizing hydrogeological settings that favor Po-210 mobilization remains essential for predicting areas prone to elevated Po-210 activity concentrations.

PTU-11 IN SITU MEASUREMENTS OF ORDINARY SALT SAMPLES USING A PORTABLE OSL READER FOR INDIVIDUALISED RADIATION DOSIMETRY

Author: Maria Karampereri | Co-Author: Tuva B. Djurberg, Christian Bernhardsson | Speaker: Maria Karampereri

Objectives/Background: During a radiological or nuclear (R/N) emergency, various population groups may be unintentionally exposure to ionising radiation. Among the potentially exposed, the expected range of individual external doses will be substantial as there is strong dependence on the distance from the zero-point, environmental conditions and behavioral patterns. Hence, methods for individualised dosimetry are crucial, in order to determine which individuals may need medical care, follow-up or if there is no need for further actions. Here we investigate the possibility of using ordinary salt (NaCl), read in situ by optically stimulated luminescence (OSL), as a method for individual dosimetry.

Methods: Irradiated samples of NaCl pellets and grains were studied by OSL. The implementation of a portable OSL reader (Helios reader, Zero-Rad, Poland) for in situ dose assessments of the NaCl

samples was investigated. Reader parameters and protocols were optimised, and several luminescence dosimetry properties were studied.

Results: Signals from infrared (IR) and blue OSL stimulation to dose response were investigated in the range 10 mGy - 15 Gy, for the pellets, and 60 mGy - 5 Gy for the grains. The minimum detectable dose (MDD) was determined for each stimulation method and type of samples. The best MDDs were obtained for NaCl pellets, which were 60 ± 20 μ Gy and 400 ± 200 μ Gy, for OSL and IRSL respectively. A dose recovery study of three “blinded” doses showed that dose predictions were within the acceptance margins ($\pm 30\%$ relative error). Fading studies showed that the NaCl grains exhibit inverse fading both for blue and IR stimulation, while pellets only exhibit this for blue stimulation light. However, signal stabilisation may occur after a certain storage period. In case the signal does not reach this stability, a correction factor may be applied. The effect of certain laboratory conditions on the OSL signal was also investigated.

Conclusions/Implications: The study supports the use of the current portable reader for conducting individualised in situ measurements during an R/N event, combined with NaCl pellets and grains.

PTU-12 EVALUATING LIGHTWEIGHT MULTILINGUAL EMBEDDING MODELS FOR DOSE-MANAGEMENT AND REGULATORY RAG IN RADIATION PROTECTION

Author: Sang Don Kim, Jeongin Kim | *Co-Author:* Hyunjun Na, Seonghoon Cho | *Speaker:* Sang Don Kim, Jeongin Kim

Objectives / Background: Retrieval-augmented generation (RAG) is being explored in radiation protection for dose-management decision support, regulatory-compliance Q&A, and operational-manual review, where retrieval must reliably surface ICRP-based dose limits and protocols. In safety-critical settings, the choice of embedding model used in retrieval largely determines whether the downstream system can be trusted. Domain-specific evidence is largely missing – especially for bilingual Korean-English operation, where dose-management programmes routinely handle both English ICRP sources and Korean regulatory translations. We benchmarked five compact open-source multilingual embedding models on the ICRP Recommendations using a TREC-style pooled, graded protocol.

Methods: Seven ICRP publications central to operational dose management (60, 103, 109, 111, 146, 147, 152) were chunked in parallel English and Korean (6,662 passages). Five models below 1B parameters – BGE-M3, Snowflake Arctic-Embed-L v2.0, EmbeddingGemma-300M, Qwen3-Embedding-0.6B, and Granite-Embedding-278M-Multilingual – were compared against BM25 (Kiwi for Korean; NLTK for English) and a 50/50 Reciprocal Rank Fusion hybrid. For 1,440 queries stratified by language, query type (definition / numerical dose limit / procedure / applied case), publication, and difficulty, candidates from 11 systems were pooled per query (cap = 12, with per-source quotas) and judged by an LLM on a 4-grade scale, yielding 17,148 labels. Queries were assigned to six pre-locked stratified blocks. The primary metric was nDCG@10. Significance was assessed by Friedman, pairwise Wilcoxon with BH-FDR, Cohen's d_z , and 5,000-resample bootstrap CIs.

Results: BGE-M3 was the only model to rank first in all four evaluation cells, with hybrid nDCG@10 of 0.740 (Korean) and 0.664 (English) – sufficient to place the correct dose-limit passage in the top 10 for most queries. The ordering Hybrid > Dense > BM25-only held in every model-language cell. Granite-r2 showed a marked English-Korean polarisation (EN-dense rank 2; KO-dense rank 5; effect size $d_z = 0.62$ versus BGE-M3 – a large effect). The current MTEB multilingual leader, Qwen3-Embedding-0.6B, finished fifth overall. BGE-M3 ranked first in 5 of 6 Korean hybrid blocks, supporting the stability of these conclusions.

Conclusions / Implications: For Korean-centred dose-management AI assistants and regulatory RAG systems in radiation protection, BGE-M3 with a 50/50 BM25-Dense hybrid is the recommended default configuration; EmbeddingGemma-300M hybrid offers a near-equivalent, memory-efficient alternative (~1% loss at half the memory) suited to on-premises deployment at dosimetry services. Granite-Embedding-278M-Multilingual should be avoided in Korean-dominant deployments. These findings inform AI tools for dose-register interpretation, operational dosimetry, and ICRP-aligned compliance.

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PTU-13 A CASE STUDY OF RADIATION DOSE ASSESSMENT FOR SABOTAGE OF NUCLEAR FACILITIES

Author: Seung Beom Yoo | Co-Author: Dong Gyu Kwak, Jung Hun Choi, Kwang Pyo Kim | Speaker: Kwang Pyo Kim

The IAEA recommended to establish physical protection for sabotage based on the graded approach for nuclear facilities considering radiological impact of sabotage. In Korea, physical protection for sabotage is established based on grade of nuclear material instead of quantitative standard based on radiological impact to determine the level of physical protection. Therefore, it is necessary to establish graded physical protection regulation for sabotage based on the radiation dose assessment of nuclear facilities in Korea. The objective of this study is to investigate the case of radiation dose assessment due to sabotage. In this study, we investigated the case of radiation dose assessment for sabotage of nuclear facilities such as nuclear reactors and research reactors. In the case of High-temperature helium-cooled prismatic microreactor of U.S, thermal power rating of 1, 10, and 50 MWt was assumed, and the core melting and core damage scenarios were considered. SCALE/TRITON and ORIGAMI computer code were used to assess the burnup and radionuclide inventories for the HTPM. The radiation dose was assessed using RASCAL computer code. As a result, maximum radiation dose was derived for 50 MWt HTPM as 67 Sv, considering core melting scenario. In the case of research reactor GHARR-1 of Ghana, terrorist attack scenario was assumed for research reactor. The terrorists installed an explosive in the reactor vessel after turning on the emergency ventilation system and the gas purged system of the reactor. The thermal power of 34 kW was assumed, and low-enriched uranium was used as a fuel. The MCNP code was used for calculating the neutron flux and reaction rate, and the ORIGEN2 code was used for calculating burnup and radionuclide inventories. The radiation dose was assessed using HotSpot code, and as a result, maximum radiation dose was derived as 5.6×10^{-9} Sv at about 100 m distance. In the case of research reactor TRIGA RC-1 of Italy, a large aircraft collision with the complete destruction of the reactor hall and the reactor core was assumed as release scenario. The thermal power of a 1 MW research reactor and 20% of enriched uranium were used as fuel. The radionuclide inventories were calculated using the ORIGEN-ARP code for the source term assessment, and the RASCAL, HotSpot, and GENII computer code were used for radiation dose assessment. As a result, a maximum radiation dose was derived as 4.0 Sv using HotSpot computer code. The case study analysis showed that the radiation dose assessment for sabotage of nuclear facilities was conducted in the order of 1) selecting the release scenario, 2) assessing radionuclide inventories and burnup of reactor, 3) assessing radiation dose using computer code such as HotSpot, RASCAL. The results of this study are expected to be used as basic data for assessing the radiological impact for sabotage of nuclear facilities in Korea. This study was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No.RS-2026-25532689).

PTU-14 ANALYSIS OF PHYSICAL PROTECTION ZONES AGAINST SABOTAGE IN NUCLEAR SECURITY FRAMEWORKS

Author: Young Kwon Kim | Co-Author: Jae Hyeon Kim, Jeong Woo Lee, Kwang Pyo Kim | Speaker: Kwang Pyo Kim

IAEA NSS No. 13 states that the objectives of a physical protection regime include protection of nuclear facilities against sabotage and mitigation of the radiological consequences of sabotage. The IAEA also proposes implementing a graded approach to physical protection that establishes Unacceptable Radiological Consequences (URC) and High Radiological Consequences (HRC) based on the potential radiological consequences of sabotage. However, in the Republic of Korea, the criteria for defining the scope and level of sabotage protection are unclearly prescribed, and physical protection zones are not defined based on quantitative standards. Accordingly, this study analyzed the physical protection regimes against sabotage of international organizations and specific countries, to establish a graded physical protection regime in Korea. The objective of this study is to examine 1) classifications of physical protection zones, and 2) requirements for each physical protection zone. Through IAEA NSS No. 13, the IAEA classifies physical protection zones against sabotage at nuclear facilities into 1) Limited Access Area, 2) Protected Area, and 3) Vital Area. HRC and URC are presented as the criteria for defining these zones. IAEA NSS No. 27-G sets out protection requirements for each zone under the following categories: Detection, Alarm assessment, Access control, Detection of prohibited items, Central alarm station, Delay, and Response. Through 10 CFR 73.55, the United States classifies physical protection zones against sabotage at nuclear power reactors into 1) Owner Controlled Area, 2) Isolation Zone, 3) Protected Area, and 4) Vital Area. Protection requirements including Access controls, Detection and assessment systems, and Response requirements are also set out. Through SOR/2025-219, Canada classifies physical protection zones against sabotage at nuclear facilities into 1) Limited Access Area, 2) Protected Area, and 3) Vital Area. Protection requirements including Nuclear security measures, Means of entry or exit, Unobstructed areas, Lighting, and Vehicle and vessel barriers are also set out. Through Order of 13 April 2023 (NOR: ENEK2233716A), France classifies physical protection zones against sabotage at facilities handling nuclear materials of Category 1 and 2, and facilities designated as PIV, into 1) Controlled Access Zone, 2) Standard Protection Zone, 3) Enhanced Protection Zone, and 4) Vital Zone. Effective dose and thyroid equivalent dose thresholds are prescribed as the criteria for establishing these zones. Protection requirements including Prevention, Detection, Delay, Alerting, and Monitoring are also set out. Across all cases examined, both a protected area and a vital area were identified. Common protection requirements include physical barriers for the protected area, and access control and detection measures for the vital area. This study is expected to serve as foundational reference for establishing a graded physical protection regime against sabotage. This work was supported by the Nuclear Safety Research Program through the Korea Foundation of Nuclear Safety(KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission(NSSC) of the Republic of Korea.(RS-2026-25532689)

PTU-15 SECURING RADIOACTIVE SOURCES IN ARMED CONFLICT: LESSONS FOR RESILIENCE AND CRISIS PREPAREDNESS

Author: Nataliia Klos | Co-Author: Suzanne Carlson | Speaker: Nataliia Klos, Suzanne Carlson

Objectives / Background: The security of radioactive sources has traditionally focused on preventing theft, sabotage and unauthorised access through physical protection measures designed around peacetime assumptions. However, experience from recent armed conflicts and other large-scale disruptions has demonstrated that security systems may be required to operate under conditions characterised by degraded infrastructure, disrupted communications, shifting

authorities, resource shortages, and rapidly evolving threats. While resilience is a well-established concept in nuclear safety, cybersecurity, and critical infrastructure protection, its application to radioactive source security has received limited attention. This study examines how resilience can strengthen radioactive source security during armed conflict and other crises and identifies key measures that support continuity of control over radioactive materials under extreme conditions.

Methods: A qualitative review of international literature on resilience, nuclear security, critical infrastructure protection, and emergency preparedness was combined with thematic analysis of discussions from a WINS workshop on strengthening the security of radioactive sources during armed conflict. The findings were analysed to identify common challenges affecting source security and the characteristics of resilient security systems capable of functioning during severe disruptions.

Results: The analysis found that many assumptions underpinning traditional security systems may become invalid during armed conflict. Recurring challenges included communication failures, infrastructure disruption, evacuation of qualified personnel, changing chains of authority, resource constraints, cyber threats, insider risks, and reduced situational awareness. The findings suggest that security systems should be designed for resilience, recognising that some failures are unavoidable and focusing on maintaining essential functions, adapting to changing circumstances, and recovering rapidly.

Four foundational elements of resilient radioactive source security were identified: (1) communication and coordination mechanisms capable of operating under degraded conditions; (2) maintenance of accurate and accessible radioactive source inventories to support situational awareness and recovery actions; (3) sustained professional competence through training, exercises and knowledge management; and (4) legal and institutional frameworks that enable adaptive decision making and coordination among stakeholders during emergencies. Across all these themes, redundancy, flexibility, adaptability and recovery planning emerged as critical resilience attributes.

Conclusions / Implications: Resilient radioactive source security extends beyond preventing malicious acts to ensuring that radioactive materials remain under control during and after severe disruptions. The concept provides a framework for integrating preparedness, response, recovery and adaptation into security arrangements. For the broader radiation protection community, adopting resilience-based approaches can strengthen the continuity of both safety and security functions not only during armed conflict but also in natural disasters, cyber incidents and other crisis situations. As threat environments become increasingly complex, resilience should be considered a fundamental objective of radioactive source security systems.

PTU-16 THE RADON BIOBANK “RADI” (RADON INHOUSE): A BIOBANK TO DECIPHER RADON-INDUCED SYSTEMIC EFFECTS

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Objectives/Background: Radon, a radioactive gas emanating in the ground from uranium-238 decay, accumulates in indoor air and is a known risk factor for lung cancer. This has been proven by large epidemiological studies - while further biological effects as well as age- and sex-specific molecular mechanisms related to radon exposure are less well investigated. Radon and its decay products release high energetic alpha particles that cause direct DNA damage and oxidative stress. Except DNA damage in directly targeted cells, effects in chronically low exposed humans remain largely

unexplored. A high-quality biobank is essential to address knowledge gaps especially in respect to Radon-induced immunological alterations.

Methods/Results: In a nationwide survey, radon indoor concentration, was measured in more than 7,400 dwellings in two rooms for usually 1 year in Germany. Based on this data, households with high and low exposure were selected, and biological samples are being collected. Blood, blood plasma, saliva, sputum, nasal- and oral mucosal swaps are being sampled from 600 individuals (adults and minors) from households with high (>300 Bq/m³) and low (<40 Bq/m³) radon exposures. Questionnaires will gather data on time and activity spent in dwellings, health status, lifestyle and other occupational or medical exposures. Specimen are collected from people at home and sent to BfS for further preparation. Samples will be prepared for various analyses and cryopreserved at the Federal Office for Radiation Protection (BfS).

Informed consent, study information, questionnaire and standardized operating procedures have been set up. Ethical and data protection approvals have been obtained. 407 high-exposure and 2,513 low-exposure households have been identified. 111 high-exposure households have already agreed to participate. Low exposed participants have been matched by age and smoking status. Samples from 185 individuals have already been collected until January 2026.

Implications: The radon biobank, which is currently being established, will provide a diverse sample repository enabling novel research approaches, from next generation sequencing projects for the detection of clonal hematopoiesis, to analyses of the transcriptome, epigenome, respiratory microbiome and proteome, particularly inflammatory cytokines in groups with contrasting radon exposure. The biobank will be accessible to external research groups, fostering collaborative efforts in radon-related health research. Project completion is anticipated by 2028.

PTU-17 BIODOSIMETRY IN PRACTICE AT THE HUNGARIAN DEFENCE FORCES

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Background: Hungarian Defence Forces personnel are deployed to various international missions where the potential for unrecognized exposure to ionizing radiation may exist. Furthermore, occupational, physiological, and lifestyle-related factors specific to military personnel may influence baseline levels of chromosomal aberrations. Ensuring diagnostical preparedness and providing support in the event of radiation-related incidents are key responsibilities of the Radiation Biology Laboratory. This study aims to establish a reliable biodosimetry facility for the retrospective assessment of radiation exposure among military personnel returning from potentially hazardous missions.

Methods: In collaboration with the military unit medical officer, baseline chromosomal aberration frequencies are being established for military personnel (soldier group - SG, $n=4$), as well as for employees working in environments associated with elevated exposure to ionizing radiation (eg. diagnostic radiology facilities or air force units) or employees working in an environment without any radiation risk (national defence employee group - NDEG, $n = 4$). The dicentric chromosome assay, the gold standard for retrospective biological dosimetry, was used for dose assessment. Baseline values are compared with national and international reference data. In addition, group-specific dose-response calibration curves are being developed for dose assessment in an eventual case of radiation exposure.

Results: Preliminary analyses were performed on 3,545 metaphases scored from peripheral blood samples of the SG and 2,514 metaphases from the NDEG. The frequency of dicentric chromosomes

was 1.9‰ in the SG and 0.39‰ in the NDE. For comparison, the reported average dicentric chromosome frequency in the Hungarian population is $1.1‰ \pm 0.008 \text{ SE}$.

Conclusions: These preliminary findings suggest a modest elevation in baseline chromosomal aberration frequency among military personnel compared with civilian defence employees. However, the limited sample size precludes definitive conclusions. Further studies involving larger cohorts are required to improve the statistical power and robustness of the findings. Future work will include comprehensive statistical analyses and the investigation of potential associations between chromosomal aberration frequencies and physiological or lifestyle-related factors.

PTU-18 ANIMAL MODEL SYSTEM FOR INVESTIGATING BIOKINETICS AND INTERNAL DOSIMETRY OF NUCLEAR FUEL COMPOUNDS FOR INHALATION HAZARD ASSESSMENT

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Background: Limited experimental data are available to quantitatively assess the dosimetric consequences associated with inhalation exposure to irradiated fuel particulates and their constituent actinides. In particular, significant uncertainties remain regarding fuel particles within the respiratory tract, including localized dose delivery to lung tissues, as well as the rate and extent of particle dissolution. These processes govern the subsequent transfer of radionuclides into the systemic circulation for redistribution and long-term deposition in critical organs and tissues. Thus, we aim to optimize risk assessment and inform medical management strategies for nuclear workers (occupational exposures), individuals involved in accidental exposures, and emergency responders. This will be achieved by developing a physiologically relevant *in vivo* lung exposure model in the rat, coupled with comprehensive biokinetic data collection to characterize the behavior and distribution of internally deposited actinide-bearing fuel particles.

Methods: Irradiated CANDU fuel pellet debris was collected, suspended in water, and subsequently size-fractionated using a water column separation technique to isolate particles with an activity median aerodynamic diameter (AMAD) of less than 5 μm . Quantitative radionuclide characterization and concentration analysis were performed using a sequential radiochemical separation procedure, followed by multi-technique analysis, including inductively coupled plasma mass spectrometry (ICP-MS), alpha spectrometry, gamma spectrometry, and liquid scintillation counting, conducted at Canadian Nuclear Laboratories (CNL). Prior to lung instillation, the size-fractionated fuel particle suspension was evaporated in water and re-suspended in BLES® solution (Bovine Lipid Extract Surfactant; BLES Biochemicals, London, ON, CAN). Approximately 0.2 mL, equating to ~15 kBq of radioactive fuel particles per dose, was introduced into the lungs of Sprague Dawley rats by intra-tracheal instillation.

Results: Results will be presented as data collection is currently underway to quantify radioactivity burden and assess the micro-distribution of key actinide elements in rodent lungs by conducting autoradiography and radiochemical analysis of digested tissue samples. The resulting lung burden measurements will inform on pulmonary deposition, retention of particles, and spatial distribution of the fuel particles in the lung tissues. Additionally, the transfer of actinide-bearing fuel particles from lungs to systemic compartments is also being evaluated through quantitative radioactivity measurements in excreta (urine and feces), blood and principal extra-pulmonary organs of retention, including the skeleton and liver.

Conclusions: We present here an experimental model system to simulate inhalation exposure to irradiated fuel particles by intratracheal instillation, enabling a controlled deposition of the material into the lungs of Sprague Dawley rats. Findings from this work will improve practical

hazard assessment and occupational radiation protection standards for both medical countermeasures and nuclear energy workers.

PTU-19 PROTEOMIC SIGNATURES ASSOCIATED WITH SURVIVAL FOLLOWING RADIATION EXPOSURE IN MINIPIGS

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Background: Large-scale radiological and nuclear incidents highlight the need for reliable biomarkers that enable rapid assessment of radiation exposure. Proteins are promising candidates because they respond dynamically to ionizing radiation and can be readily measured in clinical settings. This study aimed to identify protein signatures associated with survival in minipigs and to evaluate sex-specific differences following total body irradiation (TBI).

Methods: In this proteomic study, peripheral blood samples were collected from 27 Göttingen minipigs enrolled in three independent experiments. Samples were obtained at four time points: 3 days before irradiation and 1, 3, and 10 days after exposure to 2.1 Gy TBI. Label-free relative quantification was performed using an RP-nanoLC-ESI-MS/MS platform coupled to a Q Exactive mass spectrometer (Thermo). Plasma was isolated from whole blood, and proteins were subsequently depleted, reduced, alkylated, and digested with trypsin/LysC according to standard procedures. Protein identification and quantitative analyses were carried out using MaxQuant, Perseus, and RStudio. Statistical significance was determined using a t-test, with $p \leq 0.05$ considered significant. The complete dataset is publicly available through ProteomeXchange under accession PXD071774 (DOI: 10.6019/PXD071774).

Results: Comparative proteomic analysis identified numerous proteins differentially regulated in association with radiation exposure, survival status, and sex-specific responses. Eighteen leading candidate proteins strongly linked to gamma-radiation exposure were identified. These proteins are involved in hemostasis, inflammatory pathways, immune regulation, and tissue repair. Validation across three independent studies demonstrated the reproducibility of the principal biomarker candidates.

Plasma proteomics further revealed distinct sex-related responses to irradiation. In males, hemoglobin subunits alpha and beta (HBA/HBB) were significantly increased ($\log_2$ fold change > 2), whereas several proteins containing immunoglobulin-like domains and immunoglobulin heavy-chain components were consistently decreased. In females, marked increases were observed in fibrinogen alpha and beta chains (FGA/FGB), complement C3, and apolipoprotein E (APOE). Both sexes showed reduced levels of lysozyme C-3, serotransferrin, and von Willebrand factor, although the decreases were more pronounced in females.

Stratification according to 30-day survival revealed a distinct plasma proteomic signature associated with outcome. Non-survivors exhibited increased levels of periostin, representing the strongest signal, and lipopolysaccharide-binding protein. In contrast, survivors displayed higher abundances of immune-related proteins, including immunoglobulin lambda chain and complement C1q subunits. These differences appeared shortly after irradiation, persisted throughout the observation period, and were consistently observed across experimental cohorts.

Conclusions: These results further support the use of minipigs as a translational model for radiation biomarker research. The identified proteins represent promising candidates for future validation as biomarkers of radiation injury and predictors of clinical outcome.

PTU-20 **ELABORATION OF A METHODOLOGICAL ADVANCED FRAMEWORK FOR THE ASSESSMENT AND MANAGEMENT OF RADIOLOGICAL RISK ASSOCIATED WITH NORM RESIDUES**

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Naturally Occurring Radioactive Materials (NORM) generated by industrial activities represent a growing challenge for radiation protection, especially in the context of evolving regulatory requirements and the increasing adoption of circular economy strategies. Recently, the European community has been promoting the valorisation of NORM residues as secondary raw materials, despite their traditional management as waste. However, the safe implementation of proposals requires robust methodologies capable of integrating radiological protection, environmental sustainability and, at the same time, industrial feasibility.

This work illustrates the framework of an Italian multidisciplinary research project, funded by National Institute for Insurance against Accidents at Work (INAIL), aimed at developing advanced approaches for the characterization, radiological assessment, and potential reuse of NORM residues in construction applications. The project aligns with the holistic management principles recently promoted by international organizations (ICRP and IAEA) and adopts a graded approach to radiological risk assessment, consistent with current European radiation protection strategies.

The proposed methodology combines radiological, chemical and physical-mechanical characterization of selected NORM residues originating from different industrial sectors with significant residues generation. Specifically, these includes the production of refractories with zircon sands, the fertilizer industry, and treatment of groundwater for industrial purposes. High-resolution gamma spectrometry, both on field and in laboratory, will be employed to conduct both qualitative and quantitative measures in order to evaluate the activity concentrations of natural radionuclides, while complementary analyses will evaluate material properties relevant to their incorporation into cement-based products and other construction components. Specific experimental measurements of radon exhalation on NORM-containing building material will be performed, as this process represents a potentially significant exposure pathway for workers and members of the public.

The project will develop dose assessment methodologies for realistic occupational and public exposure scenarios, including those not fully addressed by existing guidance documents. In addition, integrated risk assessment methodologies will be explored to account for the coexistence of radiological hazards and conventional contaminants, such as heavy metals, frequently encountered in NORM residues.

A dedicated activity will investigate radon exposure in selected NORM-related industrial sectors through long-term workplace monitoring campaigns. The collected data will contribute to improving the understanding of radon-related occupational exposure and support compliance with current regulatory requirements.

Finally, the project will explore the integration of radiological indicators within Life Cycle Assessment (LCA) methodologies, enabling radiation protection considerations to be suitably incorporated into sustainability evaluation indicators for construction materials featuring, in their composition, recycled NORM residues.

The expected outcomes will include improved exposure assessment tools, harmonized data collection methodologies, enhanced support for regulatory decision-making, and scientifically based criteria for the safe implementation of circular economy pathways involving NORM residues.

PTU-21 AI-ENHANCED RAPID ASSESSMENT OF URBAN ATMOSPHERIC CONTAMINATION FOR RADIOLOGICAL EMERGENCY PREPAREDNESS AND RESPONSE

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Rapid and reliable assessment of atmospheric contamination in densely built environments is essential for effective radiological Emergency Preparedness, Response and Recovery (EPRR). In urban areas, the complexity of airflow and pollutant dispersion around buildings makes real-time analysis particularly challenging, while conventional source-term estimation and dispersion-modelling approaches often rely on repeated execution of computationally demanding numerical models. This limits their applicability in time-critical emergency situations.

This work presents an AI-enhanced framework for urban atmospheric dispersion modelling and source localisation, designed to support rapid radiological impact assessment and early protective action planning. Building on previous developments in Artificial Neural Networks (ANNs) and Temporal Convolutional Networks (TCNs), the proposed methodology uses data-driven learning to capture the temporal evolution and spatial characteristics of dispersion processes in urban environments. The framework is trained on urban-scale dispersion scenarios that incorporate release characteristics, meteorological conditions, sensor observations, and urban geometry, enabling rapid reconstruction of spatiotemporal contamination patterns from sparse measurements.

The use of TCNs enables effective modelling of temporal dependencies in evolving contamination fields and improves prediction stability during the early stages of an incident, when measurement data may still be limited. Model performance is assessed not only using standard regression metrics but also with application-oriented indicators relevant to EPRR, such as sensor-level reconstruction accuracy, contamination plume localisation, and time-dependent concentration bias.

The results indicate that TCN-based surrogate models can provide near-real-time estimates of evolving contamination fields and potentially affected areas, thereby supporting operational decision-making on sheltering, evacuation, monitoring deployment, and resource allocation. The proposed framework contributes to the ongoing development of advanced tools for radiological emergency management and represents a step towards integrating AI-based surrogate models into future EPRR platforms for complex urban environments.

PTU-22 ASSESSING THE VARIATION OF DNA DAMAGE RESPONSE OF INDIVIDUAL HUMAN CELLS EXPOSED TO PHOTON RADIATION

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Background: Individual cells of the same type and in the same position in the cell cycle show stochastic cell-to-cell variability (noise) in gene and protein expression, even under the same environmental conditions. The aim of the study was to test if radiation-induced DNA damage response of cells shows noise, on top of the randomly distributed DNA damage.

Methods: This was tested by comparing the frequency of DNA repair foci in sister nuclei of binucleated cells (intra BNC variability) and nuclei of two BNC (inter BNC variability). Inter cell variability was also measured for mononucleated cells (MNC). Binucleation was induced in U2OS cells by cytochalasin B. Cells were exposed to 2 Gy of photons, 53BP1 and γH2AX foci were visualised and counted in nuclei of binucleated and mononucleated cells 30, 60, 120 and 180 min post exposure. Coefficients of variation were calculated as indicators of variability.

Results: For both types of foci, the frequencies observed in sister nuclei within BNC were positively correlated and exhibited significantly lower variation compared to the variability measured between single nuclei from randomly paired BNC. The contribution of noise to the total variability was 28 % for 53BP1 foci and 50 % for γH2AX foci.

Conclusions: The results demonstrate that the variability of focus frequency observed in nuclei of BNC results from a combination of noise and random damage variability.

PTU-23 RADIATION EMERGENCY MEDICAL PREPAREDNESS AND RESPONSE REGULATION OF NUCLEAR LICENSEES IN SOUTH KOREA: A REVIEW OF THE INTEGRATED REGULATORY FRAMEWORK

Author: Sejong Lee | *Co-Author:* Minsu Cho, Seongjae Jang | *Speaker:* Sejong Lee

Objectives / Background: The Fukushima nuclear accident highlighted the importance of rationalizing and strengthening the national emergency preparedness systems, particularly medical response capacity. As a country with a substantial nuclear facility, including nuclear power plants, research reactors, radioactive waste facilities, and medical or industrial institutions using radioactive materials, South Korea has continuously strengthened its national radiological emergency preparedness system since the Fukushima accident. In particular, Radiation Emergency Medical Preparedness and Response (REMPR) has been developed as a critical component of this system to protect workers, emergency responders, patients, and the public from radiation exposure or contamination. This study aims to review South Korea's integrated REMPR regulatory framework for nuclear licensees and to analyze its operational characteristics, key functions, and remaining challenges.

Methods: This study presents an integrated review of regulatory activities entrusted by the Nuclear Safety and Security Commission (NSSC) to the Korea Institute of Radiological and Medical Sciences (KIRAMS). The review focuses on three major regulatory functions: technical review of Radiation Emergency Plans (REPs), periodic inspections of emergency medical preparedness, and evaluations of radiological emergency exercises of nuclear licensees. These activities are conducted in accordance with legal and regulatory requirements and implemented through a structured and complementary approach. REP reviews verify whether nuclear licensees have adequate emergency medical organizations, facilities, equipment, procedures, and training programs. Periodic inspections verify regulatory compliance and confirm whether facilities, medical equipment, supplies, radioprotective agents, and personnel capabilities are properly maintained. Emergency exercise evaluations assess scenario-based response capabilities, including casualty triage, contamination measurement, decontamination, emergency treatment, transport, and coordination with external medical institutions.

Results: From 2016 to 2025, REMPR regulatory activities were implemented consistently, with approximately 10 REP reviews, 23 inspections, and 18 exercise evaluations conducted annually. These activities collectively support continuous monitoring and improvement of licensees' preparedness and response capabilities. The use of qualified inspectors, who are required to complete specialized training and periodic refresher education, also contributed to technical

consistency and regulatory reliability. Nevertheless, recurring challenges were identified, including frequent staff rotations and gaps between documented procedures and actual field practices. These findings indicate that effective REMPR requires not only legal and institutional oversight but also sustained training, standardized procedures, regular review of operational workflows, and expert consultation to reduce gaps between planned procedures and field implementation.

Conclusions / Implications: South Korea's REMPR regulatory system provides an established and systematic framework for maintaining and strengthening emergency medical preparedness of nuclear licensees. By integrating REP reviews, periodic inspections, and emergency exercise evaluations, the system supports continuous enhancement of licensees' preparedness and verifies practical response performance beyond document compliance. In addition to strengthening emergency medical response capabilities for nuclear and radiological accidents, the REMPR safety regulation system is expected to contribute to broader industrial safety of nuclear licensees, including preparedness for severe industrial accidents and other major emergencies. This integrated regulatory approach may provide useful insights for countries seeking to strengthen the medical component of nuclear and radiological emergency preparedness.

PTU-24 A SPACE RADIATION HEALTH RISK ASSESSMENT MODEL BASED ON CHINESE POPULATION BIOLOGICAL PARAMETERS AND ITS APPLICATION IN LUNAR MISSIONS

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As China's crewed lunar exploration program advances toward the goal of landing astronauts on the Moon by 2030, the lack of global magnetic field and dense atmosphere on the lunar surface exposes astronauts to a complex radiation field dominated by galactic cosmic rays, solar particle events, and secondary particles generated from interactions between primary cosmic rays and lunar regolith. This radiation environment not only affects in-orbit safety but also poses long-term health risks, particularly radiation-induced cancer. The NASA NSCR-2012 model, currently the most widely used framework for space radiation cancer risk assessment, is built primarily on American epidemiological data and life tables. However, the cancer spectrum of Chinese population differs significantly from that of American incidence and mortality rates for stomach, liver, and esophageal cancers are substantially higher in China, while those for prostate and colorectal cancers are considerably lower. Direct application of American-based models therefore cannot accurately reflect the true risks for Chinese astronauts. This study develops a localized risk model by incorporating Chinese male life tables from the UN World Population Prospects 2024 and cancer incidence and mortality data from the 2021 Annual Report of China Cancer Registry, which covers 947 registries and approximately 634 million people. The original 5-year age group data are refined to single-year data using piecewise cubic Hermite interpolation to enable continuous risk integration. The model covers eleven major cancer types and outputs both risk of exposure-induced cancer (REIC) and risk of exposure-induced death (REID), with a minimum latency of 5 years for solid cancers and 2 years for leukemia, and a dose and dose-rate effectiveness factor of 1.5. Dose calculations are performed with the Geant4 Monte Carlo toolkit using the QGSP_INCLXX_HP physics list. The lunar regolith model is based on Chang'e-5 components, and a multi-layer composite shielding configuration is adopted, consisting of an outer layer of 20 g/cm² sintered regolith, a middle layer of 1 g/cm² aluminum, and an inner layer of boron-containing polyethylene. The ICRP 145 adult male mesh-type reference computational phantom is placed inside the base to calculate organ dose equivalents, which are then input into the localized risk model for REIC and REID estimation across exposure ages from 20 to 65 years. Results show that under the composite shielding, the whole-body effective dose rate is 0.50 mSv/d, with H, Fe, He, O, and Si as the main contributors. For a 30-day lunar surface mission, total REIC decreases from 0.1621% at age 20 to 0.0422% at age 65, while total REID decreases from 0.1060% to 0.0386%. The dominant cancer types

are lung, stomach, liver, and esophagus, with risks significantly higher than those for the American population, reflecting modulation by the Chinese baseline cancer spectrum. Under a severe SPE scenario (August 1972), REID at age 20 reaches 2.69%, approaching the NASA 3% career limit and highlighting the necessity of extreme event protection. This study achieves the translation from organ dose to Chinese-population-specific lifetime risk, providing quantitative risk-based constraints for shielding design, mission planning, and astronaut health management for China's future lunar missions.

PTU-25 ESTIMATING SPATIALLY RESOLVED RADIATION FIELDS USING NEURAL NETWORKS

Author: Felix Lehner | Co-Author: Marcus Magnor, Oliver Hupe, Pasquale Lombardo, Susanna Castillo | Speaker: Felix Lehner

We present neural networks to estimate the spatial distribution of scattered radiation fields in real-time for radiation protection dosimetry in medical radiation fields, such as those found in Interventional Radiology and Cardiology.

Additionally, we present three different synthetically generated datasets with increasing complexity for their training, using a Monte-Carlo Simulation application based on Geant4. On those datasets, we evaluate convolutional and fully connected architectures of neural networks to demonstrate, which design decisions work well for reconstructing the fluence and spectra distributions over the spatial domain of such radiation fields.

PTU-27 DOES EXPOSURE TO WEATHERED COAL ASH WITH AN ENHANCED CONTENT OF URANIUM-SERIES RADIONUCLIDES AFFECT FLORA AND FAUNA - FOCUSING ON ELEMENT TRANSFER, DOSAGE AND TOXICITY ASSESSMENT

Author: Sandra Radić Brkanac, Božena Skoko, Ivana Coha, Ivica Prlic | Co-Author: Željka Kuharić, Davorka Hackenberger Kutuzović, Marko Strok, Leja Rovani | Speaker: Ivica Prlic

Coal ash deposited in open landfills is a potential source of environmental pollutants due to the contained toxic element content. The weathered coal ash used in this study additionally contains enhanced activity concentrations of ²³⁸U series radionuclides of which ²²⁶Ra is of a special interest if the site is to be remediated. The study applies an integrated GIS and geostatistical framework to analyze the spatial distribution of multiple contaminants. Maps highlighting polluted zones are included, along with maps indicating areas with higher cumulative concentrations of contaminants. This paper also provides an important research overview of potential issues related to the detected contaminants, as well as proposals for remediation methods before repurposing the site using retrospective data about sources of residues and contaminants. This study aimed to determine the physiological effects of enhanced ionizing radiation and toxic elements on five plant species (smilo grass, sticky fleabane, blackberry, mastic and pine tree) and a study on earthworms who are one of the most exposed biota members as they live in close contact with coal ash waste throughout their entire life. Within performed set of studies we wanted to assess the uptake of Po-210 and Pb-210 by earthworm *Eisenia fetida* transplanted on the coal ash and slag sampled from the former chemical factory in Kaštela Bay (Croatia). Inhabiting the coal ash disposal site. Among the potentially toxic measured elements, contents of Sb, As and especially V significantly exceeded their respective levels at the control site, as well as the content of ²³⁸U and its progenies. Significant changes in photosynthetic pigments were recorded following chronic exposure to the plants growing on the coal ash site. GST activity was the strongest, indicating an important role of that enzyme in the adaptation to coal ash pollutants. The results of this set of studies suggest that the modulation of the studied biochemical parameters in plants growing on coal ash is primarily

species-dependent. Po-210 activity concentrations found in earthworms cultivated on coal ash and slag are 2-3 times higher compared to control group. Similar observation was found for Pb-210 only for samples without coelomic fluid, where samples with coelomic fluid did not show any significant difference between those cultivated on coal ash and slag and control ones. This indicates different distribution of Pb-210 and Po-210 between coelomic fluid and other earthworm's body compartments. All in all the site where the research was performed deserves to be kept for further long term research investigations simply because it has given us a valuable research data about the way nature recovers itself even on the most unusual or/and hostile ground like the pure coal ash up to 12 m deep layer is. Situation after a huge fire that devastated a part of natural remediated plants on coal ash will be presented. The Rn-222 issue is currently investigated in order to gather the data needed to describe the new governmental remediation plans for that site. The effort is to proclaim this site (or part of it) as Observatory site, regulated and protected.

PTU-28 WHAT DOES GERMANY THINK ABOUT RADIATION AND RADIOLOGICAL EMERGENCIES? RESULTS FROM A SURVEY IN 2026

Author: Christiane Pölzl-Viol, Matthias Klaes | Co-Author: Kelly Jones | Speaker: Matthias Klaes

Objectives: An important basis for informing the public about radiation, and for developing radiation protection as well as radiological emergency preparedness strategies, is an understanding of how society deals with radiation-related issues and potential radiological emergencies.

The aim of the project “What does Germany think about radiation” was to gain insights into the public's knowledge of radiation and radiation protection, their opinions on radiation risks and radiological emergencies, the nature of their concerns or reservations regarding radiation, their protective behaviour, and the information they would like to receive from the authorities. The survey continues a series of surveys that were previously carried out in 2019, 2022 and 2024 as nationally representative surveys across Germany.

Current topics covered radiological emergency preparedness and civil protection, as well as more in-depth aspects relating to knowledge of and handling of radiation.

Methods: The study comprised both a qualitative and a quantitative component. The qualitative interviews aimed to uncover underlying attitudes, motivations and thought processes. Two focus groups and 40 individual interviews were conducted in October 2025. Building on this and organised into similar thematic blocks, a quantitative survey was carried out from January to March 2026, providing a representative sample of the German-speaking resident population aged 16 and over. The data are based on a telephone survey (CATI = Computer-Assisted Telephone Interview) of 2,032 people.

Results: The talk will provide an overview of how radiation and radioactivity are perceived by the general public. It will especially focus on findings relating to the key topic of radiological emergency preparedness and civil defence. Particularly, results will be presented with regard to concerns of the general public about potential radiological emergencies at nuclear power stations and due to nuclear detonations; Information will be given on how well prepared people feel for a radiological emergency, whether they would know what to do in the event of one, and how great the need is to be informed about a potential emergency as a preventative measure.

Conclusions / Implications: The results highlight where and in what ways radiation protection strategies need to be refined in the context of radiological emergency preparedness or in communication with the public.

Although the findings relate to the German population, they are also of interest in a European context. Among other things, there is the possibility of conducting similar surveys in other countries as well and comparing the results.

PTU-29 EXPERIMENTAL CALIBRATION AND MONTE CARLO PERFORMANCE QUALIFICATION OF A MOBILE NaI(TL) ANTHROPOGAMMAMETRY SYSTEM FOR THYROID AND LUNG MONITORING

Author: Bouchra Lebied | Co-Author: | Speaker: Bouchra Lebied

Internal contamination monitoring is an essential component of radiation protection programmes for occupationally exposed workers during routine activities and radiological emergency situations. Reliable in vivo measurement systems are therefore required to ensure the rapid detection and quantification of incorporated radionuclides. To strengthen its internal dosimetry capabilities, the Internal Dosimetry Laboratory of the National Center for Nuclear Energy, Science and Technology (CNESTEN), Morocco, has recently commissioned a mobile anthropogammametry system equipped with a 3" × 3" NaI(Tl) scintillation detector. Before its routine implementation, the system requires comprehensive calibration and performance qualification.

The aim of this work was to calibrate, qualify and optimize the performance of the system for thyroid and lung monitoring through combined experimental measurements and Monte Carlo simulations. Energy calibration was performed using reference gamma emitting radionuclides (^{241}Am , ^{137}Cs and ^{60}Co), covering photon energies from 59.5 to 1332.5 keV. Efficiency calibration and detector response characterization were carried out using anthropomorphic BOMAB phantoms equipped with geometry-specific ^{152}Eu sources for thyroid and lung measurements, providing multiple gamma emissions over an energy range from 121 to 1408 keV. Monte Carlo simulations were performed using the GAMOS to reproduce the detector response, evaluate the influence of detector-phantom distance on photopeak efficiency and energy resolution, and optimize the measurement configuration. The simulated detector response was validated against the experimental measurements. The system performance was assessed in terms of energy calibration, photopeak efficiency, energy resolution and Minimum Detectable Activity (MDA).

Experimental measurements confirmed an energy resolution below 7.5% at the 662 keV photopeak of ^{137}Cs , in agreement with the manufacturer's specifications, and this performance was successfully reproduced by the GAMOS Monte Carlo model. Both experimental and simulated results showed a progressive decrease in photopeak efficiency with increasing detector-phantom distance. Although simulated efficiencies were consistently slightly higher than the experimental values, good overall agreement was observed, demonstrating the validity of the numerical model for predicting detector performance under different measurement conditions.

The combined experimental and Monte Carlo methodology provides a reliable framework for the calibration, qualification and optimization of mobile anthropogammametry systems. The results demonstrate the suitability of the system for reliable thyroid and lung monitoring, thereby contributing to strengthening internal dosimetry capabilities and enhancing radiological emergency preparedness.

WEDNESDAY, 7 OCTOBER

S1.2 Environmental Preparedness & Recovery

S1.2-1 FROM PRINCIPLES TO PRACTICE: HOW IS ENVIRONMENTAL RADIOLOGICAL PROTECTION REALLY APPLIED WORLDWIDE?

Author: Mike Webley | Co-Author: | Speaker: Mike Webley

Objectives / Background: Radiological protection of the environment (RPE) is an established component of the system of radiological protection (SRP), notably through the International Commission on Radiological Protection (ICRP) framework for non-human biota, including Reference Animals and Plants (RAPs) and Derived Consideration Reference Levels (DCRLs). However, the extent to which these recommendations are implemented in practice varies significantly across national, regulatory, and operational situations. In the context of the ongoing revision of the ICRP system and increasing emphasis on sustainability and ecosystem protection, the OECD Nuclear Energy Agency (NEA), through its Expert Group on Radiological Protection of the Environment (EGRPE), launched a global survey to assess the application, interpretation, and perception of ICRP RPE recommendations across regulatory, scientific, and operational domains.

Methods: A structured international survey targeting regulators, operators, technical support organisations, and researchers was conducted between 27 March and 8 May 2026. The survey captured anonymised responses on regulatory frameworks, practical implementation of ICRP RPE recommendations, use of RAPs and DCRLs, and perceived benefits and challenges. Preliminary analysis, undertaken ahead of full reporting, focuses on identifying emerging trends, common practices, and key barriers based on aggregated responses from a diverse set of countries and organisations.

Results: The 77 survey responses reflected a broad geographical spread. Preliminary findings indicate that most participating countries recognise and reference RPE principles within regulatory or guidance frameworks; however, explicit implementation of RAPs and DCRLs varies widely. In many cases, these concepts are applied in a context-dependent or conceptual manner, with more frequent use in research and environmental impact assessments than in formal regulatory decision-making. Widely used supporting tools include ERICA, BiotaDC, and RESRAD-BIOTA.

Key benefits identified include improved environmental protection, enhanced scientific transparency, and provision of a common basis for international collaboration and communication. However, significant challenges persist, notably:

- *limited awareness and practical understanding,*
- *lack of clear implementation guidance,*
- *insufficient region-specific ecological and transfer data,*
- *methodological complexity and resource constraints, and*
- *absence of explicit regulatory requirements in some jurisdictions.*

Despite these challenges, preliminary evidence suggests that where RPE frameworks are applied, dose rates to non-human biota are generally well below DCRL bands, supporting the conclusion that radiological impacts in planned exposure situations are typically low.

Conclusions / Implications: The survey highlights a transition from primarily human-centred radiological protection toward more holistic environmental approaches, while confirming that practical implementation of ICRP RPE recommendations remains uneven. Key priorities emerging from the analysis include the need for clearer guidance, simplified and user-friendly tools, enhanced training and capacity building, and improved integration with broader environmental and sustainability frameworks, including biodiversity and climate policy.

The resultant report will inform international discussions, support the ongoing revision of the SRP, and guide future development of practical, harmonised approaches to protecting the environment from ionising radiation.

S1.2-2 40 YEARS OF POST-CHORNOBYL RETROSPECTIVE DOSIMETRY: ACCOMPLISHMENTS AND IMPLICATIONS FOR FUTURE EVENTS

Author: Vadim Chumak | Co-Author: | Speaker: Vadim Chumak

The accident at the Chornobyl NPP is no doubt the largest multifaceted crisis in modern history engaging various aspects of human living - humanitarian, economical and radiological. Enormous scale of the emergency had caught authorities by surprise, leading, in particular, to the failure of pre-established preparedness plans and dosimetric monitoring facilities in place, which resulted in a lack of individual monitoring. At the same time, complex time evolution and extreme spatial heterogeneity of contamination patterns and dose rate fields, variability of individual behavior histories caused extremely broad variety of doses received by the members of public and responders (clean-up workers - liquidators). This made application of any average doses senseless calling thus for development and application of new methodologies for evaluation of individual rather than population- or group-averaged doses.

In response to this demand, since 1986, NRCRM in cooperation with international partners conducted vast amount of research and development aimed at retrospective reconstruction of individual doses within large groups of exposed populations.

Application areas included reconstruction of individual doses for about 35,000 evacuees from Pripyat and other settlements of the 30-km zone, TL dosimetry with quartz in fired bricks to validate cumulative doses in the villages downwind Chornobyl, development and application of EPR dosimetry with tooth enamel as a 'gold standard' for validation of other dose reconstruction techniques applied to the cohort of clean-up workers, estimation of beta+photon doses to lens for clean-up workers. The results of dose reconstruction were applied to dosimetric support of large-scale post-Chornobyl epidemiological studies, public assurance and ruling out suspected overexposures among members of public. One of the lessons from this effort is that given sufficient time and resources, doses could be evaluated for virtually any member of the exposed cohort. At the same time, timely application of some simple measures could ease the task of individual dose estimation tremendously. The presentation will provide an overview and summary of 40 years of experience in the reconstruction of individual doses and outline the lessons and possible updates, which could be derived from this invaluable experience.

S1.2-3 BEST PRACTICES FOR ESTABLISHING A CITIZEN SCIENCE NETWORK FOR IONIZING RADIATION MONITORING

Author: Anna Mrozik | Co-Author: Renata Kierepko, Mateusz Krzysiek, Paweł Olko, Agnieszka Szumska, Jan Helebrant, Marie Davidková | Speaker: Anna Mrozik

The development of citizen-based ionizing radiation monitoring networks has become increasingly feasible owing to the widespread availability of affordable radiation detectors and digital platforms supporting citizen-generated data collection. Such networks, including the CITISTRA project, have the potential to complement official radiological monitoring systems by enhancing spatial coverage, increasing transparency, and fostering public engagement in radiation protection and scientific research. CITISTRA serves as an example of a structured citizen science initiative designed to integrate distributed radiation measurements into a coherent monitoring framework.

In addition, the project investigates methodologies for standardizing citizen-generated data and ensuring its compatibility with professional radiological monitoring infrastructures.

This presentation discusses both the strengths and limitations of citizen-based ionizing radiation monitoring networks, with particular attention to technical aspects, data reliability, automation, and the relationship between network density and population distribution.

The major strengths of such networks include their significant development potential, low deployment and maintenance costs, rapid geographical expansion, and the ability to enhance public trust through open access to environmental radiation data. Citizen-based networks may also improve resilience during radiological emergencies by increasing situational awareness in areas where official monitoring infrastructure is limited or unavailable. Furthermore, these initiatives promote public education and foster interdisciplinary collaboration among scientists, emergency response services, public authorities, and local communities.

However, several challenges remain. Data quality may vary substantially among detectors, potentially leading to inconsistencies in measurement results. Uneven geographical distribution of detectors can create monitoring gaps, particularly in sparsely populated or geographically inaccessible regions. Maintaining long-term volunteer engagement represents another significant challenge. In addition, cybersecurity, privacy concerns, and the risk of misinformation must be carefully addressed, especially when radiation monitoring data are made publicly available. Artificial intelligence (AI) can further enhance citizen-based radiation monitoring networks by enabling automated quality control, anomaly detection, and rapid analysis of large datasets. AI tools may help identify malfunctioning detectors, distinguish genuine radiological events from false alarms, and optimize network operation.

Despite these challenges, citizen-based ionizing radiation monitoring networks represent a promising tool for strengthening radiological preparedness, enhancing public engagement, and supporting a more comprehensive, transparent, and resilient monitoring framework.

Acknowledgment

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S1.2–4 IMPROVEMENTS IN ATMOSPHERIC DISPERSION MODELLING AND PROTECTIVE ACTION STRATEGIES IN CASE OF NUCLEAR DETONATIONS – OVERVIEW OF THE PREDICT PROJECT

Author: Clemens Woda | Co-Author: Agnieszka Hac-Heimburg, Anders Axelsson, Anna Maria Blixt Buhr, Astrid Kloosterman, Christiane Pölzl-Viol, Deborah Oughton, Elias Pagh Senstius, Erik Berge, Florian Mertes, Gemma Halloran, Heiko Klein, Helen Miller, Helen Webster, Jan Pehrsson, Justin Brown, Kasper Anderson, Katie Brown, Kelly Jones, Lindis Skipperud, Lois Huggett, Mariana Rodrigues, Michiel De Bode, Ole Christian Lind, Oyvind Selnaes, Peder Kock, Peter Bedwell, Robert Ryan, Sarah Millington, Thomas Hamburger, Wolfgang Raskob, Yevgeniya Tomkiv | Speaker: Clemens Woda

Objective: Decision support systems currently used in Europe, such as JRODOS, ARGOS and other national systems were primarily developed in the 1990s for nuclear power plant accident scenarios and are not a-priori suited to assess radiological consequences from nuclear detonation fallout. The PREDICT project, funded under the first Open Call of the PIANOFORTE EJP and involving twelve

partners from seven European countries, aims to enhance the operational capabilities of these models to support informed decision-making for protection of the population.

Methods: The project is organised into six work packages (WPs). WP1-WP3 focus on characterisation of airborne radiocontaminants (source term description), modelling improvements, and model comparison. Their results feed into WP4, which addresses protective action strategies. WP5 supports education, training, and dissemination, while WP6 covers project management.

Results: WP1 established the nuclide vector and explored alternative representations of cloud geometry and activity distribution. WP2 evaluated recommendations for improving atmospheric dispersion modelling, external dose and dose-rate calculations and food-chain transfer models. WP3 is in the final stage of evaluating source term parameters through comparison with historical test data and has identified sensitivities to key model parameters and meteorological conditions. In WP4, recommendations for protective actions and communication strategies are being developed based on updated simulations and stakeholder input. WP5 has coordinated dissemination activities, developed university-level training material at NMBU, and is preparing exercise material for RODOS and ARGOS user group exercises planned for 2027. This presentation will provide an overview of all results, with emphasis on WP1, WP2, and WP5, as separate contributions with more details will be submitted for WP3 and WP4.

Conclusions / Implications: The PREDICT project has contributed to optimising source term input parameters, improving understanding of variability in model predictions and identifying priorities for future model development. It also provides a coordinated European perspective on protective action strategies and communication approaches, supporting more effective preparedness and response to nuclear detonation scenarios.

S1.2-5 SOURCE-TERM SCREENING FOR A COPENHAGEN ATOMICS-LIKE MOLTEN SALT REACTOR

Author: Josef Hisanawi | *Co-Author:* Baltasar Hemmerle | *Speaker:* Josef Hisanawi

In the onion core such as the one developed by Copenhagen Atomics, radioactive inventory is distributed across fuel salt, blanket salt, off-gas system, and moderator regions, which can add layer of complexity. Additionally, this reactor type is novel and design data is unavailable. We develop a transparent screening workflow for a Copenhagen Atomics-like molten salt reactor by fitting known data to physical constraints.

Only published benchmark data was used: material definitions, total volumes, depletion settings, reference criticality, and aggregate inventory. As the geometry description is not public, a reduced concentric "Onion Core" was reconstructed via volume constraints and a parameter sweep over inner moderator radius and cladding thickness. Neutronics and depletion were run in OpenMC and Serpent, with candidate geometries compared against reference k_{eff} , mass, and activity.

The best matching candidate used a 46 cm inner moderator radius and 3.25 mm cladding. OpenMC and Serpent agreed closely, so the remaining uncertainty is dominated by model rather than code-to-code differences. Radionuclides were grouped by molten-salt release behaviour (gaseous, soluble, semi-soluble, insoluble, actinide), and two accident cases (minor drip/spray leakage and major rupture) were evaluated with a release-fraction sensitivity study.

This is not a licensing calculation but a reproducible screening method for early radiation protection assessment and emergency preparedness under incomplete design information. The model deviates from the benchmark by an RMSE of 27%.

S1.2-6 CHALLENGING RNA SEQ DATA ANALYSIS UNDER LOW SIGNAL-TO-NOISE CONDITIONS: APPLICATION TO RADIATION AND CHEMICAL CO-EXPOSURE

Author: Malek Baroudi, Habib Zouali, Chrystelle Ibanez, Léo Mace, Stéphane Grison, Mohamedamine Benadjaoud, Imène Garali | Co-Author: | Speaker: Imène Garali

Introduction: RNA-sequencing (RNA-seq) is the gold-standard technology for large-scale transcriptomic analyses, enabling comprehensive and unbiased exploration of gene expression. However, the field of low-dose exposure research, encompassing both radiological and chemical stressors, still lacks dedicated analytical frameworks capable of reliably detecting weak biological effects that are often masked by multifactorial variability. Indeed, low doses typically elicit subtle gene expression changes, making their detection and interpretation particularly challenging. Under such conditions, gene expression changes are often too weak to be detected by conventional bioinformatics pipelines mainly based on stringent signal thresholds and empirically selected hyperparameters choices. Therefore, it is crucial to assess new analytical biostatistical and bioinformatic methodologies, specifically designed for these low dose and weak-signal conditions, to obtain significant and reliable results.

*Methods: The data analyzed in this study were derived from an in vivo experiment conducted in adult male Sprague-Dawley rat. Subjects were exposed via inhalation of a particulate aerosol at different doses (low and high) of an environmental chemical pollutant to assess its biological effects on the brain. A dataset comprising 24 subjects was generated from brain biopsy samples collected 24 hours after tungsten exposure. The subjects were divided into three groups of eight animals each (control, low-dose, and high-dose), and gene expression was assessed using both RNA-seq and RT-qPCR. First, we performed a comparative analysis of 90 bioinformatics pipeline rankings generated from our dataset against those reported in the study by Corchete *et al.* [1]. To ensure comparability and robustness, identical evaluation criteria were applied in both studies.*

*Results: Using two complementary approaches, concordance with RT-qPCR data and classification performance, we identified optimal bioinformatics pipeline configurations that ensured both analytical robustness and biological relevance. Our results reveal a significant impact of pipeline selection on RNA-seq data interpretation, particularly in contexts characterized by weak transcriptional signals, such as low-dose exposure to tungsten aerosol particles. A key observation is the near-complete opposition of pipeline in ranking between the low-dose exposure effect context investigated here and the context examined by Corchete *et al.* This striking contrast underscores the impact of dataset-specific factors highlighting the need to adapt pipeline evaluations to the context of the study. These findings also emphasize the unique challenges associated with detecting low-dose-induced effects in transcriptomic data, which differ substantially from those encountered in other research areas characterized by stronger biological signals, such as oncology.*

Conclusions: High-quality transcriptomic analyses require the selection of bioinformatics pipelines that are specifically adapted to the intrinsic characteristics of each dataset, rather than relying on generic reference workflows. In this study, we address this challenge by proposing a novel method for context-specific ranking and evaluation of pipeline performance. This method is expected to be highly valuable for multi-stressor research, improving risk assessment in toxicology and radiation protection, particularly within exposome-based approaches.

[1] Corchete LA, Rojas EA, Alonso-López D, De Las Rivas J, Gutiérrez NC, Burguillo FJ. Systematic comparison and assessment of RNA-seq procedures for gene expression quantitative analysis. Sci Rep. 2020 Nov 12;10(1):19737. doi: 10.1038/s41598-020-76881-x. PMID: 33184454; PMCID: PMC7665074.

S1.2-7 LIFE-TIME ATTRIBUTABLE RISK OF CANCER COMPARED TO COLLECTIVE DOSE DETRIMENT IN SWEDEN AFTER THE CHERNOBYL NUCLEAR POWER PLANT ACCIDENT

Author: Christopher Rääf, Katja Gabrysch, Martin Tondel, Mats Isaksson | Co-Author: | Speaker: Mats Isaksson

Objectives: Life-time attributable risk (LAR) of cancer predicts the individual risk and can be translated into attributable number of incident cases (AC). AC was compared with the excess number of incident cancer cases based on the collective dose during the 50 years following the fallout in Sweden after the Chernobyl Nuclear Power Plant accident.

Methods: A dose calculation program included external dose from ^{134}Cs and ^{137}Cs , and internal dose from ^{131}I , ^{134}Cs and ^{137}Cs . Annual sex-specific population data in 1-year classes by municipality ($n=290$), counties ($n=21$) and future population projections was retrieved as open-source data from Statistics Sweden from 1986 to 2035. Estimated organ absorbed doses (mGy) was used to calculate the collective effective dose (manSv) as defined by the International Commission on Radiological Protection. Risk coefficients for cancer provided by the United States Environmental Protection Agency was used to calculate LAR and AC.

Results: The municipality with the highest LAR was Härnösand municipality in Västernorrland county with 0.70 per thousand for males and 0.82 per thousand for females. AC in Sweden was estimated to 377 male and 448 female extra cancer cases over 50 years post-Chernobyl. The collective dose was calculated to 6,028 manSv whereas 2,148 manSv (36%) was due to internal exposure. Including skin cancer, the number of extra cases could be estimated to 665 from external and 368 from internal exposure. After excluding skin cancer, numbers were reduced to 277 from external and 154 from internal exposure in Sweden. Västernorrland county with only 3% of the Swedish population in 1986 got in total 18% of the collective dose.

Conclusions: LAR can be used in risk communication and collective dose for informed policy decisions. Our dose calculation manual and program code are freely available to be adopted to different fallout scenarios.

S2.2 AI in Medical Radiation Protection

S2.2-1 VERIFIED - REAL TIME 2D DOSIMETRY SYSTEM IN A HIGHLY REALISTIC ANTHROPOMORPHIC THORAX PHANTOM

Author: Luana Nascimento | Co-Author: Biwu Ma, Dirk Verellen, Gabriel Paiva Fonseca, Jo Goossens, Tim Stassen, Hrvoje Hrsak, Sanja Dolanski Babic, Steve Vanlanduit | Speaker: Luana Nascimento

Objectives: Adaptive radiotherapy (ART) has the potential to improve treatment accuracy by accounting for anatomical changes and respiratory motion during treatment. However, ensuring that the delivered dose remains consistent with the planned dose is critical for radiation protection, patient safety, and treatment quality assurance. This study investigates the feasibility of integrating a real-time two-dimensional (2D) scintillation-based dosimetry system into a highly realistic anthropomorphic thorax phantom to enable continuous verification of dose delivery during adaptive volumetric modulated arc therapy (VMAT). The work was conducted within the VERIFIED project (PIANOFORTE2023-027), which aims to develop advanced verification methodologies for adaptive radiotherapy.

Methods: A flexible scintillating film coupled to a high-sensitivity CMOS scientific camera was embedded within a 3D-printed tissue-equivalent thorax phantom incorporating deformable lung structures and programmable respiratory motion. The optical dosimetry system was geometrically and dosimetrically calibrated using reference ionization chamber and film measurements. During VMAT deliveries on a clinical linear accelerator, time-resolved scintillation images were acquired at frame rates exceeding 200 fps. Deep learning-based image registration was applied to align measured dose distributions with treatment planning system (TPS) predictions. Real-time comparisons were performed using γ -index analysis (3%/2 mm), and system sensitivity to delivery deviations was evaluated through controlled perturbations of machine parameters.

Results: The dosimetry system demonstrated a linear dose response over the clinical dose range ($R^2 > 0.999$) and millisecond-scale temporal resolution. Geometric accuracy was maintained within ± 0.5 mm during simulated respiratory motion. Delivery deviations involving multileaf collimator positioning and gantry speed were detected with latencies below 50 ms. Agreement between measured and planned dose distributions yielded γ -index pass rates exceeding 96% under static conditions and 91% under dynamic breathing conditions. These results indicate reliable monitoring of clinically relevant treatment deviations in real time.

Conclusions: The integration of real-time scintillation dosimetry into an anthropomorphic breathing phantom provides a powerful framework for enhancing radiation protection and quality assurance in adaptive thoracic radiotherapy. By enabling rapid detection of delivery discrepancies, the system supports safer implementation of ART, helps minimize unintended dose delivery, and contributes to the development of future automated and AI-assisted treatment verification strategies.

S2.2-2 REAL-TIME HAND DEFORMATION MODELLING AND SYRINGE/VIAL SEGMENTATION FOR EXTREMITY DOSE MONITORING IN NUCLEAR MEDICINE

Author: Francisca Abbey Blay | Co-Author: Filip Vanhavere, Joanna Domienik-Andrzejewska, Mateusz Mirowski, Pasquale Lombardo | Speaker: Francisca Abbey Blay

Background: Nuclear medicine staff involved in the preparation and administration of radiopharmaceuticals are routinely exposed to high extremity doses that may exceed legal limits.

The dose limit established by ICRP of 500 mSv per year applies to the most exposed 1 cm² of skin. However, the exact location of maximum exposure is highly variable, and thus it cannot be assessed with standard dosimeters. Ring dosimeters – the current standard monitoring tool – provide only localized point dose measurements and are subject to highly variable angular and energy sensitivities, which can be sources of high uncertainties in dose estimates. The ORAMED project assessed that extremity doses should be corrected by factors ranging from 2 to 6 for TLD ring dosimeters and by factors up to 25 for wrist TLD dosimeters.

With this project, a computational dosimetry system aimed at lowering these uncertainties and to improving dose distributions assessments by means of Monte Carlo simulations, computer vision and Machine Learning is being developed. Using virtual reality (VR) technologies, the aim is also to provide real-time dose visualization which could be used for ALARA purposes such as training of nuclear medicine staff.

Methods: Within the SINFONIA project, a prototype of the computational dosimetry system was developed, with the objective of proving the feasibility of performing offline dose assessments based on recordings of syringe preparations. The first research task of this project is extending the existing hands and syringe modelling approach of SINFONIA, which was based on a look-up table including eight hand postures and syringe positions. In this presentation, a real-time joint-driven hand mesh deformation algorithm based on Mediapipe is implemented. A segmentation model is also trained using annotated images of the syringes and vials from nuclear medicine staff, working within a lamina airflow cabinet. This is to improve radiation source detection (syringe/vial) which will eventually affect the outcome of the simulations. The tracking/ detection data from the hands, syringes and vials are encoded and transmitted via a network protocol to enable real-time hands deformation which are used to create individualized Monte Carlo simulations.

Expected Results: It is expected that with real time hand deformation modelling and a robust segmentation model the input files to be generated for the simulations will be more representative of the real-life scenario, leading to an improved accuracy in the dose calculations.

Conclusion: Work is currently underway on the first research task, with full system validation of the other research tasks planned by 2029. The project presents a systematic approach to closing the gap between monitored and actual extremity doses in nuclear medicine, providing a more robust and individualised dosimetry method that improves accuracy while safeguarding staff.

S2.2–3 RADIATION FAIR AND OPEN SCIENCE: ADVANCING DATA SHARING FOR FUTURE RADIATION PROTECTION

Author: Omid Azimzadeh | Co-Author: | Speaker: Omid Azimzadeh

Effective data management, secure data storage, and open data sharing are increasingly recognised as essential components of modern radiation protection research. In line with European Open Science policies, FAIR (Findable, Accessible, Interoperable, and Reusable) data principles are promoted through Data Management Plans (DMPs), trusted repositories, standardised metadata, and open-access practices. Together, these approaches enhance transparency, reproducibility, collaboration, and the long-term sustainability of research outputs.

Progress in radiation protection research also depends on harmonised strategies for data collection, management, storage, and sharing across disciplines. This requires reliable repositories capable of supporting diverse datasets, including biological, epidemiological, environmental, and policy-related information. In this context, STOREDB, a dedicated radiation research repository hosted by the German Federal Office for Radiation Protection (BfS), has demonstrated its value and capacity in supporting large international collaborative projects.

Emerging approaches such as artificial intelligence, machine learning and advanced analytics, cloud and federated computing, digital modelling, and interoperable research infrastructures are opening new opportunities for automated data organisation, analysis, and communication. However, several challenges still need to be addressed before these emerging technologies can be effectively and responsibly integrated into radiation protection research, including the still limited culture of data sharing, data quality and harmonisation, compatibility of existing databases with AI applications, validation and regulatory acceptance, explainability and transparency, ethical and legal considerations, the growing interdisciplinary skills gap, robustness, and cost. Sustainable implementation will also require targeted training for researchers, policy-makers, funders, and the public to support the responsible and effective use of AI in radiation protection research. This talk provided an overview of current developments and highlighted key challenges in FAIR and open radiation science.

S2.2-4 A MACHINE LEARNING METHODOLOGY FOR DOSE ESTIMATES IN X-RAY BREAST IMAGING FOR ARBITRARY PATIENTS BASED ON A BREAST MODEL WITH PATIENT-SPECIFIC FIBROGLANDULAR DISTRIBUTION

Author: Antonio Sarno, Alice Barcella, Caterina Marcon, Francesca Saveria Maddaloni, Paolo Cardarelli, Gianfranco Paternò, Ivan Veronese, Cristina Lenardi | Co-Author: | Speaker: Antonio Sarno

Background: The recent report from the EFOMP/AAPM TG282 introduced a new universal model for dose estimates in mammography (DM) and digital breast tomosynthesis (DBT). Leveraged by the use of a heterogeneous breast model, reduced the bias of the former homogeneous model with respect to digital breast phantoms with patient-specific fibroglandular distribution, used as reference. Acknowledging the benefits in quality assurance programs, the new model is not meant to estimate dose to a specific patient. With the use of Machine Learning (ML) methodologies, this work investigates the possibility to predict dose to the breast model with patient-specific fibroglandular distribution, taken as reference in the mentioned report, for investigating any possibility of patient dose estimates.

Methods: 126 digital breast phantoms derived from high-resolution 3D breast images were used in Monte Carlo simulations for determining the ground truth data used for training/testing the ML methodology. Monte Carlo simulations were based on Geant4 simulation toolkit and computed the average glandular dose (AGD) normalized by the air kerma evaluated at defined position in the field of view (K_{ref}), known as $\Gamma_{specific}$. Geometry and simulated spectra reflected those of a clinician DM/DBT scanner. A Generalized Additive Models (GAMs) ML algorithm was used for $\Gamma_{specific}$ prediction. GAM is a generalized linear model that expresses the linear predictor as a sum of smooth functions of the covariates. A total of 96 GAM models were trained, incorporating smooth functions of one or more covariates selected from the three anatomical breast features considered: compressed breast thickness (CBT), breast volume (BV) and volume glandular fraction (VGF). The optimal GAM among the 96 candidates was selected by minimizing a cost function that took into account the standard deviation of the predicted-to-validation ratio values using 5-fold cross validation. The set of simulated $\Gamma_{specific}$ were divided into two 70:30 subsets for training:testing the algorithm.

Results: The GAM ML methodology permitted to predict $\Gamma_{specific}$ with a difference of 4% on average over the testing cohort. The distribution of the differences between predicted values and ground truth had 25th and 75th percentiles of -7% and +11% bias, respectively, then predicting 50% of the cases with a difference from the ground truth lower than 11%. The average total uncertainty of the prediction, that takes into account both accuracy and precision due to the model stability, ranged between 10.3% at 26 kV and 9.6% at 32 kV. Including also the tube voltage as prediction

feature did not noticeably influence the average total uncertainty (9.5%) and causes a spread of its distribution over the testing set.

Conclusions: This work demonstrated that GAM ML methodology is a valid tool for the prediction of patient AGD, with the average difference between predicted and ground truth Γ specific - used as reference benchmarking for today models - of 4% and average estimation uncertainty not exceeding 10.3%. In order to extensively implement such approach in the routine practice, it is necessary to train the ML algorithm for Monte Carlo results obtained for each of the specific available DM/DBT protocols.

S2.2-5 INTERACTIONS BETWEEN LEPTIN, SEX HORMONES, AND RADIATION ALTER GENE EXPRESSION RESPONSES IN BREAST CANCER CELLS

Author: Joanna Tobiasz | Co-Author: Léa Di Maria, Isabelle Testard, Zuzana Kocibalova, Prabodha Kumar Meher, Andrzej Wojcik, Serge Candéias, Joanna Polanska | Speaker: Joanna Tobiasz

Background: Radiation exposure around puberty results in the greatest risk of radiation-induced breast and endometrial cancers. Early menarche age was observed to increase those risks regardless of exposure age; however, the underlying mechanism remains unknown. As the age of the first menstrual period is influenced by obesity, interaction of obesity-related factors, sex hormones, and radiation may explain the inverse association between age at menarche and radiation-related female cancer risk. This study aims to statistically explore the effect of those factors.

Methods: RT-qPCR served to measure expression levels of genes related to inflammation, DNA damage response, and stress in breast cancer cell lines exposed to various treatments (leptin to imitate obesity and/or sex hormones) and radiation scenarios. To explore treatment effects in various radiation exposure scenarios, we adjusted the data to the experimental design with the limma linear model and compared transcriptional changes using the statistical pipeline consisting of two-way ANOVA with Estimated Marginal Means (EMM) analysis for post-hoc testing and appropriate effect size estimation.

Results: Although most of the gene expression variability was explained by various radiation exposures, the comprehensive post-hoc evaluation revealed treatment-related transcriptional changes within radiation scenarios. Among various radiation options, acute radiation at the end of treatment introduced the greatest changes in gene expression levels. For example, for cells unexposed to hormones or leptin, we observed large effect sizes relative to all other radiation scenarios for expression levels of 6 out of 11 investigated genes: *BIRC3*, *CDKN1A*, *CSF1*, *DDB2*, *FDXR*, and *SOD2*.

Conclusions: Radiation exposure was a dominant factor in transcriptional variability; however, statistically significant treatment-dependent differences were revealed within radiation scenarios. Preliminary findings indicate the potential importance of interaction between radiation exposure, obesity-related factors, and hormones, which requires further investigation in terms of radiation-induced carcinogenesis in females.

This study was conducted within the MIRAMARE project, which is part of the EURATOM European Partnership for Radiation Protection Research (PIANOFORTE, grant 101061037).

S2.2-6 HUMAN-CENTRED IMPLEMENTATION OF AI IN MEDICAL RADIOLOGY: WORKFORCE BARRIERS, TRUST AND GOVERNANCE IN ISRAELI RADIOLOGY

Author: Lior Moskovich | Co-Author: Mor Saban, Nitza Geri | Speaker: Lior Moskovich

Objectives/Background: Artificial intelligence (AI) is increasingly introduced into medical imaging to support triage, image interpretation, reporting, workflow prioritization and image quality and acquisition-related processes. However, in the context of medical radiation protection, safe AI implementation depends not only on technical performance, but also on human oversight, workflow integration, transparency, accountability, and the ability of clinical teams to understand and verify AI outputs. This study examined real-world AI adoption, barriers and governance needs among the radiological workforce in Israel, with the aim of identifying the conditions required for safe and sustainable AI integration in medical imaging practice.

Methods: A mixed-methods study was conducted among radiology professionals in Israel. The qualitative phase included 32 semi-structured interviews with radiologists, residents and imaging technologists from hospital, community and private settings. Interviews explored current AI use, perceived benefits, limitations, training, workflow integration, trust, and medico-legal concerns and were analyzed using inductive thematic analysis. Findings from the qualitative phase informed the development of a structured web-based questionnaire, completed by 133 radiology professionals. The questionnaire assessed trust in AI outputs, professional role and identity, and ethics and medico-legal responsibility, alongside perceived implementation barriers and self-reported extent of AI use. Quantitative data were analyzed using descriptive and non-parametric statistics.

Results: AI was consistently perceived as a supportive tool rather than an autonomous decision-maker. Participants described AI as useful for prioritising urgent findings, supporting workflow, reducing missed findings and serving as a “second reader,” particularly in high-workload and time-sensitive settings. At the same time, adoption remained heterogeneous: 33.8% of survey respondents reported no current AI use, while higher use was observed among specialists and hospital-based staff. Key limitations included performance variability, false-positive alerts, lack of clinical context, delayed or poorly integrated outputs, and uncertainty regarding how to document or act on AI findings. Respondents strongly endorsed physician responsibility and the need for institutional policies, while showing very low willingness to rely on AI alone. The leading barriers were lack of institutional budget, insufficient training, doubts regarding AI results, and absence of clear medico-legal protocols whereas fear of job replacement was reported by only a small minority.

Conclusions/Implications: AI adoption in radiology was characterized by conditional acceptance rather than simple enthusiasm or resistance. Participants were generally willing to use AI but emphasized that AI outputs must remain clinically reviewable and that final responsibility should remain with the physician. The findings suggest that sustainable implementation requires more than access to AI tools. Institutions should develop role-specific training, PACS/RIS-integrated workflows, mechanisms for feedback and error monitoring, and clear procedures for documenting and managing disagreement between clinicians and AI outputs. In the context of responsible innovation in medical imaging, these findings highlight the importance of human-centred governance, transparency and accountability when AI systems are introduced into clinical radiology practice. This work contributes to SDG 3 by supporting safer and higher-quality healthcare, and to SDG 9 by promoting responsible innovation in digital medical infrastructure.

S3.2 Nuclear Medicine & Theranostics

S3.2-1 REFERENCE COMPARTMENTAL MODELS FOR BIOKINETICS AND DOSIMETRY OF ^{68}Ga -AND ^{18}F -LABELLED PROSTATE-SPECIFIC MEMBRANE ANTIGEN LIGANDS [^{68}Ga]Ga-PSMA-11 AND [^{18}F]F-PSMA-1007

Author: Alexandra Kamp | Co-Author: Martin Andersson, Augusto Giussani | Speaker: Alexandra Kamp

Objectives/Background: [^{68}Ga]Ga-PSMA-11 is a PET imaging agent mainly employed in the diagnostic assessment of prostate cancer. It targets prostate-specific membrane antigen (PSMA), a type II transmembrane protein markedly upregulated in prostate cancer and metastatic lesions, enabling visualization of both primary and disseminated disease. Similarly, [^{18}F]F-PSMA-1007 is used for prostate cancer images and offers practical advantages due to the longer half-life of ^{18}F and potentially higher spatial resolution.

During the revision of ICRP Publication 128, these two radiopharmaceuticals were selected for inclusion in the new publication, given their widespread clinical use and growing relevance in diagnostic nuclear medicine. Consequently, reference biokinetic models were proposed and absorbed organ dose coefficients along with the effective dose coefficients were calculated for both compounds.

Methods: Biokinetic models were developed using quantitative biodistribution data reported in the literature. In addition, individual patient time-activity data obtained through internal communication were incorporated.

In both models, blood served as the central exchange compartment, distributing the radiopharmaceuticals to organs and tissues exhibiting elevated uptake of ^{68}Ga or ^{18}F relative to the rest of the body (source regions). Transfers between compartments were assumed to follow first-order-kinetics, and recycling pathways were considered when supported by the data. Reference regional blood volumes were incorporated for each source region where applicable. Alimentary tract excretion was described using the human alimentary tract model with reference transfer coefficients.

Model predictions were simultaneously fitted to the time-activity data using the Rosenbrock integrator in SAAM II (NANOMATH LCC, version 2.3.3) to estimate unknown model parameters. Dose coefficients for reference adults were calculated with IDAC-Dose 2.1. Urinary bladder dosimetry was performed using a dynamic bladder model.

Results: Although similar source regions were identified for [^{68}Ga]Ga-PSMA-11 and [^{18}F]F-PSMA-1007, the available data and literature indicate distinct biokinetic behaviors. Accordingly, separate compartmental models were developed. For [^{68}Ga]Ga-PSMA-11, two options were considered: one excluding and one including the prostate as a source region, representing the dominant clinical population and patients undergoing primary staging, respectively. As no prostate time-activity data were available for [^{18}F]F-PSMA-1007 during the model development, the prostate was not included as a distinct source region. Model predictions showed good agreement with the experimental data. The effective dose coefficients calculated according to the current ICRP dosimetry framework were $2.11\text{E-}02$ mSv/MBq for [^{68}Ga]Ga-PSMA-11 and $2.22\text{E-}02$ mSv/MBq for [^{18}F]F-PSMA-1007.

Conclusions/Implications: Compartmental biokinetic models for [^{68}Ga]Ga-PSMA-11 and [^{18}F]F-PSMA-1007 were developed. These models and the resulting dose coefficients will be adopted in the revised ICRP Publication and can be used for reference dosimetry of these diagnostic PET radiopharmaceuticals.

S3.2-2 BRIDGING PHYSICS AND BIOLOGY FOR INTERNAL EMITTERS: THE FORRCE APPROACH TO MECHANISTIC DOSE-RESPONSE MODELLING

Author: Ana Vaniqui | Co-Author: Ans Baeyens, Carmen Villagrasa, Celine Baldeyron, Celine Bouvier Capely, David Suhard, Estelle Davesne, Filip Vanhavere, Guillaume Drouet, Guillaume Phan, Lara Struelens, Maria Luz Olaguibe, Omar Garcia Garcia, Simone Dalm, Winnok De Vos, Yann Gueguen, Yann Perrot | Speaker: Ana Vaniqui

Objectives/Background: Internal emitters present unique challenges for radiation protection and dosimetry due to heterogeneous radionuclide uptake, stochastic energy deposition, mixed radiation fields and protracted low-dose-rate exposures. These characteristics are particularly relevant in targeted radionuclide therapy (TRNT), where conventional radiobiological models, largely developed for external beam radiotherapy, are often insufficient to describe the relationship between absorbed dose and biological response. Improving the mechanistic understanding of radiation effects following internal irradiation is therefore essential for both personalised radionuclide therapy and radiation protection. The PIANOFORTE-funded FORRCE (Framework for Outcomes of Radionuclide Radiation on Cellular Environments) project has been established to address this challenge through the development of an integrated multi-scale modelling framework.

Methods: FORRCE combines radiation transport simulations, mechanistic radiobiological modelling and experimental validation within a computational framework. Realistic cellular geometries reconstructed from microscopy are coupled with Geant4-DNA track-structure simulations to quantify energy deposition at subcellular resolution. AI is employed to accelerate DNA damage prediction across heterogeneous cell populations, while the 'Mechanistic DNA Repair and Survival Model' (MEDRAS - McMahon, et al. 2021) framework is extended to model DNA repair, survival and protracted dose-rate effects. Validation is performed using complementary experimental techniques, including expansion microscopy, secondary ion mass spectrometry (SIMS), single cell with inductively coupled plasma mass spectrometry (SC/ICP-MS), solid state-based microdosimetry and radiobiological assays in two- and three-dimensional prostate cancer models exposed to PSMA-targeting radiopharmaceuticals labelled with e.g. Ac-225, Lu-177 and Tb-161. The project follows an iterative workflow in which computational predictions are continuously refined using experimental observations.

Results: FORRCE commenced in January 2026 and is currently establishing the computational and experimental infrastructure required for integrated multi-scale modelling. Initial work focuses on the development of realistic cell population geometries, adaptation of Geant4-DNA simulations for Ac-225, implementation of mechanistic repair modelling for heterogeneous and protracted exposures, and harmonisation of experimental protocols across the consortium. This contribution will introduce the scientific framework, methodology and expected research outcomes, highlighting the integration of modelling and experimental approaches to address current limitations in mechanistic dosimetry for internal emitters.

Conclusions / Implications: FORRCE aims to bridge the gap between microscopic energy deposition and biological response by integrating physics-based simulations with experimental radiobiology across multiple spatial and temporal scales. The resulting framework is expected to improve biologically informed internal dosimetry, provide a better description of heterogeneous internal exposures and provide validated computational tools supporting both targeted radionuclide therapy and radiation protection. Beyond TRNT, the methodologies developed within FORRCE are intended to contribute to a broader mechanistic understanding of radiation effects from internal emitters, supporting future advances in risk assessment and biologically based radiation protection.

S3.2–3 INHALATION DOSE ASSESSMENT FOR MEDICAL STAFF AND CAREGIVERS EXPOSED TO RN-219 GAS AND ITS PROGENY EXHALED FROM PATIENTS UNDERGOING TREATMENT WITH RA-223-DICHLORIDE

Author: Lena Katzdobler | Co-Author: Vladimir Spielmann, Astrid Delker, Augusto Giussani, Kerstin Hürkamp, Christina Kuttler, Oliver Meisenberg, Sibylle Ziegler, Weibo Li | Speaker: Weibo Li

Objectives: The radiopharmaceutical ^{223}Ra -dichloride (Xofigo®) is approved for the palliative treatment of metastatic castration-resistant prostate cancer. During treatment and subsequent patient caregiving, patients administered ^{223}Ra -dichloride may exhale its gaseous progeny, ^{219}Rn . This radioactive noble gas and its airborne decay products may be inhaled by medical staff, caregivers, and family members, resulting in potential internal radiation exposure. The objective of this study was to assess the effective dose arising from inhalation of exhaled ^{219}Rn and its progeny during and after treatment with ^{223}Ra -dichloride.

Methods: The biokinetic models and model parameters for ^{223}Ra and its progeny ^{219}Rn published by the International Commission on Radiological Protection (ICRP) were implemented in this study to estimate the exhalation of ^{219}Rn from treated patients and the resulting activity concentrations of ^{219}Rn and its airborne progeny in patient rooms. Equivalent and effective dose coefficients were calculated for inhalation of ^{219}Rn and each of its short-lived progeny (^{215}Po , ^{211}Pb , ^{211}Bi , ^{207}Tl and ^{211}Po) by medical staff, caregivers, and family members. The effective doses were subsequently estimated using realistic occupancy scenarios and ventilation rates representative of German hospital environments.

Results: The biokinetic model established in this study predicted that the activity of ^{219}Rn in room air reaches a maximum of 5.8×10^{-2} Bq approximately 1.5 minutes after administration of 1 Bq of ^{223}Ra -dichloride, which is in good agreement with measurements reported in the literature. Using the effective dose coefficients calculated in this study, the effective dose from inhalation of exhaled ^{219}Rn and its airborne progeny following a treatment administration of 4015 kBq of ^{223}Ra -dichloride was estimated to be 334.4 nSv for medical staff and 10.7 μSv for caregivers. The corresponding effective dose for family members was estimated to be 8 μSv .

Conclusions: This study set up biokinetic models to predict the activities of exhaled ^{219}Rn and its airborne progeny in the breathing air of patients and in the room air following administration of Xofigo®. Effective dose coefficients for inhalation of ^{219}Rn and its progeny were calculated and applied to estimate radiation doses to medical staff, caregivers, and family members. The proposed methodology provides a framework for assessing internal radiation exposure resulting from airborne radioactive progeny released during targeted alpha therapy and may be extended to other emerging radiopharmaceutical therapies involving vaporous radionuclide progeny.

S3.2–4 A GESTATION-DEPENDENT BIOKINETIC MODEL OF FOETAL THYROID DOSE FOLLOWING CLINICAL RADIOIODINE PROCEDURES

Author: Bill Kamtchou | Co-Author: Sean Cournane | Speaker: Bill Kamtchou

Objectives / Background: Radioiodine procedures are widely used in the investigation and treatment of benign and malignant thyroid disease. While inadvertent administration during pregnancy is uncommon, reported foetal thyroid doses can be clinically significant and may approach or exceed thresholds for deterministic effects depending on gestational age, administered activity and maternal thyroid physiology. Diagnostic I-131 uptake studies employ relatively low activities (~1 MBq); however, around the onset of foetal thyroid function, when pregnancy status may still be uncertain, limited estimates exist regarding potential foetal thyroid

exposure. This work aimed to develop a unified, gestation-dependent maternal-foetal biokinetic dosimetry model that can be tailored to different clinical scenarios, including normal thyroid physiology, hyperthyroidism and thyroid cancer, to estimate foetal thyroid dose following radioiodine administration.

Methods: A gestation-dependent maternal-foetal iodine biokinetic model based on ICRP Publication 88 was implemented in Python to estimate foetal thyroid dose following acute maternal ingestion of I-131. The compartmental model simulated iodine transport using gestational-age-dependent transfer coefficients and was validated against published maternal thyroid dose estimates and foetal iodine uptake data, achieving agreement within 2% of literature values. The model was subsequently adapted to represent hyperthyroid physiology, reproducing previously published foetal thyroid dose estimates for thyrotoxic patients and providing confidence in its application to additional clinical scenarios, including thyroid cancer patient biokinetics. Predicted doses for these scenarios will be compared with published data to place the modelled estimates within the context of currently available literature.

Results: For normal maternal uptake ranges (<30%), estimated foetal thyroid doses per MBq administered were negligible prior to approximately 10-12 weeks' gestation, reflecting the absence of functional foetal thyroid tissue. Thereafter, foetal thyroid dose increased rapidly, approaching approximately 300 mGy at 20-21 weeks' gestation (± 1 week). Increased maternal thyroid uptake substantially reduced foetal thyroid dose and delayed the gestational age at which this threshold was approached to 26-27 weeks for moderate uptake (~55%) and 34-35 weeks for high uptake (~75%) scenarios.

Conclusions / Implications: This validated, unified gestation-dependent model quantifies foetal thyroid dose following radioiodine administration and demonstrates the significant influence of maternal thyroid physiology on foetal thyroid exposure. By reproducing expected foetal thyroid doses in thyrotoxic patients and extending the methodology to thyroid cancer scenarios, the model provides a framework for assessing foetal thyroid dosimetry across a range of clinically relevant radioiodine procedures.

Clinical Impact: This work improves understanding of inadvertent foetal radiation exposure during diagnostic nuclear medicine procedures and supports evidence-based patient safety policies, robust pregnancy screening practices, and informed risk assessment for diagnostic radioiodine procedures.

S3.2-5 SETTING UP AN IN-HOUSE TL BASED ENVIRONMENTAL DOSE MONITORING SYSTEM FOR THE NM DEPARTMENT AT A MAJOR PUBLIC HOSPITAL

Author: Matthias Sultana | Co-Author: Sam Agius | Speaker: Matthias Sultana

Objectives/Background: Environmental dose monitoring in healthcare institutions is crucial to radiation safety and regulatory compliance. This process falls under the auspices of the radiation protection expert as per Article 82 of the European Directive 2013/59/EURATOM. Environmental dose monitoring often uses third-party dosimeters with limited control over the calibration process. Additionally, further dosimeter irradiation may occur during transportation to the readout entity, leading to possible discrepancies between the measured reading and the real dose. This may introduce systematic uncertainties, reduce measurement reliability, and delay the identification of high-dose areas requiring intervention. Consequently, there is a need for more efficient and locally controlled monitoring approaches. The project sought to establish an in-house thermoluminescence-based system for environmental dose monitoring and to perform and analyse an environmental dose monitoring survey of the nuclear medicine department at a major national hospital, with the aim of improving flexibility and response time in radiation protection practices.

Methods: The methodology involved calibrating and validating MCP crystals through different radiation sources, theoretical values and real-time dosimeters. Calibration was radionuclide-specific to account for variations in photon energy and detector response. A structured approach involving calibration, validation, and implementation phases was adopted to ensure system reliability. Twenty-eight crystals were placed in strategic locations across the departments for a continuous reading. After two months of environmental dose monitoring, the crystals were read obtaining the registered doses. Doses measured were classified into low occupancy, patient, general public, and staff areas, enabling a comprehensive spatial assessment of radiation exposure.

Results: Low-occupancy area yearly doses varied from 1.45 ± 0.34 mSv/yr (cold store) to 20.11 ± 5.03 mSv/yr (hot store). Patient area doses varied from 0.71 ± 0.18 mSv/yr (dedicated cardiac scanner room) to 19.86 ± 4.97 mSv/yr (positron emission tomography scanning room). Cardiac stress room doses varied from 0.89 ± 0.22 mSv/yr to 0.91 ± 0.23 mSv/yr. Radiation staff area doses varied from 0.47 ± 0.12 mSv/yr (positron emission tomography control room) to 10.06 ± 2.52 mSv/yr (hot lab). Almost all areas monitored were under dose constraints set by Maltese legislation; the exceptional areas will now apply remedial actions to decrease doses. The findings also enabled identification of dose distribution trends across the department.

Conclusions/Implications: Setting up an in-house thermoluminescence-based environmental dose monitoring system is possible with the right human resources and advantageous for gaining immediate results. The approach enhances control over calibration, reduces external uncertainties, and enables faster implementation of corrective measures. It also supports optimisation of radiation protection in line with ALARA principles. Future work requires setting up a procedure for environmental dose monitoring and a cost-benefit analysis for an accreditation procedure for environmental dose monitoring.

S3.2-6 DEVELOPMENT AND PRELIMINARY VALIDATION OF A Voxel-DOSIMETRY-BASED TREATMENT PLANNING SYSTEM (TPS) FOR B-EMITTING RADIONUCLIDE THERAPY

Author: Haijing Jin, Liye Liu, Faguo Chen, Ri Zhao, Hua Li, Jian Huang, Xin Liu, Runcheng Liang, Jing Zhang | *Co-Author:* | *Speaker:* Haijing Jin

Background: B-emitter radionuclide therapy with agents such as ^{177}Lu -DOTATATE and ^{90}Y microspheres is expanding rapidly, yet most patients still receive fixed activities without individualized internal dosimetry. A domestically developed voxel-level dosimetry system to address this clinical need is currently unavailable in China. This work develops and preliminarily validates a treatment planning system (TPS) enabling individualized, voxel-scale internal dose assessment for B-radionuclide therapy.

Methods: The TPS integrates a complete image-to-dose workflow: quantitative SPECT reconstruction with scatter, attenuation and collimator-detector-response correction; image value to activity calibration; organ segmentation and cross-modal (SPECT/CT) registration; time-activity curve (TAC) fitting at single and multiple time points; and voxel-level dose calculation using a GPU-accelerated Monte Carlo engine with variance-reduction techniques optimized for low-energy γ and β transport, producing dose distributions and dose-volume histograms (DVH). The quantification front-end was validated with purpose-built calibration phantoms; voxel dose calculation was benchmarked against the SNMMI international reference dataset using OpenDose and FLUKA.

Results: The full image-to-dose TPS framework has been established, with experimental validation of the activity-quantification front-end. Image-to-activity calibration on clinical SPECT/CT with purpose-built phantoms achieved a linearity of $R^2=0.9998$, and quantitative ^{177}Lu -DOTATATE activity measurement reached a mean deviation of 2.6%. A deep-learning cross-modal (SPECT/CT) registration further improved functional-image alignment. The voxel-level dose engine was

benchmarked on multi-region patient cases against the SNMMI international reference using OpenDose and FLUKA; when activity and segmentation inputs were matched, major-organ absorbed doses (liver, kidneys, spleen) agreed within about 10% of the reference; the TAC-fitting module is undergoing further optimization, as is the computational speed of the image registration algorithm.

Conclusions: We are developing the first domestically developed voxel-dosimetry-based TPS for B-radionuclide therapy in China, combining quantitative imaging, GPU Monte Carlo dose computation and multi-source dose verification. Preliminary validation of the quantitative-imaging front-end and initial dose benchmarking demonstrate technical feasibility, supporting a shift from fixed-activity administration toward precision, patient-centred radionuclide therapy and laying a basis for device registration and clinical translation. Future work will leverage pre-therapy ^{68}Ga PET imaging to predict ^{177}Lu activity distribution and absorbed doses before treatment, enabling individualised pre-treatment simulation; dosimetry-guided treatment-regimen optimisation will further be integrated to deliver iteratively computed optimal activity and scheduling recommendations for each administration cycle, advancing radionuclide therapy toward truly dose-driven practice.

S3.2-7 DEVELOPMENT OF A MONTE CARLO OCCUPATIONAL RADIATION DOSIMETRY MODEL FOR SURGEONS DURING LIVER TRANSPLANTATION POST- ^{90}Y SELECTIVE INTERNAL RADIATION THERAPY (SIRT).

Author: Una Maguire | **Co-Author:** Niamh McArdle, Bill Kamtchou, Seán Cournane | **Speaker:** Niamh McArdle

Background: ^{90}Y SIRT is an established treatment of hepatocellular carcinoma and liver metastases and is increasingly used as a bridging therapy to control tumour growth prior to liver transplantation. ^{90}Y is a high energy beta emitter (mean energy of 0.94 MeV; maximum energy of 2.27 MeV) with a mean tissue penetration depth of 2.5 mm and a maximum range of 11 mm. For liver transplant candidates treated with SIRT, residual ^{90}Y activity may remain within the liver with potential for significant occupational radiation exposure to surgeons' hands during the transplantation procedure. Existing recommendations on surgical scheduling following SIRT are based on radionuclide decay or external dose-rate measurements with limited consideration of extremity exposure during direct tissue handling. This work aims to develop a Monte Carlo (MC)-based radiation dosimetry model to estimate the radiation dose to surgeons' hands during liver transplantation following ^{90}Y SIRT in order to inform radiation protection strategies.

Materials and Methods: MC simulations were performed using EGSnrc to estimate radiation exposure from ^{90}Y within simulated liver models. Dose scoring regions corresponding to Hp(0.07) were implemented to estimate extremity doses. The simulation framework was first validated against published ^{90}Y dosimetry data [1]. Simplified geometric models representing the liver, embedded tumours containing ^{90}Y and the surgeon's hand were developed. Models were used to investigate the influence of tumour size (34-524 cc), tumour depth from the liver surface (0-11 mm), tumour shape (radiomic-derived spheres and ellipsoids), administered activity (0.5-6 GBq), surgeon hand contact patterns, and time post-SIRT on extremity doses. These parameters were based on a locally collated patient dataset. In addition, a patient-specific case study, incorporating an individual patient's liver and tumour geometry, will also be modelled.

Results: Validation of the ^{90}Y source model showed good agreement with published GEANT4 dosimetry data, with an average deviation of 3.4% and maximum deviation of 8.4%. Simulations demonstrated extremity dose to be strongly dependent on tumour geometry and proximity to the liver surface. For a given administered activity, smaller superficially-located tumours resulted in

higher $H_p(0.07)$ values, relative to larger tumour volumes, due to reduced beta-particle self-attenuation. Maximum extremity doses occurred directly above the tumour centre, as a result of the short penetration range of the ^{90}Y beta-particles in tissue, with rapid dose fall-off subsequently evident with increasing distance. Moreover, tumour shape also affected dose patterns: flattened geometries produced higher peak doses due to reduced beta-particle self-attenuation, whereas more elongated tumour geometries generated lower peak doses. Findings from the patient-specific model will also be presented.

Conclusion: A simple predictive model was developed to estimate surgeon hand dose during transplantation post-SIRT therapy using readily available clinical parameters (administered activity, tumour volume, depth and shape). This model provides rapid, procedure-specific dose guidance to support surgical planning and radiation protection decision-making.

References:

[1] taliano A, Amato E, Auditore L, Baldari S. A methodological approach to a realistic evaluation of skin absorbed doses during manipulation of radioactive sources by means of GAMOS Monte Carlo simulations. *Nucl Instrum Methods Phys Res A*. 2018;891:1-5.

S3.2-8 AUGER-EMITTING RADIONUCLIDES IN NUCLEAR MEDICINE: ADDRESSING UNRECOGNIZED OCCUPATIONAL EXPOSURE RISKS

Author: Akash Jana | Co-Author: | Speaker: Akash Jana

Background: Auger-emitting ^{161}Tb leverages high LET and nanometer-range emissions to deliver lethal subcellular doses to micrometastases. However, its unique physical properties introduce unrecognized occupational hazards, including monitoring pitfalls such as system dead-time and count-rate underestimation. Current safety protocols, which were developed mainly for conventional radionuclides, need to be revised to account for the internal dosimetry and contamination-control challenges associated with high-RBE Auger emitters.

Aim: This study evaluates the occupational radiation risks associated with the clinical use of Auger electron emitters and proposes an updated safety framework for their routine application in nuclear medicine.

Methods: A systematic review of studies published from 2015 to 2026 was carried out to evaluate the physical and radiobiological properties of Auger-emitting radionuclides. The review assessed decay patterns, shielding effectiveness, and monitoring challenges, especially detector dead time and underestimation of count rates related to their characteristic photon emissions. These properties were compared with established clinical radionuclides such as ^{177}Lu to identify specific operational risks.

Results: The review highlights a major gap in radionuclide-specific safety guidance for Auger emitters. Their complex emission profiles can interfere with routine monitoring and may cause detector dead time and underestimation of count rates at relatively low activities. Because of their high radiobiological effectiveness, even small amounts of internal contamination may lead to meaningful absorbed doses in highly sensitive subcellular targets.

Conclusion: The clinical use of Auger emitters will require updated safety strategies, isotope-specific guidance, and improved monitoring approaches to address their unique dosimetric and operational challenges while maintaining strong worker protection standards.

FLASH TALKS – WEDNESDAY

WFT-01 CITISTRA – SOCIOLOGICAL ASPECTS OF CITIZEN RADIATION MEASUREMENTS

Author: Jan Helebrant, Marie Davidková, Ivana Fojtíková, Pavel Fojtík, Jiří Hůlka, Renata Kierepko, Anna Mroziak, Mateusz Krzysiek, Paweł Olko, Agnieszka Szumska, Pavol Ragan, Zuzana Gonekova | Co-Author: | Speaker: Marie Davidková

Background: The increasing involvement of citizens in radiation measurements is closely linked to broader societal changes. Modern societies are characterized by higher levels of education, technical competence, and access to affordable technology. As a result, individuals are capable of understanding basic radiation concepts, operating measurement devices, and providing meaningful data. Citizen science initiatives in radiation monitoring reflect a growing demand for transparency, independent verification, and direct public participation in issues related to health, safety, and the environment.

The CITISTRA project (Citizen measurements as complementary radiation monitoring strategy in threats due to armed conflict or natural disasters) represents a tangible effort to evaluate the feasibility of large-scale citizen-based radiation monitoring in Central Europe.

Methods: A sociology survey aimed at identifying trusted public groups has been organised in all three participating countries of the project - Czechia, Slovakia and Poland. More than 1,000 respondents were interviewed in each country. Each survey was conducted in the native language of the participating country. The goal was to identify target groups credible for carrying out citizen radiation measurements.

Results and conclusions: The results obtained from the questionnaire clearly demonstrate that the most trusted professional groups in all three countries are firefighters and the rescue services. These groups are not only perceived as trustworthy in normal, but also in the emergency situations.

CzechRad detectors were distributed for one year of measurements to volunteers from different professional groups. At the end of the test period, detector users are asked for their experiences and opinions. Based on these valuable information, we hope to build citizen monitoring network meeting demands of today's modern society.

Acknowledgement:

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WFT-02 PROTECTION UNDER PRESSURE: PROTECTIVE ACTIONS FOLLOWING NUCLEAR DETONATION

Author: Emma Davidson | Co-Author: | Speaker: Emma Davidson

Objective: Nuclear detonation scenarios present challenges that differ substantially from those associated with accidents at fixed nuclear facilities. Existing emergency preparedness arrangements across Europe are largely based on nuclear power plant accident scenarios and rely on predefined emergency planning zones and established protective actions. Within the PREDICT project, work examining protective actions for nuclear detonation scenarios aims to evaluate how emergency response strategies may need to be adapted using evidence derived from modelling.

Methods: Modelling outputs generated within the project were analysed to assess projected dose, dose rate, plume movement, fallout deposition and population exposure following a nuclear detonation. These results were considered alongside existing European emergency preparedness guidance and EURATOM reference levels to evaluate the effectiveness and practicality of protective actions, including sheltering, evacuation, iodine thyroid blocking, and food bans. Particular attention was given to the timing of protective actions and the operational challenges associated with their implementation under severe disruption conditions.

Results: The analyses demonstrate that the radiation doses following a nuclear detonation differ significantly from those that are typically observed in nuclear power plant accident scenarios. Dose rates within affected areas may change rapidly, requiring protective actions to be implemented and adjusted within short timescales. Results highlight the importance of tailoring response measures to local conditions, including anticipated fallout arrival times.

Conclusions: The work will provide evidence for assessing the applicability of existing protective action strategies to nuclear detonation scenarios and identifies areas where current guidance may require adaptation.

WFT-03 FROM LABORATORY VALIDATION TO ROUTINE ENVIRONMENTAL MONITORING: DEPLOYMENT OF THE CZECHRAD DETECTOR IN A CITIZEN-BASED IONIZING RADIATION MONITORING NETWORK

Author: Mateusz Krzysiek | Co-Author: Renata Kierepko, Anna Mrozik, Paweł Olko, Agnieszka Szumska, Jan Helebrant, Marie Davidková, Ivana Fojtíková, Pavol Ragan, Zuzana Gonekova | Speaker: Mateusz Krzysiek

The effectiveness of ionizing radiation monitoring is fundamentally dependent on the measurement equipment employed. The choice of detector is determined by the intended application and the environmental conditions in which it will operate. Citizen science networks, involving trained volunteers who independently perform radiation measurements, most commonly utilize Geiger-Müller detectors because of their relatively low cost, reliability, and user-friendly operation.

One such detector employed within the citizen monitoring network established under the CITISTRA project is the CzechRad detector, a portable Geiger-Müller-based radiation monitor developed by the National Radiation Protection Institute (SÚRO, Czech Republic). The instrument was designed as an implementation of the well-established Safecast bGeigie Nano detector, which has been successfully employed in citizen science radiation monitoring initiatives worldwide after Fukushima accident. Its advantages include stable operation, high reliability, resistance to adverse weather conditions, integrated GPS positioning, autonomous data logging on an SD card, long battery life, and straightforward operation by non-specialist users.

Within the Polish part of the CITISTRA project, 200 CzechRad detectors have been distributed to volunteers across the country. The network has been operating continuously for more than one year, generating a large dataset of environmental radiation measurements under diverse conditions. This extensive field deployment has provided valuable practical experience regarding detector performance, reliability, and data quality in real-world applications.

This contribution focuses on the experimental characterization of the CzechRad detector and discusses its performance under various measurement conditions. This involves also a large set of laboratory tests. The investigated properties include the repeatability of ambient dose rate measurements in natural background radiation fields and under controlled exposure to radioactive source. Detector directional response was evaluated through angular distribution measurements performed at different orientations relative to the radiation point source as well as interpretation

of that calibration in the case of an extended source of ionizing radiation. Environmental stability was assessed using a climatic chamber, where detector response was studied over a range of temperature and humidity conditions representative of outdoor operation. Finally, low-background measurements were conducted in an underground salt mine environment to evaluate detector performance at radiation levels significantly below typical surface background.

This study represents the first comprehensive investigation of the CzechRad detector under both controlled laboratory conditions and routine environmental monitoring, providing a unique dataset for evaluating its performance in citizen-based radiation monitoring networks and will also enable the estimation of the measurement uncertainty budget, which should be taken into account when interpreting the obtained results.

WFT-04 A VIABLE METHOD FOR QUANTIFYING RESIDUAL RADIOACTIVITY IN VIVO BY SCINTIGRAPHY FOLLOWING IODINE-131 TREATMENT

Author: Xiaoxi Pang | Co-Author: | Speaker: Xiaoxi Pang

Objective: To quantify the residual radioactivity of iodine-131 (^{131}I) in a patient's body after ^{131}I therapy using ^{131}I radio-counts according to scintigraphy. **Methods:** A model consisting of 13 groups of microcentrifuge tubes representing an accurate gradient radioactivity ^{131}I ($n = 5$) was generated. The model was placed on a scintigraphy scanning bed and scanned with conventional whole-body ^{131}I scanning parameters. The corresponding radio-counts for each tube was acquired by a postprocessing software system following ^{131}I scanning. This was analyzed by a regression equation including the radio-counts and the true radioactivity. In the validation group, we included 10 patients with hyperthyroidism who were treated with a small radioactivity of ^{131}I or with differentiated thyroid cancer (DTC) and diagnosed by a small radioactivity of ^{131}I (Dx-RAI). The whole-body scan was performed immediately after a precise radioactivity of ^{131}I was administered. Next, the whole-body scanning radio-counts were substituted into the equation and these calculated radioactivity were compared with the actual radioactivity to verify the accuracy of the equation. In the application group, the radio-counts of 34 DTC patients who completed treatment with a large radioactivity of ^{131}I were substituted into the equation before discharge, and the residual radioactivity was calculated. **Results:** A standard model for the known radioactivity was successfully constructed based on radio-counts in each microcentrifuge tube and measured by scintigraphy using the post-processing workstation. The regression equation was $y \text{ (MBq)} = (0.13x + 32.70) / 1000$ (x means radio-counts, y means radioactivity, $r = 0.98$). The error between the actual radioactivity and the calculated radioactivity from patients in the verification group was no more than 5.00% ($r = 0.97$, $p = 0.007$, $n = 10$). The radioactivity of the 34 DTC patients prior to discharge after being treated with a high radioactivity of ^{131}I was $305.62 \pm 349.28 \text{ MBq}$ ($n = 34$); of these, 25/34 patients (73.53%) had a radioactivity low than 400 MBq in their bodies and met the requirements for discharge. However, 9/34 patients (26.47%) had a radioactivity was more than 400 MBq and discharge was postponed. **Conclusion:** The radio-counts quantified by scintigraphy was able to precisely quantify the radioactivity in patients following ^{131}I treatment with an accuracy that met clinical and radiation protection requirements.

WFT-05 THREE-DIMENSIONAL (3D) MAPPING OF RADIATION RESPONSE IN MULTI-LAYERED GAFCHROMIC LD-V1 FILMS IRRADIATED WITH FLUORODEOXYGLUCOSE (FDG)

Author: Mohammad Yoshandi | Co-Author: Hairil Abdul Razak | Speaker: Mohammad Yoshandi

Introduction: Conventional dosimetry tools, such as ionisation chambers and thermoluminescent dosimeters, provide accurate point measurements but lack spatial resolution. Gafchromic LD-V1 film, originally designed for radiology machine quality assurance, has not been previously investigated for spatially resolved dosimetry in nuclear medicine. This study evaluates the feasibility of using Gafchromic LD-V1 film for three-dimensional (3D) radiation response mapping, with fluorodeoxyglucose (FDG) as the radiation source.

Methods: Seven Gafchromic LD V1 films were sequentially positioned within a multilayered polystyrene-based phantom at approximately 100 MBq decay intervals, starting from an initial activity of 775 MBq. Film placement times were set at 0, 16, 40, 69, 104, 153, and 217 minutes. Each film was exposed for 120 minutes prior to removal. Following irradiation, films were scanned and net pixel values (NPVs) were calculated. A Python-based pipeline was developed for 3D reconstruction, incorporating hotspot-centred spatial alignment and exponential decay-weighted interpolation between slices.

Results: Gafchromic LD-V1 films demonstrated a measurable and spatially consistent response to F-18 FDG irradiation across all seven films, corresponding to activities of approximately 775, 700, 600, 500, 400, 300, and 200 MBq. A calibration curve was generated using polynomial fitting, yielding a coefficient of determination (R^2) of 0.97. The 3D reconstruction successfully resolved the spatial distribution of film response as a function of decaying accumulated activity.

Conclusion: This preliminary study demonstrates that Gafchromic LD-V1 film is capable of capturing spatial radiation response from FDG. The 3D reconstruction pipeline provides an activity-dependent radiation response volume from irradiated films. This approach successfully extending the capabilities of 2D film-based dosimeter to 3D radiation response mapping. This study could potentially be applied for 3D dose map distribution and may offer a low-cost alternative technique for spatial dose response characterisation in nuclear medicine applications.

WFT-06 EDUCATION AND TRAINING FOR SUSTAINABLE AND RESILIENT RADIATION MONITORING CAPABILITIES IN EPR

Author: Benjamin Zorko | Co-Author: Boštjan Črnič, Branko Vodenik, Helena Fajfar, Jasmina Kožar Logar, Klara Poiškruh, Miha Mihovilovič, Mitja Centrih, Petra Prem, Rok Roš Opaškar, Sandi Gobec, Toni Petrovič, Urška Gradišar Centa | Speaker: Benjamin Zorko

Sustainable radiation protection requires radiation monitoring capabilities that can be maintained under routine conditions and effectively activated during Emergency Preparedness and Response (EPR). Operational environmental radioactivity monitoring contributes baseline environmental knowledge, experience with sampling and measurement, long-term data interpretation and familiarity with local conditions. EPR monitoring, therefore, requires operational readiness that cannot be developed through routine measurement practice alone. It includes rapid field deployment, work in protective equipment, contamination assessment, dose-rate mapping, source localisation, emergency sampling, field-to-laboratory coordination and communication with responsible authorities.

To address this need, a scenario-based education and training concept for EPR monitoring was developed within the Infrastructure Centre for Ionizing Radiation Measurements (ICMIS) at the Jožef Stefan Institute. The concept transforms existing measurement and field-support capacities into practical competence for emergency response. The training programme is organised at different competence levels, from internal training and regular drills for operational staff to tailored courses for first responders and external participants.

The training design follows the logic of an EPR mission rather than a sequence of separate demonstrations. Participants are guided through a predefined scenario, from briefing and field deployment to debriefing and evaluation of results. Quality-assured procedures support consistent performance, while practical exercises expose trainees to instrument limitations, various measurement conditions, contamination detection, spatial dose-rate patterns, source localisation and communication between field teams and headquarters under simulated real conditions. In this way, the training evaluates not only individual measurement skills, but also the ability to integrate field observations, data quality and operational communication into a coherent response.

The added value lies in using existing radiation protection infrastructure as a continuous competence-development system for EPR. Regular drilling, equipment testing, realistic field scenarios, and laboratory exercises help preserve expertise, improve the comparability of actions, and strengthen confidence under time pressure. Modern tools such as mobile mapping systems, telemetry, geospatial presentation of results and automated data handling can be introduced where they support the same operational chain and remain subject to validation, quality assurance and expert review.

The concept contributes to SDG 3, SDG 9, and SDG 11 by supporting public health protection, resilient infrastructure, emergency preparedness, innovation in training practice, and safer communities.

WFT-07 SPATIAL-TEMPORAL EVOLUTION AND POTENTIAL SOURCE IDENTIFICATION OF ¹³⁷Cs IN GROUND LEVEL AIR IN SWEDEN

Author: Adam Johnsson, Essaid Chham, Fran Pinero-García | Co-Author: | Speaker: Fran Pinero-García

Air pollution has adverse effects on health, climate and ecosystems, even more when atmospheric aerosols transport radionuclides with the consequent radiological risk. ¹³⁷Cs has been extensively released and dispersed into the atmosphere, because of the global fallout from nuclear weapons testing and major nuclear accidents (Chernobyl 1986 and Fukushima 2011). The spatial and temporally distribution of ¹³⁷Cs in the ground air is strongly influenced by several atmospheric processes, such as wet and dry deposition, re-suspension, biomass combustion, etc. The main risks resulting from ¹³⁷Cs are its high energy gamma ray photon emission (662 keV), its chemical similarity to K and Rb and high-water solubility which favor its uptake and bioaccumulation, mainly in soft tissues.

The current work aims to determine the spatial and temporal pattern of ¹³⁷Cs in the ground air of Sweden to identify the potential sources and the radiological risks. For that, we have analyzed the weekly data of ¹³⁷Cs, between 2012 - 2024 from the six-monitoring station available in Sweden, using different statistical tools such as boxplot, time series decomposition, potential source contribution function and continuous wavelet transform.

The results showed that ¹³⁷Cs activity concentration decreased annually for all stations except Kiruna, with the stations of Umeå and Gävle having the highest activity concentration. The spatial distribution study identified five areas of high influence on ¹³⁷Cs levels detected in Sweden: i) Eastern Europe (Belarus, Ukraine, central Russia), ii) Southern Finland, iii) Nordic region (Mid Norway & central Sweden), iv) Austria and northern Italy, and v) northern British Isles. Furthermore, the seasonality study highlighted that ¹³⁷Cs levels is controlled by air masses coming from eastern Europe and southern Finland during winter, while the Nordic region air masses are responsible of the radiocesium levels during spring and summer.

WFT-08 INFLUENCE OF TIME CHANGES IN THE SOURCE TERM ON THE TRANSFER OF RADIONUCLIDES TO GROUNDWATER FROM LIQUID DISCHARGES IN NORM INDUSTRIES USING SYNTHETIC TEST SCENARIOS

Author: Francisco Javier Guillén Gerada | Co-Author: Alejandro Salas | Speaker: Francisco Javier Guillén Gerada

The use of groundwater as source of water supply is increasingly getting more importance, especially in arid zones with limited access to other water sources. However, it can present elevated concentrations of naturally occurring radionuclides, which can pose a radiological hazard. Occasionally, the source term of this enhancement may be their transfer from NORM (Naturally Occurring Radioactive Material) by-products. In this study, we present the results obtained for three different synthetic scenarios (uranium tailing, phosphogypsum pond and a leaking pipeline) in which there is a time variation of the source term in order to make a more realistic approach (droughts, intense rainfall, change in pipeline flow, ...). These scenarios were modelled using NORMALYSA software, which is a Kd-based model. Sensitivity analysis was also carried out by considering extreme values of these parameters published in international compilations. This study is clearly aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG 6, which aims to ensure the availability and sustainable management of water and sanitation for all.

Acknowledgements

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WFT-09 BEYOND DNA DAMAGE: CEREBELLAR MICROENVIRONMENT DRIVES RADIATION-INDUCED TUMORIGENESIS

Author: Barbara Tanno | Co-Author: Arianna Casciati, Clarice Patrono, Emanuela Pasquali, Emiliano Fratini, Francesca Antonelli, Ilaria De Stefano, Martina Cipolla, Simona Leonardi, Simonetta Pazzaglia | Speaker: Simonetta Pazzaglia

*Background: Exposure to ionizing radiation is a well-established risk factor for brain tumor development; however, the biological mechanisms underlying radiation-induced tumorigenesis remain only partially understood. In addition to direct DNA damage, increasing evidence highlights the role of non-targeted effects, including alterations in the tissue microenvironment, inflammatory signaling, and epigenetic regulation. These processes may critically modulate cellular responses to radiation and influence cancer risk. This study aims to investigate these mechanisms in cerebellar granule cell precursors (GCPs) isolated from *Ptch1*^{+/-} mice, a well-established model of radiation-induced medulloblastoma*

*Methods: GCPs were isolated from postnatal day 2 (P2) *Ptch1*^{+/-} mice. Co-culture systems of GCPs and glial cells - astrocytes (C8-D1A cell line) and microglia (C8-B4 cell line) were set up and exposed to low (0.1 Gy) or medium (2 Gy) doses of γ -radiation (⁶⁰Co) in various combinations to distinguish cell-autonomous and non-cell-autonomous responses. Endpoints related to carcinogenesis and inflammation were assessed 72 hours post-irradiation. Functional assays of neurospheres were carried out on GCPs grown in conditioned medium derived from cultures of gamma-irradiated glial cells.*

Results: In co-cultures unirradiated GCPs with irradiated microenvironmental cells, astrocytes and microglia displayed distinct dose-dependent radiation responses. Cytokine profiling revealed a mixed pro- and anti-inflammatory signature, reflecting a complex regulatory role in tissue homeostasis and neuroinflammation. Under conditions where both microenvironmental cells and GCPs were irradiated, microglia showed a marked modulation of cytokine profiles, suggesting crosstalk with damaged GCPs. Irradiation of GCPs triggers cellular plasticity and promotes adaptive stem-like responses. In contrast, no significant changes were observed in astrocyte-GCP co-cultures under the same conditions. Functional neurosphere assays using conditioned medium confirmed that microglia can promote expansion and maintenance of the stem-like compartment, likely through the combined secretion of pro-inflammatory mediators and growth factors. Conversely, conditioned medium from astrocytes did not support measurable sphere formation, suggesting that astrocyte-derived factors alone are insufficient to sustain stem-like population expansion.

Conclusions: Together, these findings identify microglia-mediated inflammatory signaling as a key driver of radiation-induced stem-like responses in GCPs, underscoring the critical role of microenvironmental crosstalk in shaping tumorigenic risk.

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WFT-10 ROLE OF THE CEREBELLAR MICROENVIRONMENT RESPONSE TO IONIZING RADIATION IN THE INDUCTION AND PROGRESSION OF MEDULLOBLASTOMA: EVIDENCE FROM AN EX VIVO ORGANOTYPIC CULTURE MODEL

Author: Francesca Antonelli | Co-Author: Arianna Casciati, Barbara Tanno, Elisa Ciucci, Emanuela Pasquali, Emiliano Fratini, Ilaria De Stefano, Martina Cipolla, Simona Leonardi, Simonetta Pazzaglia | Speaker: Francesca Antonelli

Background: The $Ptch1^{+/-}$ mouse model, characterized by constitutive activation of the Hedgehog pathway, is highly susceptible to radiation-induced tumorigenesis and represents a relevant system for studying medulloblastoma (MB). This study investigates the response of cerebellar granule cell progenitors (GCPs), the main cells of origin of MB, to ionizing radiation and the role of the cerebellar microenvironment in the early stages of carcinogenesis.

Methods: An ex vivo system based on organotypic cerebellar slice cultures (OCSCs) was developed from 4-day old $Ptch1^{+/-}$ mice. OCSCs are a particularly useful ex vivo model, as they preserve the three-dimensional architecture of the tissue and the relationships among the different cerebellar cell populations, maintaining cell-cell interactions and microenvironmental signals that regulate processes such as proliferation and differentiation. OCSCs were co-cultured with GCPs derived from mouse cerebellum of the same genotype, and one or both components of the system were exposed to low (0.1 Gy) or moderate (2 Gy) doses of gamma radiation.

Results: Molecular analyses at 72 hours show that the cerebellar microenvironment influences the response of GCPs to ionizing radiation. We found that combined irradiation of both OCSC and GCPs with 2 Gy of γ -rays leads to a drastic reduction of the stemness markers Nanog and Oct4, associated with activation of cell cycle checkpoints (Cyclin D1 and p21).

Radiation exposure alters tissue microenvironment homeostasis, activating cell proliferation pathways partly driven by a strong increase in IGF1 at higher doses and inducing a complex cytokine shift (activation of TNF α and TGF β , coupled with downregulation of IL-10). Understanding this biochemical crosstalk is crucial to uncovering the initial mechanisms of medulloblastoma progression and to identify new therapeutic targets.

Conclusions: The OCSC-based system is confirmed as an ideal and sensitive model for studying, in a controlled manner, the radiobiological response of the tissue and the specific cellular interactions between the cerebellar

This work was funded by the DISCOVER project, under the Euratom 2022-2027 program (PIANOFORTE), grant agreement No. 101061037.

POSTER SESSION – WEDNESDAY

PWE-01 COMPARISON OF THE EFFECTIVE INHALATION AND INGESTION DOSE WITHIN THE FRAMEWORK OF THE GERMAN “CALCULATION GUIDE MINING” WITH RESPECT TO THE DOSE COEFFICIENTS PROVIDED IN ICRP 72 AND UPDATED BY ICRP 158

Author: Jens Fohlmeister | Co-Author: Michaela Achatz, Jörg Dilling, Oleg Tischenko, Bernd Hoffmann | Speaker: Jens Fohlmeister

The dose conversion coefficients for inhalation and ingestion published by the ICRP form the backbone of calculating the effective doses of radionuclides in humans. By their application in dose assessments, they fulfil crucial role in an efficient health care (SDG goal 3: “Good health and well-being”). These dose coefficients are regularly updated to reflect the current state of the art. While they are widely used in national regulatory frameworks for dose calculation, any changes to these coefficients will impact the evaluation of exposure scenarios. The latest update of the dose coefficients for the public (ICRP Publication 158, 2026) affects only a few radionuclides, however, include some of the most important naturally occurring ones.

In Germany, the “Calculation Guide Mining” was established to focus on health issues for uranium remediation workers and the public during remediation of uranium mining legacies as well as on radio-ecological consequences. In such regulations the dose calculation for naturally occurring radionuclides for ingestion and inhalation need to be updated according to the new dose conversion coefficients. Here, we analyse the impact of the new ICRP 158 dose coefficients for naturally occurring radionuclides compared to the previously applied values (ICRP 72) in the “Calculation Guide Mining”. Our focus includes all ICRP age groups concerning the exposure paths of ingestion and inhalation. While the effective dose for adults and adolescents is generally lower with the new dose coefficients, the effective dose for newborns and infants continues to increase. This is a significant aspect, as these age groups were already the most exposed.

PWE-02 TRANSLATING ICRP RADIATION PROTECTION PRINCIPLES AND ETHICAL VALUES INTO OCCUPATIONAL HEALTH LANGUAGE: EXPLORATORY INTERVIEWS WITH OCCUPATIONAL PHYSICIANS FROM JAPANESE COMPANIES OPERATING OVERSEAS INDUSTRIAL SITES

Author: Hiroko Kitamura | Co-Author: Yoto Taguchi | Speaker: Hiroko Kitamura

Background: The radiation protection principles and ethical values proposed by the International Commission on Radiation Protection (ICRP) are internationally recognized. However, how these concepts are understood and interpreted in non-radiation-specialized occupational settings, such as manufacturing sites using industrial X-ray equipment, remains unclear. Today, it is not uncommon for manufacturing companies headquartered in Japan to have production bases overseas. In globally operating companies, occupational physicians are often involved in worker health management across both domestic and overseas sites. Ionizing radiation is one of the occupational health hazards encountered in such settings. From this vantage point, occupational physicians can offer useful insight into how radiation protection concepts are situated within broader occupational safety and health practice.

Methods: We conducted an exploratory qualitative study using semi-structured online interviews with four occupational physicians from three Japanese companies operating both domestic and overseas manufacturing sites using industrial X-ray equipment. Interview topics addressed perceptions of the ICRP’s three principles of radiation protection (justification, optimization, and dose limitation) and four ethical values (beneficence/non-maleficence, prudence, justice, and

dignity), and how these related to routine occupational safety and health activities. Interview transcripts were qualitatively reviewed to identify recurring characteristic themes regarding interpretation, implementation, and situational constraints.

Results: Among participants, no one explicitly recognized ICRP principles and ethical values. However, participants described radiation protection concepts that substantially overlapped with the ICRP principles using existing occupational health language, including respect for workers, hazard communication, ensuring safe work environments and practices, provision of appropriate protective equipment, and education. Ethical values were rarely narrated as abstract concepts; instead, they were reinterpreted through individual experiences, considering practical feasibility, regional differences in culture and social values, and perceived scopes of corporate responsibility, and articulated within the context of daily occupational safety and health activities. Furthermore, three feasibility statuses were identified regarding the principles and ethical values: (1) aspects regarded as self-evident within occupational safety and health practice, (2) measures considered realistically limited due to workplace constraints, and (3) ideals that were recognized but perceived as difficult to translate into concrete implementation.

Conclusions: These findings suggest that ionizing radiation tends to be addressed as one of multiple occupational hazards within existing occupational safety and health frameworks, which typically consist of five management areas: working environment management, operation management, health management, general management, and occupational health education. A key consideration in non-radiation specialized occupational settings is the clear recognition of radiation as a workplace hazard. To strengthen radiation protection in such settings, it may be beneficial not only to disseminate concepts but also to carefully translate them into language used in existing occupational safety and health practices.

PWE-03 INTERNAL DOSIMETRY OF SHORT-LIVED ALPHA EMITTERS: CURRENT CHALLENGES AND APPROACHES

Author: Sven Hartmann | *Co-Author:* Oliver Meisenberg, Raashina Ulakanathan-Thavarajah, Simone Löscher | *Speaker:* Sven Hartmann

The expanding use of cancer therapies employing short-lived alpha-emitting radionuclides presents new challenges for occupational radiation protection. Radionuclides such as astatine-211, lead-212 and, in particular, actinium-225 (Ac-225) are of interest here, as even small amounts incorporated into the body can result in significant effective doses for workers. As the development of radiopharmaceuticals progresses, their production and use will also increase, thereby raising the need for practical approaches to incorporation monitoring.

This contribution aims to present an initial approach and discuss open questions regarding how such monitoring could be carried out systematically. The starting point is the identification and comparison of the various monitoring methods: in vivo or in vitro measurements, as well as ambient air monitoring. A possible combination is presented to meet legal requirements and enhance practicality in operation. This will be discussed using the example of Ac-225 with illustrative scenarios and detection limits to highlight the challenges and limitations of monitoring.

In addition, open questions are outlined: Which routes of exposure are relevant? Which biokinetic models are required? What form might quality assurance measures, such as interlaboratory tests or standardised recommendations for action, take?

The aim is to raise awareness of the practical and methodological issues involved and to stimulate discussion on possible strategies for the internal dosimetry of short-lived alpha emitters.

PWE-04 DEVELOPMENT OF A DIRECTIONAL NEUTRON SPECTROMETER AND ITS APPLICATION IN EPITHERMAL NEUTRON BEAM MEASUREMENT

Author: Zhihui Tang | Co-Author: Hua Li, Liye Liu, Zhenglin Huang, Bowen Sun | Speaker: Zhihui Tang

Directional neutron beams—such as those from accelerator-based neutron sources, horizontal channel beams of nuclear reactors, and epithermal neutron beams of boron neutron capture therapy (BNCT) facilities—play a vital role in nuclear physics experiments, material irradiation testing, medical physics, and radiation protection. These beams typically exhibit a broad energy distribution (from thermal neutrons to several MeV), high flux (often above $109 \text{ n}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$), strong directionality, and a concomitant intense gamma mixed field. Accurate measurement of the neutron energy spectrum is not only essential for beam quality control, treatment planning system input, shielding design verification, and compliance with increasingly stringent radiation protection and clinical quality assurance standards, but also provides data guidance for beamline optimization and upgrading.

Conventional neutron spectrometry methods—the Bonner sphere spectrometer and the multi-foil activation technique—are mature and can generally provide accurate spectrum measurements in the above scenarios. However, the Bonner sphere spectrometer requires sequential measurements using multiple spheres of different sizes, leading to bulky equipment, cumbersome operation, and a measurement time of several hours per session. The multi-foil activation method relies on offline gamma-ray spectrometry, lacks timeliness, and cannot provide real-time on-site feedback. Both methods are ill-suited for special environments that demand narrow-space deployment, high-flux dynamic monitoring, short-interval repeated measurements, and real-time response.

Notably, in 2025 the China Institute for Radiation Protection conducted systematic research on the quasi-directional epithermal neutron field of BNCT. Focusing on the demand for on-site, real-time, and compact epithermal neutron beam measurement, they developed a compact directional neutron spectrometer and successfully applied it to epithermal beam quality assurance at a BNCT facility. This spectrometer uses a cylindrical moderator composed of high-density polyethylene and boron-loaded polyethylene (outer dimensions $\Phi 20 \text{ cm} \times 30 \text{ cm}$). 6 LiF-coated SiC semiconductor detectors are arranged along the axis of the cylindrical probe. Monte Carlo simulations optimized the moderator geometry, radial layered structure, and detector depth distribution, resulting in a response matrix with good energy resolution from thermal to 10 MeV while reducing side-scattering contributions to below 6.5%. In signal processing, pulse width is compressed to avoid pile-up under high-neutron-flux conditions, and an FPGA-based multi-channel parallel pulse acquisition system is implemented. A Windows-based control software with an iterative unfolding algorithm enables remote online operation. After calibration in standard isotope reference radiation fields, the system was tested at the exit of a BNCT beam shaping assembly. The results showed a relative deviation of the measured neutron spectrum below 10%, satisfying the real-time, fast measurement requirements for the high-flux, quasi-directional epithermal neutron beam of BNCT.

The successful development of this directional neutron spectrometer provides a fast, online, and compact measurement tool for BNCT beam quality control, effectively reducing the dependence of clinical quality assurance on specialized physicists and thereby accelerating the clinical adoption and industrialization of BNCT devices. Moreover, the “single-moderator - multiple-detector” integrated design concept and real-time unfolding technique can be adapted to various scenarios by tailoring the moderator and detector designs. Therefore, directional neutron spectrometers hold great scientific significance and engineering practical value in nuclear physics, nuclear engineering, and nuclear technology applications.

PWE-05 DOSE-RATE EFFECTS OF RADIATION RELEVANT TO BREAST CANCER RISK ASSESSMENT: MAMMARY EPITHELIAL CELL DYNAMICS IN A RAT MODEL

Author: Kento Nagata | Co-Author: Daisuke Iizuka, Kazuhiro Daino, Mayumi Nishimura, Shizuko Kakinuma, Tatsuhiko Imaoka, Yukiko Nishimura-Yano | Speaker: Kento Nagata

Objectives / Background: Radiation is a well-established risk factor for breast cancer, and the rat mammary gland provides a valuable experimental model for investigating radiation dose-rate effects. Although DNA double-strand breaks are widely regarded as the initiating lesions in radiation-induced carcinogenesis, the early- and mid-term tissue-level processes that link radiation exposure to subsequent cancer development—particularly those underlying dose-rate effects—remain poorly understood.

Methods: In this study, we analyzed cellular dynamics in the mammary glands of female rats from hours to weeks after irradiation, focusing on basal cells (BCs), luminal progenitor cells (LPCs), and luminal mature cells (LMCs). (1) As an initial response (~24 h), DNA damage was quantified using 53BP1 foci. We then examined mid-term dynamics (2-6 weeks post-irradiation), including proliferation, differentiation, and changes in cell composition.

Results: (1) Although not statistically significant, 53BP1 foci in BCs tended to be fewer than in LPC and LMC at 1 h post-irradiation, regardless of the location. (2) The number of Ki-67-positive LPCs was markedly reduced at 2 weeks after exposure to 2 Gy of γ rays, regardless of whether irradiation was delivered at a high (0.5 Gy/min) or low (0.1 mGy/min) dose rate. Furthermore, flow cytometric analysis revealed a significant, dose-rate-dependent decrease in the proportion of LMCs, which persisted for at least 6 weeks after irradiation.

Conclusions: Our data indicate that prolonged suppression of cell differentiation in mammary epithelial cells precedes radiation-induced breast carcinogenesis. Such prolonged impairment of differentiation may create a tissue microenvironment that favors the expansion of LPCs harboring radiation-induced mutations. Importantly, radiation-induced alterations in mammary epithelial cell composition may represent a key biological mechanism underlying dose-rate effects relevant to cancer risk assessment and radiation protection.

PWE-06 DEVELOPMENT OF A REAL-TIME MONITORING FRAMEWORK FOR INDOOR RADON PROGENY PARTICLE SIZE DISTRIBUTION MEASUREMENTS

Author: Dalma Günter, András Kocsonya, Veronika Groma | Co-Author: | Speaker: Dalma Günter

Objectives / Background: The health effects of inhaled aerosols strongly depend on their deposition within the respiratory tract. Radon progeny contribute significantly to the radiation dose delivered to the lungs, while fine and ultrafine aerosols influence both progeny attachment processes and respiratory deposition. However, currently applied impactor-based methods for measuring radon progeny size distributions are labour-intensive and require substantial post-processing. The aim of this work is to support the development of a novel monitoring approach capable of providing high time-resolution measurements of radon progeny particle size distributions.

Methods: Radon progeny size distributions were investigated using a newly developed measurement system consisting of a Differential Mobility Analyzer (DMA) coupled with an AlphaPM monitor. The system is capable of characterizing radon progeny attached to aerosol particles in the 10 nm-1 μ m size range across up to 64 size channels. Preliminary measurements were performed at several locations within in the campus of the HUN-REN Centre for Energy Research, covering a wide range of indoor radon concentrations.

For validation and complementary aerosol characterization, particle size distributions were also measured using a Scanning Mobility Particle Sizer (SMPS), while radon concentrations were monitored with AlphaGUARD instruments.

Results: Preliminary measurements performed at multiple locations within the institute revealed substantial variability in aerosol and radon-related parameters. Several locations suitable for future measurement campaigns were identified. In an underground indoor environment, radon concentrations exceeding 3000 Bq m⁻³ were observed, while in another room, radon concentrations increased up to approximately 500 Bq m⁻³ under closed conditions. At the latter location, aerosol size distributions remained relatively stable, with particle number concentrations on the order of 10⁴ particles cm⁻³. These environments provide favourable conditions for testing the measurement system and conducting size-resolved radon progeny measurement campaigns. In addition, the preliminary measurements supported the optimization of the instrumentation and confirmed the feasibility of the proposed integrated monitoring approach.

Conclusions / Implications: The ongoing work represents an important step towards the development of a monitoring system capable of determining radon progeny particle size distributions with minimal post-processing requirements. Compared with traditional impactor-based approaches, the proposed methodology offers significantly improved temporal resolution and the potential for continuous long-term monitoring. The project contributes to improved characterization of radon progeny behaviour and supports future studies on respiratory deposition and dose assessment in indoor environments. The proposed monitoring framework contributes to SDG 3 (Good Health and Well-being) by supporting more accurate assessment of inhalation exposure and radon-related lung dose, thereby improving the scientific basis for protecting human health. Furthermore, it contributes to SDG 11 (Sustainable Cities and Communities) by providing advanced monitoring capabilities that support the development of healthier indoor environments and evidence-based indoor air quality management strategies.

PWE-07 DEVELOPING THE NEXT GENERATION OF RADIATION AND RADIOLOGICAL SECURITY PROFESSIONALS IN THE ERA OF EMERGING TECHNOLOGIES: LESSONS FROM AN INTERNATIONAL EXPERT ROUNDTABLE

Author: Suzanne Carlson | Co-Author: | Speaker: Suzanne Carlson

Background: Radiological security is a rapidly evolving field shaped by increasing global reliance on radioactive sources in medicine, industry, research, and emerging nuclear applications. At the same time, new technologies and the shift to digital systems are transforming how radioactive materials are managed and protected. While these developments create significant opportunities to enhance safety and security, they also introduce new challenges for workforce readiness. This study explores key workforce development needs for radiation and radiological security professionals in the context of emerging technologies, with a focus on identifying gaps in training, competencies and professional pathways.

Methods: The study is based on qualitative thematic analysis of discussions from a WINS roundtable of international experts including regulators, operators, international organisations, academia and early-career professionals. The analysis was informed by key themes related to workforce development, interdisciplinary collaboration, training approaches, professional competencies, access and inclusion, and the impact of digitalisation and emerging technologies such as AI. The findings were synthesised to identify consensus views and priority areas for strengthening future workforce capacity.

Results: A strong consensus emerged that radiological security faces a significant workforce development gap driven by limited access to structured training, fragmented disciplinary approaches, and unclear career entry pathways. Early-career professionals were identified as critical to the future sustainability and innovation capacity of the field, yet awareness of career opportunities remains low.

Participants agreed that future professionals must operate in increasingly technology-driven environments and therefore require expanded competencies beyond traditional technical knowledge. These include digital literacy, cybersecurity awareness, and the ability to work effectively with AI-supported and automated systems. However, technological advancement was found to be outpacing workforce preparedness, creating a growing capability gap.

Interdisciplinary collaboration between technical, regulatory and security domains was identified as essential for effective practice. In addition, participants highlighted the importance of practical, hands-on training, early career engagement, and clear professional pathways. Security culture, defined by ownership, accountability and behavioural awareness, was also emphasised as a core component of effective practice. Persistent barriers include unequal access to training, financial constraints, and limited global inclusivity. Mentorship and professional networks were consistently recognised as key enablers of workforce development.

Implications: The findings demonstrate as the nuclear renaissance expands the use of nuclear and radioactive materials across multiple sectors, ensuring the availability of qualified professionals will be essential for maintaining safe, secure and sustainable operations. As digitalisation, automation and AI-driven tools become increasingly integrated into practice, the ability of professionals to adapt to technological change is becoming essential for system resilience. Addressing current gaps requires investment in interdisciplinary, practice-oriented training, improved access to career pathways, and stronger integration of digital competencies into professional development frameworks. Strengthening the next generation of professionals is essential to ensure capacity development keeps pace with technological innovation in order to support the long-term safety, security and sustainability of radiation and nuclear applications.

PWE-08 COMPREHENSIVE EARL ACCREDITATION FOR F-18, GA-68, AND BRAIN PET/CT: A COLOMBIAN INSTITUTIONAL EXPERIENCE

Author: Julian Paez, Oscar Azula | Co-Author: Carlos Enciso, Carolina Cardenas, Marylin Acuña | Speaker: Oscar Azula

Objectives / Background: Quantitative harmonization in PET/CT is fundamental to ensure that biomarkers, such as the Standardized Uptake Value (SUV), are comparable across different institutions and scanner manufacturers. This is vital for therapeutic monitoring and multicenter research. The purpose of this work is to describe the implementation and attainment of EANM Research Ltd. (EARL) accreditation at the Instituto Nacional de Cancerología (Colombia), covering four simultaneous standards: F-18 calibration, Ga-68 calibration, image quality (NEMA), and Brain PET, setting a precedent for excellence in Latin America through the adoption of international harmonization protocols.

Methods: The study utilized a digital Siemens Biograph Vision.X PET/CT system and Capintec dose calibrators (models CRC-25 PET and CRC-55tR). Experimental procedures followed the EARL v4.4 protocol, utilizing uniform cylindrical phantoms, the NEMA IEC Body Phantom, and the Hoffman 3D Brain Phantom. The "one-syringe" methodology was implemented for image quality control. Image reconstruction incorporated clinical parameters. Cross calibration procedures were performed between the PET/CT system and institutional dose calibrators to ensure measurement traceability.

Results: The accreditation process made it possible to identify and address critical technical challenges in institutional practice. In the case of Ga-68, discrepancies in quantification related to the dose calibrator's response were detected, which highlighted the need to strengthen metrological traceability and opened up the possibility of future optimization of patient dosing protocols without compromising diagnostic image quality.

Furthermore, F-18 calibration tests, image quality assessment (NEMA), and brain accreditation confirmed that the institute's acquisition and reconstruction protocols adhere to international harmonization standards.

The resolution of volumetric inconsistencies in the phantoms, achieved through collaboration with the EARL technical team, validated the system's accuracy in recovering contrast and spatial resolution, ensuring that the biomarkers obtained are reproducible and globally comparable.

Conclusions / Implications: The Instituto Nacional de Cancerología is currently the only center in Latin America to hold these four EARL accreditations simultaneously. Beyond technical validation, this process proves that metrological rigor is the guarantor of clinical SUV validity. These results suggest significant opportunities for radiation protection, including the potential reduction of administered doses without compromising diagnostic quality. This success underscores the institution's ethical commitment to high-precision oncological care.

PWE-09 PIONEERING PRECISION ONCOLOGY: HOW THE NUCLEAR MEDICINE DEPARTMENT AT INC ACHIEVED SIX GLOBAL ACCREDITATIONS

Author: Marylin Acuña Hernandez | Co-Author: Humberto Varela Ramirez, Julian Orlando Paez Lopez | Speaker: Julian Orlando Paez Lopez

Background: The Nuclear Medicine Department at the Instituto Nacional de Cancerología (INC) in Colombia is driven by a core mission to provide comprehensive, state-of-the-art cancer care. To elevate patient outcomes and align with the most rigorous international quality standards, the department embarked on a strategic initiative to globally certify its diagnostic and theranostic practices.

Methods: Between 2024 and 2026, the department implemented exhaustive protocol standardization, advanced cross-calibration of imaging systems, and uncompromising radiation safety measures. This comprehensive overhaul targeted the strict accreditation criteria set by the European Society of Radiology (ESR), EANM Research Ltd (EARL), and the International Centers for Precision Oncology (ICPO).

Results: By 2026, the Nuclear Medicine Department successfully consolidated six distinguished Centers of Excellence. The facility earned the EuroSafe Imaging 5-Star Premium rating, standing as the only nuclear medicine department outside Europe to achieve this pinnacle of radiation safety. In targeted radionuclide therapy, it became Colombia's exclusive EARL Theranostics Center of Excellence in 2024, with consecutive recertifications in 2025 and 2026. In molecular imaging, the department secured the EARL PET/CT 18F Standard 2 accreditation in 2025. Strikingly, by 2026, it expanded its portfolio with the EARL 68Ga and EARL Brain/Neurology certifications, making the INC the only institution outside Europe to hold all these EANM/EARL accreditations simultaneously. Concurrently, the department was officially designated as an ICPO Theranostics Clinical Center of Excellence.

Conclusion: Securing these six prestigious international accreditations is a direct realization of the INC's institutional mission. By establishing an unprecedented global benchmark in Latin America,

the Nuclear Medicine Department ensures that patients receive the safest, most highly targeted radiomolecular therapies available worldwide.

PWE-10 IMPACT OF INCORPORATING ORGANICALLY BOUND TRITIUM (OBT) IN PC-CREAM: MODEL INTERCOMPARISON AND SENSITIVITY ANALYSIS

Author: Justin Smith, Lucie Coath | Co-Author: | Speaker: Lucie Coath

Tritium (H-3), being an isotope of hydrogen, follows the water cycle when discharged to the environment and can contribute to the radiation dose received by members of the public. Tritium is released in several forms such as tritiated gas (HT), tritiated water (HTO) and organically bound tritium (OBT). While HT is considered the least hazardous to human health, it gradually converts to HTO in the environment and subsequently to OBT which is of greater radiological concern owing in part to dose coefficients that are approximately twice those of HTO, leading to a greater contribution to committed dose.

The specific activity model for gaseous ^3H releases implemented in UKHSA's PC CREAM radiological impact assessment software currently represents tritium as HTO. However, to further enhance the model's capability and align with evolving scientific understanding, an extension to explicitly account for OBT formation is proposed. This builds on the existing specific activity methodology, retaining its strengths while broadening its applicability.

This presentation compares PC-CREAM existing and proposed H-3 dose assessment models with other approaches. Appropriate source terms are used to estimate the potential impact of organically bound tritium (OBT) on the dose received by members of the public from planned atmospheric discharges. The presentation will compare several models, including the existing SRS-19 model, to assess consistency and understand the factors influencing variability in results.

A sensitivity analysis was undertaken to quantify the influence of key parameters on dose estimates within the new modelling approach. The results provide insight into model robustness and identify the environmental factors that most strongly drive variability in dose outcomes.

PWE-11 A TIME-DEPENDENT AC-225 DECAY CHAIN SOURCE MODEL FOR CELLULAR DOSIMETRY INCLUDING RECOIL NUCLEI: A FORRCE PROJECT CONTRIBUTION

Author: Maria Luz Olaguibe | Co-Author: Ana Vaniqui, Filip Vanhavere, Omar Garcia Garcia, Stephen McMahon, Yann Perrot | Speaker: Maria Luz Olaguibe

Background: Targeted radionuclide therapy (TRNT) delivers radiation through radiopharmaceuticals that selectively bind to cancer cells. Ac-225 is particularly promising, as its decay chain releases multiple α -particles enabling highly localized energy deposition and complex DNA damage. However, current dosimetry models assume a time-independent decay spectrum in secular equilibrium, neglecting temporal evolution and recoil nucleus contributions. This work is developed within the FORRCE project (Framework for Outcomes of Radionuclide Radiation on Cellular Environment), funded by PIANOFORTE, which aims to advance the understanding of dose-response relationships in TRNT through a modular, mechanistic framework bridging physical energy deposition with biological outcomes across multiple spatial and temporal scales. In this context, we present a time-dependent Ac-225 source model that accounts for both α -emission and recoil nuclei across multiple cellular geometries, providing a more realistic dosimetric scenario for subsequent scoring of DNA damage distribution and subcellular dosimetry estimation

Methods: Monte Carlo simulations were performed using a custom OpenTOPAS extension implementing Bateman equations for the Ac-225 decay chain. Spherical and ellipsoidal cell geometries were embedded in cubical, spherical, and spheroidal irradiation media. A phase space scorer recorded α -particle energy spectra and absorbed dose to cell and nucleus. All cases were simulated under equal activity and volume conditions.

Results: For a spherical cell, a spherical emission medium yielded 10% higher absorbed dose compared to a cubical medium, consistent with more uniform source exposure. When comparing cell shapes using conformal emission shells of equal volume and activity, the ellipsoidal cell received 54% higher absorbed dose than the spherical cell, despite approximately 50% fewer particles reaching its surface. This results from two compounding geometric effects: a non-isotropic source distribution relative to the flattened geometry, and preferential traversal of the longer semi-axis among particles that do reach the cell, increasing Bragg peak containment within the cellular volume. Recoil nuclei contributed less than 0.12% of total absorbed dose. The temporal evolution of the α -energy spectrum was also characterized, showing the growing contribution of decay chain daughters over time.

Conclusions: Both emission medium geometry and cellular shape significantly influence absorbed dose, with the ellipsoidal cell configuration yielding the highest dose deposition despite receiving fewer incident particles at its surface, as a result of geometric self-shielding effects within the flattened cell volume. While medium geometry was varied here to characterize these effects systematically, in realistic exposure scenarios cells are typically embedded in much larger volumes and exposed to particles from a wide range of distances and directions (e.g., adherent to a culture surface or embedded in a 3D matrix); the surrounding medium shape itself is therefore expected to be of secondary importance compared to the local source distribution and cell geometry. The low recoil nucleus contribution at the cellular surface is consistent with a non-internalized radiopharmaceutical distribution.

Future work will extend the framework by incorporating a radiopharmaceutical concentration gradient model, investigating cell internalization scenarios, and expanding to more realistic cellular geometries.

PWE-12 INTEGRATING STAKEHOLDER NEEDS INTO RADIATION PROTECTION RESEARCH ACROSS DISCIPLINES

Author: Jelena Mrdakovic Popic | Co-Author: Mandy Birschwilks, Andreas Blume, Almudena Real, Florian Rauser | Speaker: Jelena Mrdakovic Popic

Radiation protection research supports decision-making in healthcare, environmental protection, industry, emergency preparedness, and public health. However, research priorities are often defined primarily by scientific communities, while the needs of end-users, regulators, practitioners, and society may remain underrepresented. The European Partnership PIANOFORTE established a comprehensive stakeholder engagement framework to systematically integrate stakeholder perspectives into strategic planning, research prioritisation, partnership implementation, and knowledge mobilisation. The objective is to ensure that radiation protection research addresses societal challenges, policy needs, and emerging scientific questions, while enhancing its transparency, relevance, and impact.

PIANOFORTE developed a multi-level stakeholder engagement strategy based on three complementary pillars: (1) collaboration with international organisations, European partnerships, research platforms, and industry networks; (2) establishment of a multidisciplinary Stakeholder and Advisory Board (SAB); and (3) direct engagement through surveys, workshops, and online consultations. User and societal needs were collected and analysed within the framework of a

dedicated Stakeholder Engagement Plan and integrated into research prioritisation using transparent evaluation criteria, ranking exercises, and social multi-criteria analysis. Engagement activities were tailored to a diverse matrix of external stakeholders to ensure that their perspectives were systematically considered in the preparation of research and innovation (R&I) calls and the Strategic Research and Innovation Agenda (SRIA).

A Europe-wide online survey collected responses from 440 participants representing 34 countries and a broad range of stakeholder groups, including regulators, researchers, healthcare professionals, industry representatives, and civil society organisations. Approximately 70% of respondents were first-time participants in radiation protection consultations, demonstrating successful outreach beyond traditional expert communities. The survey identified priority topics including health effects of radiation exposure, optimisation of medical applications, protection of workers and the public, emergency preparedness, and integrated environmental risk assessment.

To ensure that stakeholder perspectives directly influenced research funding priorities, four topical online stakeholder meetings were organised during the partnership. These consultations brought together representatives from academia, regulatory authorities, healthcare, international organisations, consultancies and civil society to discuss and rank candidate research topics for PIANOFORTE Open Calls. The resulting input was systematically analysed and incorporated into the prioritisation process, ensuring that research funding priorities reflect real-world needs and expectations.

In addition, two high-level European workshops were organised to address emerging challenges related to global threats, radiation safety, security, resilience, and preparedness, providing strategic input for future research directions and policy development.

PIANOFORTE demonstrates that structured and transparent stakeholder engagement can successfully bridge the gap between science, policy, practice, and society. By embedding stakeholder input throughout the research lifecycle, the partnership enhances the relevance, legitimacy, and uptake of radiation protection research. The approach provides a transferable model for collaborative governance and evidence-based priority setting, thereby supporting more responsive and impactful European research programmes that are better equipped to address future radiation protection challenges.

PWE-13 APPLICATION OF RADIATION CONSEQUENCE CODES FOR SMALL MODULAR REACTORS

Author: Adam Kecek, Klara Jurcakova, Anna Selivanova, Jan Crha, Hana Hustakova | Co-Author: | Speaker: Anna Selivanova

The decision support system JRODOS is routinely used within the UJV Rez and SURO to assess potential radiological consequences beyond the boundaries of nuclear power plants. In contrast to traditional nuclear power plants, small modular reactors (SMRs) are likely to be located in or near urban settings, where complex flow behavior and a reduced plant footprint bring the facility's boundaries much closer to nearby infrastructure. With the anticipated deployment of SMRs, the need to evaluate such scenarios in new environments becomes increasingly important.

To examine the performance of JRODOS under these conditions, model predictions were compared with wind-tunnel measurements for a scaled representation (1:800) of a potential SMR site situated in an industrial zone of Prague. The site was selected to capture two distinct inflow regimes: highly turbulent flow generated by dense urban structures under westerly winds, and comparatively less turbulent flow from open, semi-rural surroundings under easterly winds.

This contribution presents the methodology used for the comparison, discusses the agreement between measured and simulated dispersion patterns, and highlights key considerations for applying JRODOS in the context of future SMR deployments.

The works presented here were carried out within the RACOPSAC (Radiation consequences of postulated accidents of SMRs - TS01010162) joint project of UJV Rez, NRPI and Institute of Thermomechanics, CAS, and has been supported by Technology Agency of the Czech Republic with the aim to overcome new challenges and to support the State Office for Nuclear Safety.

PWE-14 PTB REFERENCE SITES FOR ENVIRONMENTAL DOSIMETRY: A UNIQUE INFRASTRUCTURE FOR INTERCOMPARISONS AND RESEARCH

Author: Faton Krasniqi | Co-Author: Amer Al-Qaad, Ulf Stolzenberg | Speaker: Faton Krasniqi

This contribution provides an overview of PTB's reference sites and facilities supporting the intercomparison, calibration and performance assessment of counting and spectrometric dosimetry systems. These measurement infrastructures include the Environmental Radiation Dosimetry Site (ERADOS), the Cosmic Radiation Dosimetry Site (CORADOS), the Underground Laboratory for Dosimetry and Spectrometry (UDO II), and the free-field reference site equipped with a photon irradiation facility, the so-called plume simulator. The plume simulator is designed to reproduce the radiological conditions associated with a bypassing radioactive plume, such as those that may occur during a nuclear or radiological emergency.

The objective of this contribution is to show how these complementary infrastructures can be used to support traceable measurements, harmonized environmental monitoring procedures and the evaluation of detector systems under well-defined radiation-field conditions. The presented approach is based on the use of site-specific exposure conditions, ranging from terrestrial radiation fields and secondary cosmic radiation to low-background underground conditions and controlled photon irradiation scenarios.

The measurement infrastructures presented here provide a metrological basis for comparing detector responses, assessing measurement procedures and supporting the development and validation of monitoring systems for field deployment. Beyond routine intercomparisons and metrological quality assurance, they also provide a platform for projects related to emergency preparedness and response, environmental radiation monitoring, climate- and environment-related studies, and the assessment of radiation detection systems.

By enabling controlled yet realistic measurement scenarios, these facilities contribute to improving the reliability, comparability and operational readiness of monitoring systems used to protect people and the environment.

PWE-15 H*(10) RESULTS FOR THE SPECTRODOSIMETRY AND CLASSICAL COUNTING SYSTEMS IN THE EURADOS INTERCOMPARISON IC2024SPEC

Author: Ulf Stolzenberg | Co-Author: Faton Krasniqi | Speaker: Ulf Stolzenberg

The EURADOS intercomparison IC2024spec, conducted in September 2024 at the PTB environmental reference sites, investigated the performance and harmonization of novel spectrodosimetry systems for environmental radiation monitoring. Following the completion of the measurement campaign, the collected data have now been fully analyzed, allowing a quantitative assessment of the basic instrument parameters of the participating systems under realistic field conditions.

The results identify systematic differences in energy response, dose rate estimation, and inherent background, highlighting both strengths and limitations of advanced spectrodosimetry systems. Based on these findings, recommendations for improved calibration and characterization strategies are derived, supporting more robust and harmonized environmental radiation measurements across European monitoring networks.

This contribution presents the final results of IC2024spec and discusses their implications for future calibration practices and quality assurance in environmental dosimetry.

PWE-16 DEVELOPMENT AND VALIDATION OF AN INTERNAL DOSIMETRY FOR ACTINIUM-225 THROUGH EXCRETION ANALYSIS

Author: Raashina Ulakanathan-Thavarajah | Co-Author: Katja Weinert, Carsten Wanke, Lilly Geworski, Sven Hartmann | Speaker: Raashina Ulakanathan-Thavarajah

*Actinium-225 (Ac-225) is becoming increasingly important as a promising alpha-emitting radionuclide in the field of nuclear medicine, which is reflected in the growing global demand for Ac-225 production, clinical application and waste disposal. Several Ac-225-based radiopharmaceuticals are currently being tested in clinical studies for targeted alpha therapy at multiple medical facilities. Due to the handling of high activities in the MBq range and the potentially high dose coefficient, a reliable method for occupational internal dosimetry is required. However, to date, no validated method for the *in vitro* excretion analysis of Ac-225 has been published.*

This work presents an excretion analysis for the determination of Ac-225. A combination of coprecipitation and ion chromatography, along with the internal tracer americium-243 (Am-243), was used to determine Ac-225 in urine samples. Initial laboratory-scale investigations focused on optimizing parameters like coprecipitation methods, resin materials and pH values to maximize recovery. Promising results were obtained in these laboratory-scale investigations, achieving radiochemical yields of over 50 % for Ac-225 and over 70 % for Am-243 tracer. A pilot phase is currently being conducted to evaluate method performance and practical applicability under real working conditions. Employees from different fields of work and institutions who handle Ac-225 provide urine samples after potential occupational exposure. To provide a reliable positive control for method validation, urine samples from patients following treatment with an Ac-225-labelled radiopharmaceutical will be analyzed in parallel.

The pilot phase aims to assess the transferability, robustness and practicability of the developed method for future occupational monitoring of Ac-225 exposure. This will significantly contribute to the standardization of radiation protection practices for occupational exposure to Ac-225.

PWE-17 THE IMPACT OF CO-OCCURRING CHEMICAL AND PHYSICAL STRESSORS ON ENVIRONMENTAL RADIATION HAZARD

Author: Boguslaw Michalik | Co-Author: | Speaker: Boguslaw Michalik

Background: Environmental radiation protection typically treats ionizing radiation as the primary hazard, assuming radionuclides act within unaltered ecosystems. Most exposures occur in anthropogenically modified environments, agricultural, urban, and industrial, where chemical and physical stressors co-occur. Assessing hazard based solely on radioactivity may therefore either overestimate or underestimate actual risk, particularly in NORM-related scenarios.

Methods: Co-occurring stressors were evaluated at three levels: (1) biological effects and their contribution to overall hazard; (2) migration processes, exposure pathways, and scenario specificity; and (3) hazard mitigation strategies. Radiological and toxicological frameworks were compared in terms of units, dose-response models (linear no-threshold vs. threshold-based), and regulatory approaches. The analysis also considered the environmental behavior of radionuclides and chemically analogous stable elements, emphasizing the roles of speciation and geochemical conditions. The effectiveness of conventional occupational health and safety (OSH) and waste management systems was also assessed.

Results: Radiation and chemical toxicants act via distinct mechanisms but often produce similar biological outcomes. Combined exposures may therefore be synergistic or antagonistic, rather than additive, as illustrated by radon-smoking interactions. Direct comparison of chemical toxicity and radiotoxicity remains limited by incompatible metrics and regulatory fragmentation. Environmental mobility and then exposure scenario depend strongly on chemical behavior, (e.g., radium-barium co-precipitation as sulphate) with uranium representing a case where chemical toxicity may dominate depending on the isotope considered. Existing OSH and waste management measures for carcinogenic, mutagenic, and teratogenic agents are generally effective for radionuclides when supplemented with controls for external exposure and radon.

Conclusions: Accurate hazard assessment in modified environments requires integrated consideration of radiological, chemical, and physical stressors, particularly in NORM contexts. Because interactions between stressors can modify final exposure scenarios, each case should be evaluated individually. Integrating radiation protection into established OSH and waste management systems is both scientifically justified and practically feasible, despite regulatory inconsistencies.

PWE-18 EVALUATION OF A CUSTOM 3D-PRINTED EYE LENS DOSIMETER ADAPTER FOR RADIATION EXPOSURE MONITORING IN INTERVENTIONAL PROCEDURES.

Author: Georgios Kyranos | *Co-Author:* Argiro Boziari, Chariklia Kyrgiakou, Eleni Papadomarkaki, Eleni Stamatopoulou, Panagiotis Askounis, Sofia Karagianni, Efthimios Karabetsos | *Speaker:* Georgios Kyranos

Background: The Dosimetry Laboratory of the Dosimetry and Calibration Unit (DCU) at the Greek Atomic Energy Commission (EEAE) has provided accredited dosimetry services under EN ISO/IEC 17025 for over 25 years, currently monitoring more than 12000 workers on a monthly basis, using Thermoluminescent Dosimetry (TLD) systems. Over the past decade, in alignment with ICRP recommendations, the DCU integrated eye lens dosimeters (Eye-D) to estimate the personal dose equivalent, $H_p(3)$ for radiation-exposed workers, primarily those who are involved in interventional procedures.

The conventional configuration utilizes the Eye-D, comprising a LiF: Mg, Cu, P detector enclosed in a dedicated holder and worn on an elastic headband. This configuration presents several operational challenges in practice. These include user discomfort, unstable or non-representative detector positioning, lack of compatibility with standard radiation protection goggles, and potential shielding by the worker's head when facing high-angle radiation incidences opposite to the dosimeter.

Methods: To overcome these limitations, the DCU designed a novel, versatile cover that can be securely attached either to an elastic headband or directly onto radiation protection goggles using a custom-engineered adapter. The components were designed using Computer-Aided Design (CAD) software and fabricated in-house utilizing Fused Deposition Modeling (FDM) 3D printing technology.

Results: This study presents the experimental evaluation of this new configuration. The energy and angular responses of both the conventional headband assembly and the new goggle-adapted assembly are characterized. Furthermore, measurements from both setups are compared against a reference dosimetric element placed inside an anthropomorphic phantom to determine which configuration offers the most accurate and representative estimation of eye lens dose.

Conclusion: Optimizing eye lens dosimetry is crucial for the radiation protection of medical staff. This study aims to validate a comfortable, ergonomically sound, and accurate 3D-printed solution developed by the DCU which seamlessly integrates into the daily workflow of exposed workers in interventional procedures while ensuring dosimetric reliability.

PWE-19 PRESENTATION OF A MULTIPLE DONOR DOSE-RESPONSE CALIBRATION CURVE AND COMPARATIVE METHODOLOGIES FOR DICENTRIC CHROMOSOME ASSAY (DCA)

Author: Anna Francès-Abellán | Co-Author: Pere Puig, Pablo Carrasco, Jaime Pérez-Alija, Gemma Armengol, Joan Francesc Barquinero | Speaker: Anna Francès-Abellán

After any radiological accident, there is a need to use validated biomarkers (e.g. dicentric chromosomes) capable of quickly determine radiation exposure with sufficient accuracy for an initial classification and medical management. Following ISO19238 2023 guidelines, DCA calibration curves should be constructed from at least two adult, healthy donors and data should be pooled from these multiple donors. In this study we present two dose-response calibration curves for DCA (manual and semi-automatic) following X-ray exposure, using in vitro irradiated peripheral blood samples from three different healthy donors. In addition, it proposes a methodology to assess inter-donor variability and determine whether significant differences exist between donors, allowing this variability to be accounted for during curve fitting. Strategies for addressing such variability are also presented. Samples were exposed to doses of 0, 0.1, 0.25, 0.5, 0.75, 1, 2, 3, 4, and 5 Gy at the Radiation Physics and Protection Service of Hospital de la Santa Creu i Sant Pau (Barcelona, Spain), using a linear electron accelerator (6 MV (TPR_{20,10}) = 0.665; dose rate: 0.99338 Gy/min). After standard cytogenetic culture protocol, dicentrics were manually scored: up to 2500 metaphases/donor for 0 Gy and up to 1000 for doses from 0.1 to 0.5 Gy. For doses from 0.75 to 5 Gy dicentrics were counted up to 100 per metaphase or at least 100 metaphases were counted per donor. For the semi-automatic calibration curve, the frequency data was generated by scanning the same slides using the DCSScore module integrated into Metafer 3.12.11 which was reviewed using a quick scan technique. Finally, dose-response curves for each donor were fitted using the Biodose Tools software and methods for evaluating differences between donor-specific curves are presented. Upon further validation, this work is intended to be added into the online Biodose Tools platform as a new module.

PWE-20 WASHING STRATEGY FOR SOILS CONTAMINATED WITH RADIONUCLIDES: STRONTIUM AND COBALT

Author: Concepción Olondo Castro | Co-Author: Maria Teresa Rodriguez, Astrid Varona, Erik Sandonis, Naiara Rojo, Raquel Idoeta | Speaker: Concepción Olondo Castro

Objectives and background: The development of advanced and efficient technologies is essential to remediate soils contaminated with radionuclides and, consequently, to reduce waste generation. The dismantling of nuclear power plants is the main source of large quantities of low- or medium-level radioactive soils that require permanent disposal in specialized facilities if they are not treated properly. Thus, soil washing has emerged as a remediation alternative that has the advantages of flexible application, simple operation, high removal efficiency and short operating

time. Nevertheless, search on effective and cost-effective washing agents for radionuclide decontamination in soils is challenging.

The main objective of this study is to optimise the conditions for effectively cleaning soil contaminated with strontium and cobalt through laboratory tests, and to extrapolate these results for subsequent industrial application.

Methods: Five types of soil, representative of those found at Spanish nuclear power plants, were studied as part of the experimental study. Caesium and cobalt are gamma emitters; with the aim of simplifying analytical methods, these soils were contaminated with Sr-85, a gamma emitter instead of Sr-90, a pure beta emitter. Four different chelating compounds have been selected as the washing agent to probe their ability to decontaminate the soil: the commonly used KCl and oxalic acid and GLDA and HIDS, a more sustainable candidates than the widely documented ethylenediaminetetraacetic acid (EDTA) because they are considered biodegradable, with more than 60% biodegradation occurring within 28 days (according to the OECD 301D protocol).

Results: The results show that the highest washing efficiency is obtained by using an aqueous solution of GLDA 0.05 M at pH 5 and HIDS 0.05 M at pH 9.5 with agitation for 2 hours. Under these conditions, 90% elimination of radiostrotium and 84% elimination of radiocobalt (reaching the conditional classification level of 1.5 Bq/g from values of 5 Bq/g), has been obtained which is considerably higher than the elimination obtained by water washing (around 10%).

Conclusions: The combination of a washing agent such as the biodegradable GLDA and HIDS with vigorous agitation rendered the higher elimination efficiency of two radionuclides from the laboratory contaminated soils. Despite these promising results, other practical aspects should be carefully considered, such as, cost and market availability, real biodegradability of the chelator in the liquid residue, or final composition of the soil for future uses.

PWE-21 A SUMMARY OF CURRENT FINDINGS FROM THE IMMPRINT PROJECT: INTEGRATED MOLECULAR IMAGING FOR PERSONALIZED BIOMARKER-BASED BREAST CANCER CHARACTERIZATION AND TREATMENT

Author: Kunal Kumar | **Co-Author:** Andrej Studen, Axel Boese, Balázs Gyebrovski, Cecilia Riani, Carlos Lacasta, Christoph Hoeschen, Christoph Janiak, Dejan Žontar, Gabriela Llosá, Jelena Ninković, Johannes Treis, Julia Overhoff, Karol Brzeziński, Katalin Balázs, Katalin Lumniczky, Marko Mikuz | **Speaker:** Kunal Kumar, Xiaolei Yan

Objectives/Background: Breast cancer remains one of the leading causes of cancer-related deaths worldwide, with high levels of disparities in diagnosis, prognosis, and treatment outcomes of patients, largely attributed to the disease's heterogeneity. Despite advancements in individualised approaches, significant disparities persist. This is attributed in part to the lack of precise, integrated information at the tumor level, currently unavailable due to the absence of suitable, synergistic imaging tools. The IMMPRINT project, part of the EU-funded PIANOFORTE initiative, contributes towards the development of disease-optimized imaging tools for future *in vivo** applications in breast cancer by improving our understanding of tumor characteristics and by guiding further work on practical instrumentation. Specifically, IMMPRINT focuses on developing an advanced molecular imaging technique (i.e., X-ray fluorescence computed tomography - XFCT), supported by concurrent development of novel nanoparticles (NPs) as contrast probes, targeted-biomarkers, and application-specific particle-detectors, to enable high-resolution quantitative insights into breast tumor characteristics.

Methods: IMMPRINT is organized into five interconnected work-packages (WPs):

- WP1 performs technical developments, conceptualizing an integrated XFCT imaging technique aimed at characterizing breast cancer disease.
- WP2 provides framework and recommendations for nanoparticle development, focusing on gold NPs as contrast probes for imaging, optimizing NP stability, sizes, functionalization, and bioconjugation.
- WP3 characterizes breast cancer and its markers, concurrently identifying suitable targets for XFCT and facilitating NP design.
- WP4 develops application-specific, optimized particle detectors for XFCT technique.
- WP5 manages project-execution, impact-creation, dissemination, communication, knowledge management, and E&T activities.

Results: **In silico** Monte Carlo (MC) studies in WP1 have identified Gadolinium, Hafnium, and Gold as candidate probes for heterogeneity characterization using XFCT technique, with detection sensitivity of a few-tens-of-ppm (few-tens-of ng/mL in breast under **in vivo** conditions). WP1 has commissioned a prototype XFCT system based on identified optimal imaging parameters and specifications from MC studies, with experiments ongoing. WP2 has synthesized reproducible, polymer-coated, FITC-labelled gold NPs with improved stability and various sizes/morphologies. These NPs serve as tailored imaging agents with potential for coupling therapeutic agents for theranostic use. WP3 has characterized HCC38 and MCF7 breast-cancer- and MCF10A control-cell-lines, demonstrated NP uptake via flow cytometry, and studied cytotoxicity using several viability assays. Cellular uptake of NPs proved to be time- and concentration-dependent in each cell-line. Of all tested NPs, PLA-, Chitosan-, and PVA-coated gold NPs yielded the highest uptake (above 60%, in HCC38 cells after 4 hours incubation). WP4 has developed a proof-of-principle pnCCD detector concept for integration into WP1 XFCT system, consisting of a compact, operational stack of up to four detector-plane-assemblies; the first version of IMMPRINT hybrid printed-circuit-boards was manufactured for further testing with radiation sources.

Conclusions/Implications: Findings related to the imaging approach, breast cancer characterization, and NP synthesis techniques within IMMPRINT could serve instrumental in future development of practical early-stage medical devices and instrumentation, refining further research by expanding current evidence base, and informing future directions in breast cancer and radiation-protection research.

Funding: This work received funding from the Euratom research and training programme 2022-2027 in the framework of PIANOFORTE under grant agreement No.101061037

PWE-22 SUCORA PROJECT: ESTABLISHING THE CRITERIA FOR THE CONSIDERATION OF RADIOLOGICALLY CONTAMINATED SOILS IDENTIFYING THE KEY PARAMETERS OF DOSE-ASSESSMENT MODEL PARAMETERS: A SENSITIVITY ANALYSIS

Author: Concepción Olondo Castro | *Co-Author:* Evelin Tatiana Mora-Carrillo, Anna Rigol, Sebastian Martorell, Juan Pedro Bolivar, Rafael Garcia-Tenorio | *Speaker:* Concepción Olondo Castro

Objectives and background: SUCORA is a project that, supported financially by the CSN (Spanish regulatory body), is developed by a consortium of teams from five Spanish universities for whose main objective is to analyse the current international situation regarding strategies for dose estimation and the establishment of release levels for radiologically contaminated soils, providing to CSN a tool and methodologies to determine the activity concentration levels required to classify soil as radiologically contaminated.

The appropriate declaration of radiologically contaminated soils requires the estimation and establishment of appropriate activity concentration release levels in accordance with the national site release criteria. Dose estimation models have been developed to facilitate the definition of

the derived concentration guide levels (DCGL) required to classify a soil as radiologically contaminated and the integration in those models of the site specific data and representative national input parameters can be significantly improved the uncertainties that contributes to resultant doses. This work focus on the definition of the key input parameters that influence most dose estimation performing a sensitivity analysis.

Materials and Methods: RESRAD-OFFSITE model has been applied to former industrial NORM site modelling an urban-residential scenario: detached houses with the option of a small garden for growing their own produce.

Considered natural radionuclides are Ra-226, Pb-210, U-234 and U-238 and total dose is calculated for following exposure pathways: external radiation, inhalation of resuspended material, food ingestion and soil ingestion. Doses estimation has been performed for age ranges considered by ICRP 72.

For determining the key parameters that influence in dose estimation, a multiparametric sensitivity analysis has been perform for each radionuclide and for the most vulnerable age range.

Results: The sensitivity analysis for <1 age year shows that the system's response depends significantly on the radionuclide in question, reflecting different dominant exposure mechanisms. U-238, for example, exhibits behaviour predominantly governed by external exposure ('pure external'), while Ra-226 shows a mixed response influenced by both external exposure and ingestion. Pb-210, on the other hand, is dominated by the dietary route and demonstrates high sensitivity to soil-to-plant transfer parameters.

Conclusions: Obtained results highlight the importance of conducting specific analyses for each isotope to adequately assess radiological risk, as it is inappropriate to assume uniform behaviour across radionuclides.

PWE-23 ASSOCIATIONS BETWEEN NATURAL RADIONUCLIDES IN BOREHOLE WATER AND OVERALL AND SITE-SPECIFIC CANCER RISK: A COMPREHENSIVE POPULATION-BASED STUDY FROM FINLAND

Author: Peng Li, Pekka Martikainen, Mikko Myrskylä | Co-Author: | Speaker: Peng Li

Background: Carcinogenic effects of radioactive elements in environmental background for all cancer types have not been fully investigated.

Methods: This paper assesses the associations between radioactive elements in borehole water and all cancer types based on total Finnish population. National registries of the general population living continuously in Finland during 1987-2016 were linked to annual municipality-level concentrations of uranium (Ur) and radon (Rn) in borehole water. Average radiation exposures over 30 years were calculated individually based on residential location annually. Newly diagnosed cancers were followed from 2017 until 2021 based on national cancer registry. Associations between exposures and cancer incidences were assessed via Cox proportional hazards models, adjusted for pre-existing health conditions and socio-economic factors. Multiplicity was adjusted using Bonferroni correction.

Results: Totally 1,013,054 men and 1,101,589 women with non-missing municipality-level exposures were included. During follow-up period, totally 62,085 cancer cases of 70 sub-types were diagnosed in men and 57,627 cancer cases of 73 sub-types were diagnosed in women respectively. Significant associations between environmental radiation exposures and elevated risks of cancer were observed in men (Ur: hazard ratio [HR] 1.05, 95% confidence interval [CI] 1.03-1.07; Rn: 1.04, 1.02-

1.05) and women (Ur: 1.07, 1.05-1.09; Rn: 1.05, 1.03-1.07). After correction of multiplicity, significantly elevated risks were observed for cancers of uncertain lymphoid and hematopoietic tissue (1.66, 1.39-1.97), mesothelioma (1.48, 1.18-1.86), myeloma (1.36, 1.18-1.57), melanoma (1.31, 1.22-1.40), leukemia lymphoid (1.28, 1.12-1.48) in men with higher exposure to Ur; and Polycythemia vera (1.79, 1.30-2.45), uncertain lymphoid and hematopoietic tissue (1.61, 1.36-1.91), myeloma (1.52, 1.32-1.75), melanoma (1.22, 1.14-1.31) and bladder (1.20, 1.08-1.32) with higher exposure to Rn. Significantly elevated risks were observed for uncertain lymphoid and hematopoietic tissue (1.78, 1.52-2.08), leukemia lymphoid (1.48, 1.24-1.77), melanoma (1.33, 1.24-1.44), lung (1.26, 1.19-1.34) and breast (1.07, 1.04-1.10) in women with higher exposure to Ur; and uncertain lymphoid and hematopoietic tissue (1.73, 1.48-2.03), Polycythemia vera (1.72, 1.26-2.35), myeloma (1.51, 1.30-1.75), melanoma (1.28, 1.19-1.38) and lung (1.21, 1.14-1.29) with higher exposure to Rn. In sensitivity analysis, similar patterns were observed in samples who only lived in houses during 1987-2016. Dosage-response trends were observed for total cancer risks in men and women respectively.

Interpretations: High environmental radiation exposures were significantly associated with elevated total cancer risks and several sub-types in the general population.

PWE-24 AN INVESTIGATION OF LONG-TERM PROGRESSION OF CAROTID INTIMA MEDIA THICKNESS IN A COHORT OF CHORNOBYL CLEAN-UP WORKERS: INTEGRATING MOLECULAR, SUBCLINICAL, AND LIFESTYLE FACTORS

Author: Joshua Louis Ziegler | Co-Author: Alicia Schulze, Daniel Wollschläger, Dmitry Bazyka, Federico Marini, Konstantin Strauch, Matthias Port, Michael Abend, Nikolai Schmid, Patrick Ostheim, Samantha Stewart, Stefan Eder | Speaker: Joshua Louis Ziegler

Objective: Exposure to ionising radiation above 0.5 Gy is a well-established risk factor for diseases of the circulatory system (DCS), whereas risks at lower doses are currently uncertain. The Chornobyl clean-up workers (CCW) cohort provides a unique opportunity to investigate long-term health effects of low-to-moderate radiation exposure relevant to current occupational settings. This study examines associations between radiation exposure, gene expression changes, and subclinical markers of atherosclerosis, including carotid intima-media thickness (CIMT), in biannual follow-ups over five years. Given a long time since exposure of nearly 40 years, lifestyle factors, such as smoking and BMI, are considered as possible confounders. The findings contribute to the United Nations Sustainable Development Goal 3. This study is conducted within the European Defence Fund (EDF) RESILIENCE R 2023 sub-project 2.

Methods: At baseline, the cohort included n=400 male CCW aged 51-62 years, first examined during in-hospital visits in Ukraine in 2019-2020 (t0). Follow-ups were conducted in 2022 (t1, n=302) and 2024 (t2, n=247). Participants were exposed to cumulative effective doses of 1-990 mSv (median=150 mSv) during clean-up work at the Chornobyl nuclear power plant in 1986-1989. A linear mixed model (LMM) for repeated measurements was applied to model progression of left CIMT associated with radiation dose. The model allowed a random intercept by CCW and adjusted for pack years, body-mass-index (BMI), age at baseline, and time since baseline. Blood samples were collected at all three time points for transcriptome analysis (RNA and small RNA sequencing) to be integrated in a structural equation model (SEM) at a later stage.

Results: Ultrasound measurements of CIMT were available at t0 and t2 for 232 CCW. CIMT increased for 157 (67%) CCW, remained stagnant for 59 (25%) and decreased for 16 (7%). At t0, mean CIMT of the left carotid artery was 0.74 ± 0.17 mm, with mean increase of 0.133 ± 0.141 mm until t2. In our model, CIMT was estimated to decrease by 0.03 mm/Sv (95%CI -0.11-0.04), with wide confidence intervals.

Conclusion: This cohort offers a unique opportunity to study the long-term effects of low to moderate radiation exposure on DCS at a subclinical and molecular level. Based on a LMM, no association between radiation dose and progression of CIMT could be confirmed. Further analyses integrating additional subclinical markers and gene expression changes in a SEM could help distinguish pathways of radiation effects on atherosclerosis.

Disclaimer

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PWE-25 CHARACTERIZATION OF CUSTOM G-CODE CALIBRATION PHANTOMS FOR TISSUE EQUIVALENCE STUDY

Author: Victor Bender | Co-Author: Beatrice Schneider, Cristina Chifu, Christoph Hoeschen | Speaker: Victor Bender

Objectives / Background: The deployment of artificial intelligence (AI) could enhance Image-Quality (IQ) in Low Dose Computed Tomography (LDCT) settings thus reducing patients dose exposure. However, the deployment of AI in the medical settings requires special attention as potential misdiagnosis is a critical concern for patient safety. Verification methods have to be developed to test the AI-methods on their robustness and accuracy. 3D printing is one avenue explored to create verification phantoms, in which the ground truth is known. Those verification phantoms allow for adaptability of critical structures e.g. pathologies to ensure the creation of new structures which have not been seen by the AI-method before. Conventional slicing methods to generate G-code instructions for 3D-Printers were not made with the needs of medical imaging phantoms in mind, therefore an adaptation is required to manufacture anthropomorphic phantoms. This PHD Project resulting from the internal call 2025 (co-funded by the European PIANOFORTE partnership) aims to develop anthropomorphic imaging phantoms for verification of AI-based IQ enhancements and definition on regulatory needs.

Methods: To this aim, we devised an inhouse method of generation for G-code instructions to create dynamic infill on section-by-section basis within a single print. This method is used to create calibration phantoms using a wide range of different print settings. Those phantoms are then characterized by performing CT scans using relevant scan protocols and reconstruction filters. The resulting images are used to analyze Hounsfield Units (HU) and noise characteristics (NC) between different regions. This information is then used to build Look-Up-Tables (LUTs) and compared versus Region-Of-Interest (ROI) derived from patient image data to find patient tissue equivalence print settings.

Results: The in-house G-code generator was used to create 3D-printer instructions. Using these instructions, first calibration phantoms were produced and are currently being characterized.

Conclusions / Implications: The material and print setting study allows for better understanding of properties and limits of 3D-printed phantoms. The LUTs will allow for as close as possible patient tissue equivalence. This will help in the creation of anthropomorphic phantoms usable for verification of AI-based IQ enhancements.

PWE-26 IMPACT OF THE NEW OPERATIONAL QUANTITIES ON THE DOSIMETRY OF MEDICAL STAFF WEARING PROTECTIVE APRON

Author: Jérémie Dabin, Mahmoud Abdelrahman, Joanna Domienik-Andrzejewska, Mateusz Mirowski, Filip Vanhavere | Co-Author: | Speaker: Filip Vanhavere

Background: For most workers, the effective dose (E) is estimated by measuring the personal dose equivalent $H_p(10)$ with a physical dosimeter. In interventional radiology (IR) procedures, however, the medical staff wears a protective lead apron. As a result, $H_p(10)$ no longer provides a good estimate of E. Double dosimetry (DD) algorithms combine measurements from two dosimeters to produce a more accurate estimate of E. The International Commission on Radiation Units and Measurements (ICRU) proposed new operational quantities for external radiation exposure. The influence of the new quantity H_p on DD algorithms yet has to be investigated.

A Monte Carlo (MC) study was performed to investigate the impact of the new operational quantity H_p on E estimates when a protective apron is worn in IR procedures.

Methods: The response of two types of H_p and $H_p(10)$ dosimeters, worn over and under a lead apron, were calculated and compared using MC simulations. These dosimeter types are:

- (i) Front-back symmetric: a dosimeter showing identical response from the front and the back, like most thermoluminescent (TL) and optically stimulated luminescence (OSL) dosimeters presently used for routine monitoring.*
- (ii) Backscatter-free: a dosimeter with no response from the back, like most active personal dosimeters (APDs).*

The staff was modelled as a slab phantom wearing a lead apron and two dosimeters. The patient was as a mathematical phantom. The imaging x-ray system was a collimated point source and an imaging receptor. Five hundred sixty exposure configurations, including various field sizes, x-ray spectra, beam projections and staff positions, were simulated. E was calculated using five DD algorithms with the simulated $H_p(10)$ values as input, and compared with an E estimate (E_{Hp}) calculated using H_p as input for the DD algorithms.

Results: When worn over the apron, $H_p(10)$ values were comparable for both dosimeter types (median dose 3% greater for the front-back symmetric dosimeter). Under the apron, $H_p(10)$ values calculated with the front-back symmetric dosimeter were on average 100% greater (median 50%) than with the backscatter-free dosimeter.

Similar trends were observed for H_p . Over the apron, H_p values were comparable for both dosimeter types (median dose 3% greater for the front-back symmetric response). Under the apron, the front-back symmetric dosimeter produced H_p values on average 100% greater (median 50%) than the backscatter-free dosimeter.

The comparison of H_p with $H_p(10)$ delivered similar results for both dosimeter types. Over the apron, the calculated H_p values were within [56; 70] % (median 64%) of the corresponding $H_p(10)$ values; while under the apron, the calculated H_p values were within [61; 76] % (median 71%) of the corresponding $H_p(10)$ values.

To account for the consistently lower H_p values, a unique correction factor was derived and applied to the DD algorithms. E_{Hp} estimates within ~10% of the original $H_p(10)$ -based E estimates could then be achieved.

Implications

Our results suggest that, by introducing a single correction factor, the tested DD algorithms can be used with H_p as input to estimate E without significantly increasing their original uncertainty.

PWE-27 STUDY OF AN EMERGENCY SCENARIO INVOLVING A NUCLEAR POWER VESSEL

Author: Sara Mendes | Co-Author: Paulo Nunes | Speaker: Paulo Nunes, Sara Mendes

The present work evaluates the potential consequences of a radiological emergency caused by the accidental release of radioactive material from a nuclear-powered submarine near Portugal's coastline, particularly focusing on Lisbon area.

The atmospheric dispersion of the radioactive plume was modelled using the HYSPLIT and RIMPUFF models (available on JRODOS decision support system).

Weather data causing a “worst-case scenario” was considered, selecting the 48-hour period within the year 2023 when weather conditions would lead to the most severe radiological deposition in the densely populated areas of Lisbon.

Our results reveal significant risks to both urban and agricultural zones, with potential contamination of population and key food sources, such as leafy vegetables and milk. This analysis highlights the need for effective emergency preparedness and response strategies to address the public health and food safety concerns in the event of such an emergency.

PWE-28 ASSESSMENT OF MOBILITY AND POTENTIAL BIOAVAILABILITY OF RADIOACTIVE AND NON-RADIOACTIVE HAZARDOUS ELEMENTS CO-OCCURRING IN SOIL

Author: Dorottya Jakab | Co-Author: Lindis Skipperud, Hallvard Haanes, Jelena Mrdakovic Popic | Speaker: Dorottya Jakab

Soil sampling campaigns and comprehensive investigations were conducted to characterize the geochemical behavior of naturally occurring radionuclides (NORs), rare earth elements (REEs) and potentially toxic elements (PTEs) co-occurring in the soil from a legacy mining area and enhanced natural radiation area. To gain a deeper understanding of their mobility and potential bioavailability, a sequential extraction procedure was applied. This approach provided information on the distribution of elements among different fractions (water-soluble, exchangeable, carbonate-bound, Fe/Mn oxide-bound, organic matter-bound, residual) within the soil matrix. These fractions exhibit varying degrees of stability and reactivity under changing environmental conditions, and therefore, differ in their potential for mobilization, release and transfer through environmental media, and for uptake by living organisms. Fractionation therefore provided additional insight into the environmental behavior and fate of the elements investigated beyond that obtainable from total concentration data alone. The complex dataset, obtained from the sequential extraction analysis, comprised multiple elements (NORs: ^{232}Th , ^{238}U ; REEs: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y; PTEs: Cr, Co, Ni, Cu, Zn, As, Cd, Pb) distributed across several extraction fractions and soil samples collected from sites differing in both geological characteristics and the degree of anthropogenic disturbance. The interpretation of these multidimensional data structures therefore required advanced multivariate statistical techniques, such as Principal Component Analysis (PCA), using multi-way approaches.

The results of the analysis and the main findings concerning the behavior of radioactive and non-radioactive elements co-occurring in surface soil will be presented. Particular emphasis will be placed on the spatial distributions and fractionation patterns of the investigated elements and their implications for understanding the processes governing retention, mobility and potential

bioavailability under field conditions. These findings contribute to a more robust understanding of radionuclide, REE and PTE dynamics in complex environmental systems and support the integration of site-specific geochemical information into environmental risk and impact assessment frameworks to better account for the complexity of real-world environmental systems.

PWE-29 PASSIVE GAMMA-FIELD MAPPING OF Tc-99m SOURCES USING B-CaSiO₃ THERMOLUMINESCENT PELLET ARRAYS

Author: Carlos Gonzales Lorenzo | Co-Author: Shiguelo Watanabe | Speaker: Carlos Gonzales Lorenzo

The localization and control of Tc-99m sources are essential tasks in diagnostic nuclear medicine, particularly for radiation protection, quality assurance, and training procedures. In this work, B-CaSiO₃ thermoluminescent pellet arrays were evaluated as a low-cost passive system for mapping the spatial distribution of gamma exposure from Tc-99m sources under phantom conditions. A rectangular water-filled phantom was used to simulate photon attenuation in a soft-tissue-equivalent medium. Tc-99m solutions contained in syringes were immersed in the phantom, while B-CaSiO₃ pellet arrays were externally positioned to record the emitted gamma field. Two experimental configurations were investigated: a 5 × 10 pellet array exposed for approximately 20 min to two Tc-99m sources with activities of 32.0 and 15.5 mCi, and a 6 × 7 pellet array exposed for approximately 12 min to a single Tc-99m source of 29.9 mCi.

After irradiation, the pellets were analyzed by thermoluminescence, and the integrated TL signals were used to reconstruct spatial response maps. The resulting TL maps showed localized high-intensity regions associated with the physical positions of the Tc-99m sources. In the two-source configuration, the pellet matrix allowed visual discrimination of regions corresponding to sources with different activities, while the single-source configuration produced a concentrated response area consistent with the expected source location. These results demonstrate that B-CaSiO₃ pellet arrays can passively register spatial variations in the 140 keV gamma field emitted by Tc-99m.

This proof-of-concept study indicates that B-CaSiO₃ thermoluminescent arrays may serve as accessible complementary tools for qualitative source localization, radiation protection education, and quality-control studies in nuclear medicine environments. Further work should focus on quantitative calibration, spatial resolution, reproducibility, fading behavior, and comparison with standard dosimetric systems.

THURSDAY, 8 OCTOBER

S1.3 RP in the Nuclear Renaissance – New Technologies, New Challenges

S1.3–1 EMERGENCY PLANNING ZONES ACROSS EUROPE FOR NOVEL NUCLEAR REACTORS: PRACTICAL DIFFERENCES IN NATIONAL IMPLEMENTATION

Author: Anna Wawrzyńczak-Szaban, Piotr Kopka, Marie Simon-Cornu, N. Abdul-Rashid, Fabrizio Gabrielli | Co-Author: | Speaker: Anna Wawrzyńczak-Szaban

The deployment of small modular reactors and other advanced reactor technologies has renewed the need to review how Emergency Planning Zones (EPZs) are defined and implemented across Europe. Within GIROSCOPE and CATAPULT, particular attention is being given to the licensing framework and to the practical application of emergency preparedness and response requirements for both advanced and conventional reactor concepts, with a focus on how international guidance is translated into national practice.

This presentation, prepared in the framework of GIROSCOPE WP4 and linked to the comparative work performed across GIROSCOPE and CATAPULT, provides an overview of national approaches to emergency planning in selected European countries and Canada. The comparison addresses the main planning concepts and zones used in practice, including the Precautionary Action Zone (PAZ), Urgent Protective Action Zone (UPZ), Extended Planning Distance (EPD), and Ingestion and Commodities Planning Distance (ICPD), as well as country-specific equivalents and naming conventions. It also considers differences in associated dose criteria, planning distances, regulatory frameworks, and the balance between distance-based and dose-based approaches. Attention is given to the differences between emergency planning at the licensing stage and emergency preparedness. The analysis shows that despite a strong common conceptual basis informed by IAEA recommendations and European radiation protection principles, national implementations of EPZs differ significantly. Important variations are observed in zone sizes, dose thresholds, terminology, and the degree of flexibility allowed in emergency planning arrangements. Some countries define dedicated ingestion planning distances, while others rely on national food protection mechanisms. Similarly, some emergency planning systems remain strongly distance-based, whereas others increasingly adopt risk-informed and dose-based approaches supported by operational decision-making tools. Where relevant, the presentation introduces the differences between predefined zones (for a given site and installation, irrespective of the accident conditions) and zones which would be defined for a specific accident scenario (single source term, single weather series).

By synthesising results from GIROSCOPE and CATAPULT, this work aims to identify commonalities, differences and practical challenges relevant to the future deployment of advanced reactors in Europe. The comparison supports the development of recommendations for more coherent and transparent emergency planning approaches, while preserving the flexibility needed to reflect national regulatory traditions, local conditions and reactor-specific characteristics. The results are expected to inform ongoing discussions on how emergency preparedness frameworks should evolve for both standard reactors and new reactor technologies.

S1.3–2 VALIDATION OF JRODOS AND QUIC FOR ATMOSPHERIC DISPERSAL SIMULATIONS IN URBAN ENVIRONMENTS

Author: Michał Jędrzejczyk, Piotr Kopka, Anna Wawrzyńczak-Szaban | Co-Author: | Speaker: Michał Jędrzejczyk

Defining the boundaries of Emergency Planning Zones (EPZs) is essential for maintaining public safety near nuclear reactors. While established protocols exist for reactors situated in rural areas, comparable procedures for urban environments remain underdeveloped. EPZs are frequently delineated using atmospheric radiological dispersion simulation tools such as JRODOS, which were not originally intended for application in urban settings. This limitation necessitates validation of these tools for complex urban topographies. Within the PIANOFORTE GIROSCOPE project, the atmospheric dispersion models were evaluated using data from atmospheric dispersal experiments conducted in an urbanised area. These experiments formed part of the DIFLU experimental campaign, carried out in 2019 in the French city of Beuvry. This presentation benchmarks KIT's JRODOS and LANL's QUIC against these experimental datasets and examines the implications for emergency preparedness and planning.

The findings indicate that QUIC achieves strong agreement with experimental results for certain metrics, whereas JRODOS does not adequately resolve the effects of buildings and vegetation at resolutions relevant to urban areas. Simulation outcomes are highly sensitive to meteorological inputs, particularly the Monin-Obukhov length, which is challenging to determine reliably in urban environments. Furthermore, obtaining accurate meteorological data from the Weather Research and Forecasting (WRF) model for use in atmospheric dispersal simulations requires assimilation of local micrometeorological measurements. This consideration is critical for authorities responsible for radiological safety, as many rely on forecast weather data to conduct daily simulations of radiological releases for emergency preparedness.

S1.3–3 RESEARCH ON KEY TECHNOLOGIES FOR DIGITAL RADIATION PROTECTION AND THE DEVELOPMENT OF THE SMARP SYSTEM IN NUCLEAR FACILITIES

Author: Liye Liu | Co-Author: Chuan Wang, Hua Li, Jinzhong Zeng, Peitao Song, Qinjian Cao, Yuan Zhao | Speaker: Peitao Song

1. Objectives/Background: To meet the digital transformation requirements of the nuclear industry, the China Institute for Radiation Protection (CIRP) has proposed the SMart ALARA system for Radiation Protection (SMARP) and its development roadmap. The aim is to integrate digital twins, the Industrial Internet of Things (IIoT), and artificial intelligence (AI) to build an intelligent radiation monitoring and protection framework, thereby improving efficiency, reducing costs, and lowering collective doses.

2. Methods: Guided by the development roadmap, SMARP evolved from version 1.0 to 3.0.

SMARP 1.0, centered on digital twin technology, constructs high-precision 3D models for Radiation Controlled Areas (RCAs) and uses point kernel integration, interpolation, and source term inversion to rapidly reconstruct 3D dynamic radiation fields. It enables simulation, dose pre-assessment for high-risk operations, path navigation, and the digital circulation of Radiation Work Permits (RWPs).

SMARP 2.0 incorporates all the functionalities of version 1.0 while integrating key digital data acquisition hardware for personal dosimetry, area radiation monitoring, and surface contamination monitoring. It encompasses the entire process for personnel from entry to exit of the RCA. For personal dosimetry, automated Whole-Body Counter and TLD management systems were developed, together with a WiP-DMS that uses UWB and 5G for synchronized location-dose

monitoring. Area monitoring integrates DoseMap (portable 3D mapper), Gamma FreeMapper (free-moving 3D γ imaging with LiDAR and spherical detectors), and 5G stationary monitors; intelligent inspection devices and electronic signage enable standardized digital workflows. Contamination monitors equipped with facial recognition and 5G achieve automated correlation of personnel identity and contamination data.

SMARP 3.0 will incorporate AI and data mining for predictive radiation trend modeling and intelligent decision-making, advancing radiation protection from digitalization to intelligence.

3. Results: SMARP 1.0 is currently deployed across 25 nuclear power units in China, while SMARP 2.0 is being demonstrated at Qinshan and Changjiang NPPs. Testing shows that WiP-DMS achieves a static positioning error below 0.5 m; DoseMap is 26.8 times faster than traditional methods with localization accuracy better than 6.5 cm; Gamma FreeMapper reaches Compton imaging angular resolution of $(12.52 \pm 0.14)^\circ$ at 662 keV, mapping a 1000 m² area in 10 minutes. Mobile online γ dose meters provide remote monitoring with data latency under 0.5 s. Preliminary results indicate an approximate 10 % reduction in radiation protection costs, a 10-20 % reduction in collective dose, and a 30 % improvement in protection management efficiency.

4. Conclusions/Implications: This study develops SMARP, a digital radiation protection system that deeply integrates digital twin technology with real-time monitoring. By converging 3D spatial modeling, multi-source spatiotemporal sensing, and advanced radiation field reconstruction with traditional management needs, the system digitizes the monitoring of personnel location, area dose, and surface contamination. A unified data platform enables centralized oversight and visual analysis, giving nuclear facilities intuitive situational awareness, precise dose assessment, and end-to-end decision support. By advancing digital infrastructure and nuclear safety innovation, this work contributes to SDG 9 and lays the foundation for intelligent radiation protection.

S1.3–4 RANE: BRIDGING THE GAP BETWEEN RAPID GENERIC RESPONSE AND ACCURATE PLANT-SPECIFIC DECISION SUPPORT IN NUCLEAR EMERGENCIES

Author: Juan Carlos de la Rosa Blul | Co-Author: | Speaker: Juan Carlos de la Rosa Blul

Effective emergency preparedness and response (EPR) for nuclear and radiological events critically depends on the ability to support decision-making under severe time constraints while maintaining sufficient physical realism. In current practice, operational capabilities tend to diverge into two distinct approaches: rapid but generic methods, based on predefined scenarios and simplified assumptions, and accurate but time-consuming approaches relying on detailed plant-specific modelling of accident progression, source term, and radiological consequences. This fundamental trade-off limits the effectiveness of early decision-making, when timely and reliable information is most needed.

This contribution presents the RANE (Radiological Assessment for Nuclear Emergencies) framework developed at the European Commission's Joint Research Centre (JRC), which is specifically designed to bridge this gap. RANE combines rapid, AI-enabled situation assessment with mechanistic, plant-specific modelling capabilities, enabling a progressive transition from early generic evaluations to physically grounded, facility-specific analyses within operationally relevant timescales.

The RANE workflow is structured into three integrated modules: (1) input and activation, (2) core radiological assessment, and (3) output-to-outcome transformation. The input module leverages machine learning and artificial intelligence techniques to rapidly capture, filter, and interpret heterogeneous data streams, including early notifications, plant characteristics (e.g. PRIS-based, EURDEP, etc.), and contextual information. This enables robust and timely identification and

activation of plausible accident scenarios, even under incomplete, uncertain, or evolving conditions.

The core module performs plant-specific mechanistic calculations of accident progression, including thermal-hydraulic behavior, severe accident evolution, and source term estimation. These calculations rely on design-based surrogate models, tailored with plant-specific information such as reactor design, safety and mitigation systems, and relevant initial and boundary conditions affecting radionuclide releases. In addition, the core module computes atmospheric dispersion and deposition, enabling consistent dose projection assessments. By integrating accident progression and off-site consequence modelling within a unified framework, RANE ensures coherence between source term estimation and radiological impact evaluation.

A key feature of RANE is its ability to progressively refine assessments as new information becomes available, ensuring continuity between early rapid evaluations and subsequent high-fidelity analyses, and avoiding discontinuities in decision-making. The output-to-outcome module translates radiological results into structured and traceable recommendations for protective actions, explicitly linking projected consequences to generic intervention criteria. This supports transparent, defensible, and harmonized decision-making across different operational contexts.

The applicability of RANE is particularly relevant in complex and emerging scenarios, including multi-hazard and conflict-driven contexts, where uncertainties on initiating events and system performance challenge traditional approaches and are properly taken into account by RANE. By bridging the gap between rapid response and accurate plant-specific modelling, RANE provides a robust framework to support timely, consistent, and evidence-based decision-making in nuclear emergencies.

S1.3–5 ASSESSING THE ENVIRONMENTAL AND RADIOLOGICAL IMPACT OF SMALL MODULAR REACTORS (SMRs) ACROSS DIFFERENT LANDSCAPES

Author: Anca Tacu | Co-Author: Benjamin Meijer, Gerwin Sandker, Govert de With | Speaker: Anca Tacu

Background & Objective: Small Modular Reactors (SMRs), including water-cooled and advanced designs, are being considered for deployment in a wide range of environments, such as riverine systems, coastal zones, and industrial harbours. Assessing the environmental and radiological impact of routine radionuclide releases remains challenging due to limited operational data and site-specific experience.

To support the development of comprehensive guidance for Environmental Impact Assessment (EIA) and Emergency Preparedness and Response (EP&R), it is important to determine the required level of modelling complexity for reliable impact evaluation. This study therefore applies a multi-scale modelling approach to evaluate radionuclide dispersion and associated radiological impacts for representative deployment scenarios across different European environmental settings, with particular focus on near-field processes and site-specific hydrodynamics, and on identifying when advanced tools provide added value over simpler approaches.

Methods: Radionuclide transport was simulated using a coupled near-field/far-field modelling framework. Near-field dispersion was modelled with TELEMAC-3D under representative hydrodynamic conditions (e.g., flow velocity, stratification, and density effects), assuming continuous liquid discharges and conservative radionuclide behaviour.

Far-field transport, longer-term redistribution, and dose assessment were performed using the compartment-based POSEIDON(-R) model, accounting for advection, dispersion, decay, and

simplified sediment interactions. An automated data exchange procedure was implemented to transfer spatially resolved outputs from TELEMAC-3D into POSEIDON, ensuring consistency between modelling scales.

The modelling framework accounts for complex hydrological processes, including density-driven flow, stratification, and tidal influences in transitional environments. Simulations were conducted for representative riverine, coastal, and harbour/estuarine scenarios. Resulting activity concentrations were used to estimate doses to aquatic biota and humans via relevant exposure pathways.

Results: The simulations show that peak near-field concentrations differ by up to an order of magnitude between confined systems (rivers and harbours) and open coastal environments, primarily due to differences in dilution capacity. Riverine scenarios exhibit higher local concentrations under limited flow conditions, whereas coastal systems show lower peak concentrations but a wider spatial distribution.

Hydrodynamic processes such as tidal motion increase radionuclide retention in estuarine environments, leading to partial accumulation in nearby and upstream compartments. These processes influence both spatial concentration patterns and exposure pathways.

Despite these variations, estimated doses remain within low-level ranges for routine discharges. In estuarine environments, lower dissolved concentrations due to enhanced mixing can coincide with relatively higher uptake in biota under saline conditions, indicating that environmental composition influences exposure pathways in addition to hydrodynamics.

Conclusions & Implications: The results demonstrate that local hydrodynamics and environmental setting are key drivers of radionuclide dispersion and radiological impact. Consequently, site-independent or overly simplified models may overlook important near-field processes relevant for robust EIA and EP&R assessments.

The multi-scale approach presented here, combining detailed hydrodynamic modelling with efficient large-scale assessment, provides a practical and scalable framework for SMR evaluation. It supports early-stage, site-specific analyses and helps determine the appropriate level of modelling complexity required for regulatory and safety applications across different reactor technologies.

Future work will further refine the coupling between near- and far-field models and use TELEMAC-3D to identify potential accumulation zones, improving predictive accuracy in transitional environments.

S1.3–6 PHYSICS-INFORMED GAUSSIAN PROCESS REGRESSION FOR 3D DOSE RATE FIELD RECONSTRUCTION IN DECOMMISSIONING ENVIRONMENTS

Author: Federica Roberto | Co-Author: Filip Vanhavere, John A. Lee, Mahmoud Abdelrahman, Pasquale Lombardo | Speaker: Federica Roberto

Decommissioning and Dismantling (D&D) of nuclear facilities requires accurate radiation field characterization for worker dose assessment and operational planning. Traditional approaches, like point-kernel methods and Monte Carlo (MC) simulations, face significant limitations in terms of speed, flexibility, and adaptability to complex geometries. This work addresses these challenges by presenting a Machine Learning (ML)-based computational pipeline designed to reconstruct 3D dose rate fields from sparse input data, supporting safer and more efficient D&D operations.

The proposed methodology combines measurement surveys or MC simulations with physics-informed Gaussian Process (GP) regression for 3D dose rate field interpolation. The input consists

of a dose rate map, from either direct measurements or MC simulations, along with a geometric description of objects present in the facility. The algorithm performs virtual sources identification and placement in the environment, accounts for shielding effects, then trains a physics-informed GP model to interpolate the dose field over a customizable 3D prediction grid. Conceivably, an active learning strategy will be embedded in the pipeline: after the initial prediction, the algorithm identifies optimal locations for additional measurements that would improve the prediction model. As new measurements become available, the GP model is updated incrementally, without full retraining, preserving computational efficiency.

The approach was validated on several representative D&D case studies, demonstrating the feasibility of reconstructing full 3D dose rate fields from limited survey data. The physics-informed GP model achieved high predictive accuracy while maintaining fast execution times. Prediction uncertainty is quantified at each grid location, providing actionable guidance for measurement campaign optimization. The active learning component should further reduce the number of measurements needed to reach a target accuracy threshold compared to passive survey strategies.

This ML-based pipeline offers a practical and scalable alternative to conventional dose field reconstruction methods for D&D environments. By combining physics-informed interpolation, uncertainty quantification, and active learning, it enables fast, accurate, and resource-efficient radiation mapping with minimal prior knowledge of the facility.

S1.3-7 PRELIMINARY RESULTS OF THE GIROSCOPE MODEL INTERCOMPARISON BENCHMARK: VALIDATION AGAINST IN SITU CLOSE-RANGE DISPERSION MEASUREMENTS

Author: Anna Wawrzyńczak-Szaban, Blanca Garcia-Puerta, Claire Delides, Clemens Woda, Erwan Rondeaux, Guilhem Balvet, Irene Korsakissou, Joseph Wellings, Michał Jędrzejczyk, Milagros Montero Prieto, Piotr Kopka, Spyros Andronopoulos, Thomas Hamburger | Co-Author: | Speaker: Guilhem Balvet

Novel nuclear reactors (NNRs) are a promising low-carbon energy solution for various applications, such as providing industrial heat, residential electricity and remote or maritime power. Unlike standard nuclear reactors, NNRs produce lower power levels (tens to hundreds of MW) and might be intended to be located closer to populated or industrial areas. Because of this proximity and the smaller quantity of radionuclides emitted in operational and accidental scenarios, in order to ensure an adequate response and propose relevant planning zones, it is crucial to be able to properly estimate exposure in the immediate vicinity of such facilities. At these scales, the plume shape may be strongly affected by local topography, including buildings and vegetational features, which is difficult to handle using simplified methods such as Gaussian methods, which are often used to model accidental releases at longer distances.

The GIROSCOPE project, a European project funded by the PIANOFORTE platform which focuses on emergency preparedness, response and recovery around NNRs, addresses these challenges. To assert the confidence level of various approaches in the close surroundings of installations, a model intercomparison benchmark is carried out by several partners: ASNR (France); (BfS) Germany; CIEMAT (Spain); DEMOKRITOS (Greece); NCBJ (Poland), and UKSHA (UK). A range of numerical models, including CFD, Lagrangian particle dispersion, and Gaussian models, are applied to simulate dispersion in a peri-urban environment. These numerical results are validated against experimental data from the DIFLU in situ campaign, conducted in Beuvry, France, in the presence of buildings and tree rows. This campaign involved repeated helium releases from a point source on a cyclotron roof, with concentration measurements taken at distances of 10-200 meters. While most situations demonstrate neutral atmospheric stability, some release scenarios are affected by non-neutral atmospheric stability.

By comparing model outputs against high-quality in situ data, the project sheds light on the strengths and limitations of each method, enabling the quantification of error and confidence intervals for each approach. This validation is a critical step towards evaluating the reliability of dispersion predictions in realistic source-term scenarios, which are vital for devising effective emergency planning measures and ensuring NNR safety assessments.

S1.3–8 DESIGN AND VALIDATION OF NOVEL ACTIVE AMBIENT NEUTRON DOSIMETERS: ADDRESSING TECHNOLOGICAL GAPS FOR A CHANGING RADIATION PROTECTION LANDSCAPE

Author: Ariel Tarifeno-Saldivia | Co-Author: Benedetta Brusasco | Speaker: Ariel Tarifeno-Saldivia, Benedetta Brusasco

Background. Real-time monitoring of neutron ambient dose equivalent is a key requirement for radiation protection across nuclear industry, research accelerators, and modern medical facilities such as particle therapy centres. Most commercially available active ambient neutron dosimeters were designed in the late 1990s and early 2000s, presenting well-known limitations in portability, energy response coverage, and performance in pulsed radiation fields. A further, emerging gap is the forthcoming transition to the new operational quantities recommended by ICRU Report 95, which will require the instrument response of existing technologies to be reassessed and adapted over the coming years.

Methods. Within the LINrem project, two novel active neutron dosimeters were developed to address these gaps: LINrem, an ultra-portable non-extended-range dosimeter (total mass <4 kg, thermal to 10 MeV), and LINremext, an extended-range dosimeter (total mass <11 kg, thermal to 10 GeV). Both designs result from Monte Carlo-assisted numerical optimization of the moderator geometry to match the relevant fluence-to-dose conversion factors. The same design methodology has been applied to produce a first conceptual design adapted to the ICRU 95 operational quantities. Complementary passive variants developed within the project are addressed in a separate contribution.

Results. Experimental validation campaigns were conducted in diverse neutron environments, including reference neutron fields, intercomparisons at particle accelerator facilities, and research nuclear reactors. Results were benchmarked against standard commercial ambient neutron dosimeters, demonstrating consistency with design specifications and supporting advancement toward higher technology readiness levels.

Conclusions. The LINrem active dosimeters demonstrate that substantial improvements in portability and energy coverage are achievable with current detection technology, while the design methodology provides a clear pathway toward instruments compliant with future operational quantities. This work supports a more competitive and resilient European radiation protection instrumentation landscape (SDG 9), contributing to occupational safety and health protection of workers (SDG 3).

S2.3 Innovation in Therapy & Imaging

S2.3-1 STUDY OF ACTINIDE DECONTAMINATION USING AN EX VIVO MODEL OF DAMAGED RAT SKIN.

Author: Laurie De Castro | Co-Author: Karine Devilliers, Anne-Sophie Chaplault, Martine Defrance, Agnès Moureau, Olivier Grémy | Speaker: Laurie De Castro

Objectives/Background: In the event of an explosion of a radionuclide dispersal device or a nuclear bomb, soldiers or first responders may be internally exposed to radionuclides such as actinides (plutonium, uranium) through wound or damaged skin. To reduce spreading of radionuclides and their blood absorption, medical countermeasure must be initiated as soon as possible. However, currently available treatments have a limited efficacy, do not cover all radionuclides of interest, and are not easily applicable to skin decontamination. As part of the European Alliance for Medical Defense Countermeasures, our laboratory is participating in a project to develop and test topical gels loaded in chelating or complexing agents for treating wounds or damaged skin contaminated with radionuclides.

*Methods: In the absence of OECD guidelines for assessing skin or wound decontamination, the laboratory has developed dedicated experimental models. Our *ex vivo* model of damaged skin consists of a dissected whole-body rat skin that then was been lacerated. The radionuclide of interested was deposited on the skin and half an hour later, different decontamination procedures were applied. The remaining activity on the damaged skin was then measured. Different gel formulations of chelating and complexing agents are currently being developed by our project partners (ASNR, Galien Institute, and University of Latvia). For soldiers in particular, semi-solid decontamination products offer the advantage of being easier to apply than liquid forms. Using the experimental model described above, we are able to assess the effectiveness of applying these chelating gels compared to washing with water or with chelating agents in solution form.*

Results: Our results on plutonium and uranium show that gels without chelating agents are as effective as water, and do not allow for the highlight of a mechanical action of the gel itself. For the diethylenetriaminepentaacetic acid (DTPA, reference chelating agent for plutonium), decontamination of plutonium by applying the gel form is as effective as washing with its commercial solution form. Regarding gel forms of 3,4,3-Li(1,2-HOPO), they are slightly more effective than water in removing uranium from the damaged skin, and almost 3-times more for plutonium. Moreover, HOPO-loaded gels are twice as effective than HOPO in solution for plutonium. Finally for plutonium, HOPO gels are comparable in effectiveness to DTPA gel, but at doses that are 200-times lower.

*Conclusions: For DTPA, since the effectiveness of solutions and gels is comparable, in an emergency context, applying a gel might be a simpler option. Regarding to chelating agents, HOPO gels is effective for plutonium chelation at lower doses than DTPA. HOPO also appears to be slightly more effective than water at chelating uranium. Similar *ex vivo* experimental design is applied to evaluate the efficacy of gels loaded with complexing agents for the decontamination of cesium and cobalt. The most promising gels identified in *ex vivo* studies for each radionuclide of interest will be selected for testing their efficacy *in vivo* using a deep wound model in rats.*

Acknowledgement: This work has received funding from the European Defence Fund (EDF) under the grant agreement RESILIENCE-R-2023 no. 101168024.

S2.3-2 IMPLICATIONS OF REVISED SKIN CONTAMINATION DOSE COEFFICIENTS FOR HIGH ENERGY ALPHAS

Author: Diane Aube, Holly Laakso, James Harrington | Co-Author: Joseph Lemieux, Leah Pearson | Speaker: Holly Laakso

Regulatory attention on high energy alpha emitters (HEAs) has led to the adoption of revised skin dose coefficients that exceed those for beta emitters by multiple orders of magnitude. These dose coefficients have the potential to significantly change how alpha contamination on the skin is assessed and controlled in Canada. At Canadian Nuclear Laboratories, activities involving targeted alpha therapy nuclides have been substantially affected by the implementation of these revised dose coefficients.

The updated dose coefficients are grounded in physical modelling of stopping power, particle range, and energy deposition at specific tissue depths, but empirical evidence of deterministic skin effects from HEA exposures remains limited. The standard method for calculating dose now introduces operational challenges for any sector working with Ra 226, radon progeny, NORM, and targeted alpha therapy isotopes such as Ac 225. These challenges include increased risks of exceeding regulatory dose limits, practical difficulties in monitoring contamination, and inconsistencies with guidance and regulation.

The application of updated HEA skin dose coefficients will create a shared problem for historically separate sectors of the nuclear industry. There is an opportunity to build bridges by fostering scientific and operational collaboration and developing consistent and defensible approaches to dose evaluation. Effective collaboration has the potential to resolve uncertainty in regulatory expectations, and to ensure that skin dose management practices remain evidence-informed and practical across industry, healthcare, and research settings. Although further biological research is needed to validate the skin effects of HEA exposures, interim guidance that reflects current scientific understanding is required now.

This presentation seeks to inform industry of the scope and scale of the problem, discuss unique operational challenges at Chalk River Laboratories, identify research priorities, and support evidence-based radiation protection practices for HEA skin contamination.

S2.3-3 OPTIMISING CT HEAD IMAGING IN MILD TRAUMATIC BRAIN INJURY: A BIOMARKER GUIDED APPROACH TO RADIATION PROTECTION

Author: Paul Tansey, Ferdia Bolster, Etimbukedet Umana, Paula M. O'Shea, Philip J. O'Halloran | Co-Author: | Speaker: Paul Tansey

Objectives/Background: Reducing unnecessary CT scans is an important part of radiation protection and helps ensure that imaging is only used when it is likely to benefit the patient (1). Non-Contrast CT (Computed Tomography) head is the standard imaging test for patients with suspected mild traumatic brain injury (mTBI). However, approximately 90-95% of CT studies performed for this indication do not demonstrate intracranial haemorrhage, exposing many patients to ionising radiation (2,3).

Biomarker-guided triage may therefore support radiation protection by improving CT justification, provided diagnostic safety is maintained. Glial fibrillary acidic protein (GFAP) and ubiquitin C-terminal hydrolase-L1 (UCH-L1) are blood biomarkers associated with traumatic intracranial injury, but fixed thresholds may generate false-positive results, particularly in older adults (4,5).

Methods: Adults presenting to a major trauma centre with suspected mTBI, Glasgow Coma Scale 13-15, who underwent CT head imaging according to the NICE Head Injury pathway (5) and GFAP/UCH-L1 testing within 12 hours of injury. CT findings were used as the reference standard. Diagnostic performance using manufacturer thresholds was compared with an age-adjusted approach applying higher biomarker thresholds in patients aged ≥ 65 years (5). The potential impact on CT utilisation was estimated by the proportion of patients classified as biomarker negative

Results: In total, 215 patients were included; 19, 8.8%, had intracranial haemorrhage on CT. Manufacturer thresholds identified all haemorrhage-positive cases but generated frequent positive biomarker results in patients without haemorrhage. The age-adjusted algorithm also identified all haemorrhage-positive cases, while reducing false-positive biomarker results. The proportion of patients classified as biomarker negative increased from 27.0%, 58/215, with manufacturer thresholds to 50.2%, 108/215, using age-adjusted thresholds, suggesting that an additional 50 patients could potentially have avoided CT without missed intracranial haemorrhage in this cohort (4).

Conclusion: Age-adjusted GFAP/UCH-L1 thresholds may improve CT stewardship in suspected mTBI by preserving sensitivity for intracranial haemorrhage while increasing specificity. This biomarker-guided approach could strengthen justification of CT head imaging and reduce avoidable radiation exposure. Prospective implementation studies are required before routine clinical adoption.

S2.3–4 OPTIMIZING THE BENEFIT-RISK RATIO IN BREAST CANCER DIAGNOSIS AND RADIOTHERAPY THROUGH MOLECULAR, CELLULAR, AND IMAGING SIGNATURES OF TUMOUR HETEROGENEITY

Author: Katalin Lumniczky | Co-Author: Albert Alegret-Garcia, Altay Myssayev, Balázs Gyebrovski, Blanka Zeöld, Cecilia Riani, Christoph Hoeschen, Claudia Scotti, Giorgio Baiocco, Isabella Guardamagna, Isabelle Thierry-Chef, Katalin Balázs, Kunal Kumar, Maristella Maggi, Melanie Facht, Muna Abboush | Speaker: Katalin Lumniczky

Objectives / Background: Breast cancer remains a major public health challenge, and improving the benefit-risk ratio of diagnosis and radiotherapy requires more precise patient stratification. The IMAGEOMICS project aims to identify molecular, cellular, and imaging signatures associated with breast cancer heterogeneity to support personalized therapeutic strategies and reduce unnecessary ionizing radiation exposure. The project integrates in vitro and in vivo experimental models with imaging-based approaches and bioinformatics analysis. It investigates how radiotherapy shapes the immunogenic heterogeneity of breast cancer subtypes, evaluates nanoparticle-based X-ray fluorescence computed tomography for improved detection of tumour heterogeneity, and combines experimental data with human studies and epidemiological information to build stratification protocols. The effectiveness of breast cancer diagnosis and therapy fundamentally depends on the molecular properties of the tumour. Therefore, our group within the IMAGEOMICS project proposed to characterise the molecular and phenotypical landscape of HER2+/HER2- and triple negative BC cells.

Methods: Relevant aggressiveness, immune checkpoint and Toll-like receptor markers were measured and compared based on the radiation-induced phenotypic changes. To investigate the systemic presence of key immunogenicity markers carried by extracellular vesicles (EV), EV production and content is also being studied. Gene expression changes are also measured in a cluster of ten radioresponsive genes to assess the radiosensitivity index (RSI) of the cell lines of interest. This is being correlated with immune gene signatures indicating immunogenicity changes in the studied cell lines.

Results: The cancerous status highly increased the expression level of TLR7, TLR8, PD-L1, CD39 receptors and the presence of CD24+CD44+ stem cells compared to the control level (MCF10A). The acute effect of 2Gy irradiation was most pronounced in TLR4 receptor expression in certain cell lines. The most responsive triple negative cells were the HCC1187 with increased expression level of TLR4, CD39, ICAM3, Ki67 and Cytokeratin markers after irradiation. The yield of EVs was increased in case of MCF7, DU4475 and HCC38 cells after 2Gy exposure. Preliminary genotyping data show dose dependent changes in some but not all genes labelled as radiosensitive in HCC38.

Conclusions / Implications: By linking tumour biology, imaging, and translational data, IMAGEOMICS may contribute to more individualized breast cancer care, improved treatment selection, and safer diagnostic pathways and therefore aligns with PIANOFORTE's mission to improve radiation protection in the medical field.

Funding: This work has received funding from the Euratom research and training programme 2022-2027 in the framework of PIANOFORTE under grant agreement No 101061037

S2.3–5 BORON–GADOLINIUM COMBINED NEUTRON CAPTURE THERAPY FOR THE TREATMENT OF MALIGNANT PROSTATE CANCER AND ITS UNDERLYING MECHANISMS

Author: Xiaoxi Pang | Co-Author: | Speaker: Xiaoxi Pang

Purpose We reported a novel prostate-specific membrane antigen (PSMA)-targeted theranostic agent GBN based on gadolinium-boron conjugates, which enabled integrated PET/MR imaging, neutron capture therapy and its radio-mechanisms. Method and result Dynamic PET/CT imaging was used to observe the in vivo biodistribution and pharmacokinetics of GBN in the tumor model, which demonstrated that ^{68}Ga -GBN reached peak tumor uptake at 4 h post-injection in 22RV1 tumor-bearing mice, with a tumor-to-non-tumor (T/NT) ratio of 44.62 ± 63.20 ($n = 3$). Boron and gadolinium concentrations in various tissues were quantified by inductively coupled plasma mass spectrometry (ICP-MS), revealing effective tumor delivery of boron ($42.38 \mu\text{g}$ [^{10}B]/g) and gadolinium ($101.07 \mu\text{g}$ [^{157}Gd]/g), with tumor-to-blood (T/B) and tumor-to-normal tissue (T/NT) ratios of 2.82 ± 0.34 and 4.34 ± 0.18 for boron, and 4.12 ± 0.22 and 3.21 ± 0.23 for gadolinium, respectively ($n = 3$). In GBN(+)-NCT(+) treated cell experiments, 22RV1 cells exhibited significantly reduced proliferative capacity and suppressed colony formation ($P < 0.05$), which correlated with increased DNA damage and apoptosis, along with a significant loss of mitochondrial membrane potential. Western blot analysis revealed increased expression of the DNA damage marker γH2AX and the pro-apoptotic protein Bax, decreased levels of the anti-apoptotic protein BCL2 and the proliferation marker PCNA, along with activation of the cGAS-STING signaling pathway. Transmission electron microscopy (TEM) demonstrated pronounced mitochondrial structural damage in tumor tissues following GBN-NCT treatment. Survival analysis in tumor-bearing mice showed that tumor volume in the GBN-NCT group was 1.65-fold lower than that in the control group at 65 days post-irradiation ($P < 0.05$), while no significant differences in body weight were observed among groups ($P > 0.05$). GBN-NCT treatment significantly prolonged survival, with median survival extended from 40 days in the control group to 59 days ($P < 0.05$), indicating a clear therapeutic benefit in tumor-bearing mice. Conclusion GBN represented a novel dual boron-gadolinium delivery agent that enabled efficient and targeted delivery to prostate cancer, markedly enhancing the efficacy of neutron capture therapy and offering a promising precision therapeutic strategy.

S2.3–6 MEDICAL DIAGNOSTIC RADIATION PROMOTES MURINE APC/KRAS-DRIVEN COLON CARCINOGENESIS

Author: Méliandre Gomot, Guillaume Vares | Co-Author: Nora Essakhi, Clément Codan, Tasneem Abaza, Meryem Ulas, Marie Thérage, Chloé Brizais, Florence Bachelot, Amandine Sache, Karen Chaaya, Imène Garali, Quentin Pascal, Dmitry Klovov | Speaker: Guillaume Vares

Objectives / Background: Computed tomography (CT) is among the most commonly employed diagnostic imaging modalities worldwide; however, the biological risks associated with such exposures are still not fully understood. This study aimed to determine whether clinically relevant radiation doses promote colon carcinogenesis, particularly in genetically predisposed contexts involving key colorectal cancer driver mutations.

Methods: We combined in vivo and ex vivo approaches using KPC:APC transgenic mice and derived colon organoids harboring inducible Apc and Kras mutations. Animals and organoids were exposed to low (25 mGy) or moderate (250 mGy) X ray doses, representative of single or repeated CT examinations. Histopathological analyses quantified pre cancerous lesions, while multi omics approaches (RNA seq, proteomics, and m6A RNA methylation profiling) characterized radiation induced molecular alterations.

Results: Radiation exposure did not initiate carcinogenesis in wild type tissues nor significantly affect lesion development in Apc-mutant models. In contrast, combined Apc/Kras mutations conferred strong susceptibility: radiation significantly promoted progression of precancerous lesions, particularly when delivered during early tumor initiation. In organoids, this was associated with increased size and proliferation, specifically in cyst-like structures. Transcriptomic analyses revealed extensive dysregulation of cancer related genes, including downregulation of tumor suppressors and enrichment of pathways linked to proliferation and survival. Proteomic and enrichment analyses suggested mTORC1 signaling as a central pathway activated across radiation doses. Additionally, radiation induced selective changes in m6A RNA methylation affecting transcripts involved in key cancer hallmarks, suggesting a role for post transcriptional regulation.

Conclusions / Implications: Clinically relevant diagnostic radiation doses can enhance colorectal carcinogenesis in genetically predisposed systems without initiating tumorigenesis de novo. These effects depend strongly on genetic background and timing of exposure, with early-stage lesions being particularly sensitive. Our findings highlight mTORC1 signaling and RNA methylation as potential mediators of radiation induced tumor promotion. This work underscores the importance of incorporating individual susceptibility into benefit-risk assessments of medical imaging and reinforces the need for optimized radiation protection strategies.

S3.3 Patient-centred Radiation Protection

S3.3–1 STRENGTHENING RADIATION PROTECTION THROUGH SHARED RESPONSIBILITY: HEALTHCARE PROFESSIONALS’ PERSPECTIVES FROM SOUTH AFRICA.

Author: Moyahabo Makgato | Co-Author: Mathildah Mokgatle, Shantel Lewis | Speaker: Shantel Lewis

Background: Radiation protection is essential for safeguarding patients, personnel and the public from the harmful effects of ionising radiation used in medical imaging. In South Africa, healthcare professionals authorised to request ionising radiation-based imaging (IRBI) share responsibility for radiation protection with radiographers, challenging the common misconception that radiation protection is the sole responsibility of radiographers and radiologists. However, there is limited literature in African developing countries, such as South African literature, that explores how these professionals perceive their role in radiation protection. Therefore, this study aimed to explore and describe healthcare professionals’ perceptions of their role in radiation protection. With an objective to provide evidence that can inform future strategies for strengthening radiation protection frameworks in developing countries.

Methods: A qualitative approach with an exploratory and descriptive design was employed. One-on-one semi-structured interviews were conducted with sixteen purposively sampled South African healthcare professionals authorised to request medical imaging. Data were analysed inductively using thematic analysis guided by Tesch’s steps of qualitative data analysis.

Results: Five themes were generated from the data: (1) a conceptual understanding of radiation protection shaped by training; (2) variable perceptions of radiation protection role and responsibility; (3) imaging decision-making influenced by clinical judgement, patient expectations, defensive medicine; (4) system-level constraints related to resource distribution, access, and infrastructure; and (5) awareness but limited use of non-ionising radiation imaging alternatives. These findings reveal role ambiguity, inconsistent justification of imaging requests, and systemic inequalities that hinder optimal radiation protection.

Conclusion: Healthcare professionals’ perceptions of radiation protection are shaped by both individual and systemic factors. Defensive medicine, patient expectations and limited access to non-ionising modalities complicate imaging decisions. For developing countries, these findings underscore the need for a coordinated system-level strategies that integrate education, equitable resource distribution and policy innovation to ensure exposures remain as low as reasonably achievable. The findings of this study highlight priority areas for strengthening radiation protection in developing countries, thereby informing strategic efforts to achieve Sustainable Development Goals 3 (Good health and well-being) and 10 (Reduce inequalities).

S3.3–2 PREVENTION AND MINIMIZATION OF PATIENT RISKS IN LIGHT OF THE SIGNIFICANT INCREASE IN THE NUMBER AND AVAILABILITY OF CT AND ANGIOGRAPHIC DEVICES IN GEORGIA

Author: Davit Nadareishvili, Ketevan Jariashvili, Manan Gvasalia, Salome Kiparoidze | Co-Author: | Speaker: Davit Nadareishvili, Salome Kiparoidze

The number and types of radiological procedures are increasing worldwide, and despite their significant benefits, these procedures are also associated with certain negative impacts. Proper management of the patient’s radiation exposure is essential to mitigate and prevent adverse effects. Computer tomography (CT) scanners and Angiography devices contribute significantly to

the patient's radiation dose load, and since dose limitation principles do not apply in medical imaging as they do in other fields, radiation safety relies on the principles of justification and optimization.

The aim of this study is to analyze new representative database of all computed tomography and angiography devices in Georgia, which we created based on information provided by the national regulatory body, in order to find ways to prevent and minimize radiation risks. All the data provided to us had to be clarified, a new database had to be created, the distribution of CT and angiographic devices across cities and regions of the country had to be calculated, their technical and other data had to be clarified, as well as using data from manufacturers, data from National Statistics Office of Georgia, publicly available data, and IAEA materials. The data we obtained were compared with the corresponding indicators of European and some other countries, and very significant growth dynamics were revealed for a number of important indicators.

Based on newly obtained data and taking into account the recommendations of the IAEA and ICRP, we have proposed a number of proposals for consideration by all interested stakeholders in Georgia, both regarding the CT and angiography fleet and its monitoring, and on enhancing the competencies of professionals. Suggestions have been made regarding a number of approaches new to Georgia, both in terms of optimization and training, and in terms of enhancing the overall safety culture. This comprehensive approach will contribute to the prevention and minimization of patient risks in Georgia.

S3.3-3 POST-IRRADIATION REMODELING IN ESTROGEN-, PROGESTERONE- AND LEPTIN-STIMULATED BREAST EPITHELIAL CELLS

Author: Domenico Aprile | Co-Author: Andrzej Wojcik, Giovanni Di Bernardo, Kiran Dhakal, Nicola Alessio, Prabodha Kumar Meher, Umberto Galderisi, Zuzana Kocibalova | Speaker: Domenico Aprile

Background: Early menarche is associated with prolonged lifetime exposure to sex hormones and increased breast and endometrial cancer risk, while obesity may further influence epithelial biology through altered adipokine signaling. However, how endocrine exposure, obesity-related signaling and ionizing radiation interact to shape long-term epithelial responses remains poorly understood. Within the MIRAMARE project, we investigated whether hormonal stimulation and leptin modulate radiation-induced stress, senescence and functional remodeling in MCF10A breast epithelial cells, with the broader aim of identifying biological responses relevant to breast and endometrial cancer risk.

Methods: MCF10A cells were exposed to four experimental scenarios: hormone treatment (HT) followed by acute irradiation (AI), AI followed by HT, chronic irradiation during HT, and HT followed by AI plus long-term recovery. Treatments included control medium, sex hormones, leptin, or hormones plus leptin. Cellular responses were assessed using cell-cycle analysis, CCK-8 viability/proliferation assay, Annexin V assay, caspase-3 expression, DCF-DA detection, SA- β -gal/Ki67 immunocytochemistry, senescence and cell-cycle arrest markers, LDHA expression, invasion assay, colony-forming assay and EMT/stress-associated gene expression.

Results: Preliminary data showed that the recovery scenario, consisting of four weeks of HT followed by AI and four weeks of recovery, produced the strongest persistent phenotype. It showed increased senescence, reduced proliferation, sustained oxidative/metabolic stress and LDHA induction. Notably, despite reduced proliferation and high senescence, leptin-containing recovery groups also showed recovered clonogenic capacity, increased invasion and induction of EMT/stress-associated genes. Chronic irradiation was complementary, with leptin mainly increasing ROS and stressed-cell fraction while preserving viability and clonogenicity.

Conclusions: These findings suggest that post-irradiation recovery may generate heterogeneous surviving populations, including senescent cells and adapted/pro-remodeling subsets. Future studies will validate this scenario in endometrial epithelial cells and dissect SASP/metabolic mechanisms supporting survival and remodeling of non-senescent cells. By advancing knowledge for radiation protection and cancer prevention in women's health, this work contributes to SDG 3, Good Health and Well-being. This project received funding from the European Union's "EURATOM" research and innovation program under the 101061037 grant agreement.

S3.3–4 IONIZING RADIATION CANCER RISKS MODELLING ASSOCIATED WITH SCREENING PRACTICES FOR BREAST AND LUNG CANCER

Author: Christophe Bonaldi, Dominique Laurier, Enora Clero, Julie Sage, Nicolas Minier, Agnes Rogel | Co-Author: Marie-Odile Bernier | Speaker: Marie-Odile Bernier

Objectives/Background: Screening practices have appeared in France in the 1980s and a National Breast Cancer Screening Program (NBCSP) has been implemented in 2004, based on invitation for biannual mammography for women between 50 and 74 years old. Lung cancer screening based on low-dose computed tomography (LDCT) is currently being considered in France. Both screening programs involve prolonged exposure to low-dose ionizing radiation. Several epidemiological studies have shown radiation-associated increased risks of cancer in such low dose range. In this context, we estimated the radiation-induced cancer risks associated with these two screenings.

Methods: Breast cancer screening practices were reconstructed for the period 1980-2019, based on the NBCSP database, National Health Data System, completed by the literature and expert knowledges. The radiation doses absorbed by the breast were modelled based on existing literature, and reports on French practices.

The baseline cancer risks by smoking status were computed using available data and literature. Three groups were considered according to smoking behavior: continuation of smoking, cessation of smoking at enrollment, and being weaned for 15 years.

Excess breast cancer cases were estimated using two radiation-risk models (BEIR VII and ICRP), and the attributable fraction to radiation associated breast cancer in 2019 were calculated. Excess risks of lung, breast, thyroid, stomach, liver, hematological cancers following LDCT screening were also estimated. A benefit-risk ratio was estimated as the ratio of prevented deaths over attributable deaths, assuming a decrease in lung cancer specific mortality during screening.

Results: About 27 out of 55,000 new breast cancer cases in 2019 were estimated to be attributable to breast screening practices between ages 50 and 74, with an additional 16 cases from screening between ages 40 and 49. This corresponds to an overall population attributable risk of 0.077% across all birth cohorts.

Among 100 000 smoking women (men, respectively), we estimated a lifetime attributable risk of about 15 (5) radiation-induced cancers, including 9 (3) lung cancers, and 2 breast cancers, leading to 9 (4) deaths. Compared to expected lung cancer deaths prevented, this leads to an estimated benefit-risk ratio of 23 in women (32 in men). Participants who stopped smoking have lower all-cause mortality risks and incidence rates, leading to greatly reduced benefit-risk ratios.

Conclusions/Implications: The overall contribution of breast cancer screening to the cancer burden is limited, but efforts to further reduce radiation doses should continue.

The estimated number of radio-induced lung cancers following repeated LDCT in the continuing group remains low compared to expected prevented deaths. Long-time quitters' better survival and lower cancer rate reduce screening benefit. Our results highlight that benefit-risk balance of

such screening is greatly dependent on smoking behavior. Optimizing doses will ensure that all enrolled individuals face a favorable ratio. Moreover, our work underlines the importance of considering the risk of radio-induced cancers for sites other than lung.

More generally, our work highlights the necessary consideration of the harmful effects of medical imaging techniques using ionising radiation when general population without clinical signs is invited to participate in a public health program.

S3.3–5 RADIATION AWARENESS AND OCCUPATIONAL CONCERNS AMONG NURSES WORKING WITH IONISING RADIATION - A DANISH SURVEY

Author: Malene Roland Vils Pedersen, Theresa Junker, Charlotte Abrahamsen, Sally Alsted Nørgaard, Helle Precht, Pernille Lund Hansen, Karen Brage | Co-Author: | Speaker: Karen Brage

Background: Nurses increasingly work in clinical environments involving ionising radiation (IR), yet little is known about their radiation protection knowledge, training, and occupational concerns in a Danish context.

The aim of this study was to investigate Danish nurses' knowledge, perceptions, practices, and concerns related to occupational IR exposure.

Methods: A national cross-sectional survey was conducted among Danish nurses working in environments involving IR. The survey included items on demographics, radiation protection training, self-reported knowledge of dose limits, use of protective measures, pregnancy-related workplace adjustments, and occupational concerns. Data was analysed using descriptive statistics as well as chi-square and Fisher's exact tests. Free-text responses were summarised thematically.

Results: A total of 498 nurses participated. Most respondents had received radiation protection training (72.7%); however, training was brief (median 1 hour), and follow-up education varied considerably. Only 16.4% reported knowledge of the occupational dose limit and 9.9% of the dose limit for pregnant workers. Dosimeter use was reported by 58.1% of respondents.

Concerns regarding radiation exposure affecting personal health, fertility, and children's health were reported by 20%, 13%, and 13% of respondents, respectively. Nurses younger than 40 years reported significantly greater concern regarding all three outcomes ($p < 0.001$).

Radiation protection training was associated with greater perceived preparedness, higher self-reported knowledge, increased dosimeter use, and more consistent use of protective measures.

Conclusions: Radiation protection training, knowledge, and protective practices varied considerably among Danish nurses working with IR. More structured and regularly updated radiation protection education is needed to strengthen occupational radiation safety.

S3.3–6 DIAGNOSTIC RADIOLOGY PROCEDURES DURING PREGNANCY: INITIAL FINDINGS FROM SONORA IN PHANTOM MEASUREMENTS AND EURADOS WG12 MULTI CENTRE FETAL DOSE ESTIMATIONS

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Objectives / Background: Within the EU-funded SONORA project, enhancing the accuracy of fetal dose estimation in diagnostic and interventional radiology during pregnancy is one of the objectives. Reliable fetal dose assessment in diagnostic radiology is essential for optimization of imaging protocols, transparent risk communication and clinical decision making. However, fetal dose varies substantially with gestational age, patient's morphology (height and weight) and beam geometry. In addition, methodological differences exist among the various approaches and tools used for fetal dose assessment. This study presents combined initial findings from SONORA WP3: (1) direct fetal dose measurements in TENA phantoms representing three gestation periods (GP1-GP3), and (2) a EURADOS WG12 multi-centre exercise in which nine dosimetry teams estimated fetal doses for the same radiographic and CT cases using their routinely applied calculation methods.

Methods: Measurements were performed for three clinical imaging scenarios representative of common diagnostic radiology procedures with the fetus positioned entirely inside the primary X-ray beam (abdominal radiography, abdominal CT, and polytrauma CT) using three TENA phantoms constructed according to ICRP 89 and validated in previous SONORA work. Radiophotoluminescent dosimeters (RPLD) (1 in GP1, 2 in GP2, 7 in GP3) were positioned within the fetal volume to capture spatial dose variation. Corresponding clinical cases and imaging parameters were distributed to nine EURADOS WG12 teams of experts, who estimated fetal doses using Monte Carlo-based software, analytical models, and hybrid tools. A comparative analysis of measured and estimated doses was performed across different modalities, hospitals and dosimetry teams, gestational periods, and methods ensuring a comprehensive understanding of fetal dose variations in clinical practice.

Results: Measured fetal doses showed significant inter hospital variability for the same procedure, reflecting differences in imaging protocols and optimization practices. Fetal dose depends on both gestational age and CT acquisition parameters, particularly CTDIvol. In GP3, intra-fetal dose variations reached up to a factor of four in radiography and approximately a factor of 1.5 in CT imaging. The comparison of doses estimated using calculation methods revealed substantial inter method variability, influenced by scanner modelling, field edge definition, fetal depth assumptions, and user-dependent choices. Even within the same tool, small parameter changes produced notable differences. Most tools returned a single fetal dose value, which fails to capture the measured dose gradients in late pregnancy.

Conclusions / Implications: This combined SONORA-EURADOS study presents a dataset of fetal doses across three gestational periods for the most frequent abdominal radiology procedures. The findings highlight the need for (1) standardized fetal dose estimation workflows, (2) explicit reporting of uncertainties, and (3) the consideration of dose ranges rather than relying on single values, especially for patients in the third trimester. These results contribute to evidence based optimisation strategies ultimately improving patient safety and care.

S3.3-7 CLAUD-IT: IMPROVING CLINICAL AUDITS ACROSS EUROPEAN BORDERS

Author: Esther Koke | *Co-Author:* | *Speaker:* Esther Koke

Background: The CLAUD-IT project was founded to support clinical audits in nuclear medicine and radiology across different European countries. Clinical audits are an important tool for improving quality and safety in daily clinical practice by reviewing the organization within the department. But there are no standardized cross-border requirements for the audits, so that all countries have different procedures. CLAUD-IT aims to detect the differences and establish comparability. At the same time, CLAUD-IT helps to build a routine in auditing with trainings from experts.

Methods: CLAUD-IT is planned as a 36-month project from 2024 to 2027 in 9 EU member states. The implementation of clinical audits is to be carried out in 6 work packages. The 11 participating first-round hospitals are connected among one another and supported by step-by-step training. The first aim is to conduct clinical audits under external guidance and gather insights into the implementation. The audits were separated in different templates. Each hospital had to choose three of the given themes and check one provided audit regarding the existence of signed patients consent forms. A mock audit was performed to validate the organization and to train for real audits. Later, the audits are to be expanded to additional second-round hospitals with the knowledge and learnings from the first round.

Results: The project showed a considerable variability in performed quality controls and internal standards across the countries. An exchange of knowledge was facilitated through online meetings and visits from external auditors to improve clinical audits. The recognized variability highlighted the need for the standardization of audits.

Conclusion: The implementation of clinical audits is important to improve and check quality controls to enhance patient safety. The exchange with other countries and hospitals helps to identify differences and establish comparability. In case of Germany, audits are well known and carried out regularly. So, the project did not improve the German audits but showed that the standards are already demanding.

POSTER SESSION - THURSDAY

PTH-01 CLINICALLY RELEVANT CYTOGENETIC BIODOSIMETRY FOR RADIOTHERAPY: ANTHROPOMORPHIC PHANTOM-BASED DOSE-RESPONSE CALIBRATION AND IN VIVO VALIDATION

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Biological dosimetry of partial-body irradiation remains challenging due to highly heterogeneous dose distributions in real-life exposure scenarios. Conventional cytogenetic dose-response calibration curves are typically generated under homogeneous in vitro conditions and may therefore insufficiently reflect clinically realistic exposure geometries required for accurate retrospective dose reconstruction. Modern radiation therapy, combined with three-dimensional dose planning, provides an opportunity to establish well-characterized partial-body irradiation settings suitable for the development and validation of improved calibration approaches.

In this study, a cytogenetic dose-response curve was generated by irradiating peripheral blood samples from a healthy donor inside a tissue-equivalent anthropomorphic RANDO phantom using 6 MV linac photons under clinically realistic radiotherapy conditions. The experimental setup reproduced dose distributions corresponding to single-fraction treatment of glioblastoma and breast cancer using VMAT and IMRT techniques, respectively. Delivered doses inside irradiated volume ranged from 0.1 to 2.67 Gy. Dicentrics and centric rings were evaluated in first-division metaphases of cultured lymphocytes using standard cytogenetic methodology.

The resulting dose-response curve showed very good agreement with the linear-quadratic model across the investigated dose range. Validation was performed using blood samples collected from glioblastoma and breast cancer patients after the first radiotherapy fraction. Reverse biodosimetry based on individual dose-volume data combined with the phantom-derived calibration curve provided estimates of chromosomal aberration yields, which were consistent with those observed in vivo.

This proof-of-principle study demonstrates the feasibility of cytogenetic dose reconstruction using anthropomorphic phantom-based calibration and supports the applicability of reverse biodosimetry under partial-body irradiation conditions with well-defined dose distributions. The approach may also be transferable to other non-uniform exposure scenarios with reliable physical reconstruction of dose geometry. Future calibration experiments will include a broader dose range and additional anatomical irradiation sites within the anthropomorphic phantom. The generated datasets may further contribute to the development and validation of AI-assisted biodosimetric tools within the RENEB framework.

Funding: This research work was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. [09I03-03-V01-00068], and co-financed by the European Regional Development Fund and Scientific Grant Agency (Vedecká grantová agentúra, VEGA) of the Ministry of Education, Research, Development and Youth of the Slovak Republic, grants No [2/0079/23] & [2/0140/23].

PTH-02 DESIGN AND WORKPLACE PERFORMANCE OF THE DOIN ELECTRONIC PERSONAL DOSEMETER FOR NEUTRONS

Author: Abner Ivan Castro Campoy, Roberto Bedogni | Co-Author: Antonino Pietropaolo, Charlotte Balderas, Claudio Antonio Federico, Ettore Mafucci, Evangelina Martinez-Frances, Felipe Lopes Frigi, Jose Maria Gomez-Ros, Luigi Russo, Paolo Ferrari, Stefano Turchi | Speaker: Abner Ivan Castro Campoy

Electronic personal dosimeters (EPDs) are widely used for operational radiation protection. While EPDs for photon radiation are well established and generally comply with relevant standards, neutron EPDs remain scarce. Those that do exist often exhibit strong energy and angular dependences, limiting their use without prior, field-specific information. DOIN is a novel type of active neutron personal dosimeter conceptualized and prototyped at INFN Frascati (Italy). Thanks to an innovative combination of differently filtered and moderated neutron sensors, DOIN estimates the energy distribution of the incident field, in turn selecting the most adequate calibration factor. After proving this concept for a preliminary prototype, a compact, wearable and fully functional device was built and replicated in a pre-industrial mini-series. These dosimeters were deployed to external users for evaluation in workplace environments and for the systematic collection of user feedback. This work describes the response of the new device determined in monoenergetic neutron fields and as well as using reference radionuclide neutron sources. In addition, the results of the workplace measurements are presented. The device, which satisfies the IEC 61526 accuracy criterion and exhibits larger sensitivity compared to state-of-art devices, is now ready for operational use.

PTH-03 TRANSFER OF SEDIMENT-DERIVED CARBON INTO BLACKWORM (LUMBRICULUS VARIEGATUS) AND CRUCIAN CARP (CARASSIUS CARASSIUS): IMPLICATIONS FOR ¹⁴C BIOSPHERE ASSESSMENT IN FRESHWATER ECOSYSTEMS

Author: Soroush Majlesi, Sayed Tariq Uzzaman, Zahra Shirani, Jaakko Haverinen, Ari T.K. Ikonen, Jarkko Akkanen | Co-Author: | Speaker: Soroush Majlesi

Objectives / Background: Radiocarbon (¹⁴C) is an important radionuclide in safety assessments of radioactive waste disposal because of its long half-life and potential transfer through aquatic food webs. While sediment-derived carbon may contribute to aquatic organisms, its role in freshwater consumers remains insufficiently understood. This study investigated the contribution of sediment-derived carbon to benthic invertebrates and fish and evaluated its implications for ¹⁴C biosphere assessment.

*Methods: A freshwater food chain was established in a microcosm using blackworm (*Lumbriculus variegatus*) and crucian carp (*Carassius carassius*). Natural differences in ¹⁴C abundance between sediment and food sources were used to estimate the contribution of sediment-derived carbon. Isotope mixing models were applied to quantify carbon-source partitioning, and $\delta^{15}\text{N}$ was used to support trophic-level characterization.*

Results: Sediment-derived carbon contributed substantially to blackworms (70-80% of tissue carbon), whereas only a minor contribution was observed in crucian carp (1-5%). Sediment and fish food were identified as the primary carbon sources for blackworms and fish, respectively. Food availability influenced carbon uptake pathways, with increased reliance on sediment-derived carbon under food-limited conditions.

Conclusions / Implications: The results demonstrate that sediment-derived carbon can represent an important transfer pathway for ¹⁴C in freshwater ecosystems, particularly for benthic organisms.

Improved understanding of these pathways supports the development of more realistic biosphere models and reduces uncertainty in environmental radiological protection and radioactive waste safety assessments.

PTH-04 TRANSCRIPTOMIC BIOMARKERS OF SYSTEMIC RESPONSE TO RADIOTHERAPY ALONE AND COMBINED RADIOTHERAPY–IMMUNOTHERAPY IN BREAST CANCER

Author: Albert Alegret-García | Co-Author: Altay Myssayev, Isabelle Thierry-Chef, Sophie Jacob | Speaker: Altay Myssayev

Background: Radiotherapy (RT) induces tumor cell death and modulates antitumor immune responses, effects potentially enhanced when combined with immunotherapy (RT+IO). However, transcriptomic biomarkers predicting systemic and pathological response remain insufficiently characterized. We aimed to identify reproducible gene expression signatures associated with RT and RT+IO in breast cancer.

Methods: Publicly available breast cancer transcriptomic datasets (GEO, ArrayExpress) evaluating RT and RT+IO were reprocessed from raw data (RNA-seq and microarrays). Differential gene expression analysis was performed using DESeq2 and limma with repeated-measures modeling when appropriate. Mixed-effect models were applied for targeted analyses with repeated measures. Associations with survival outcomes were evaluated using Kaplan-Meier and Cox proportional hazards models. Random Forest algorithms were applied to identify genes contributing most strongly to treatment-associated transcriptional variation.

Results: Keratin family genes emerged as consistent signatures of treatment response. In RT only datasets, basal/stress keratins (KRT5, KRT6B, KRT14) were significantly upregulated following RT, suggesting radiation-induced activation of stress-adaptive epithelial programs. KRT5 expression was further associated with survival outcomes. In contrast, luminal keratins (KRT8, KRT18, KRT19) were enriched in radiosensitive models but were not strongly induced post-RT, indicating that baseline epithelial differentiation state may influence radiosensitivity rather than reflect treatment-induced transcriptional changes. Additional immune-related genes including CD44, HLA family members, and CD14 were also modulated after RT. In a dataset combining RT with a TLR7 agonist, KRT7 was significantly downregulated, accompanied by interferon/Th1-oriented immune signatures and reduced DNA repair programs.

Conclusions: RT induces a transcriptional shift toward a basal, stress-associated phenotype, whereas RT+IO promotes immune activation together with reduced epithelial plasticity and DNA repair signaling. Keratin dynamics combined with immune-related markers represent candidate biomarkers to stratify patients and optimize RT-based therapeutic strategies in breast cancer.

PTH-05 DOSELIA PROJECT TASK 6.1: GENETIC SUSCEPTIBILITY TO RADIATION-INDUCED CANCER AND TREATMENT RESPONSE: THE ROLE OF TRISOMY 21, ATM, BRCA1/2 AND RADIATION QUALITY

Author: Vasiliki Zanni | Co-Author: Charlotte Robert, Kave Moloudi, Neige Journy, Siamak Haghdoost | Speaker: Vasiliki Zanni

Radiation-induced carcinogenesis is determined by a complex interplay between host genetic susceptibility and the physical characteristics of radiation exposure. This study examines how defects in the DNA damage response (DDR) pathway, particularly involving Ataxia-Telangiectasia Mutated (ATM) kinase and the BRCA1/2 homologous recombination (HR) complex, as well as

constitutional chromosomal abnormalities such as Trisomy 21, influence cancer risk, tissue-specific vulnerability, and therapeutic response following exposure to different radiation qualities.

A systematic review of 60 multidisciplinary studies was performed, encompassing experimental studies in animal tissues, case series or cohorts in humans, and peer-reviewed publications within the radiobiology field. Cellular responses, mutational signatures, and tissue-specific effects were evaluated across three radiation modalities: low-linear energy transfer (LET) photons (X-rays and γ -rays), proton therapy characterized by a Bragg Peak, and high-LET neutron radiation.

Low-LET photon radiation predominantly induces isolated DNA double-strand breaks (DSBs), whose accurate repair relies on ATM signaling and BRCA1/2-mediated HR. For carriers of BRCA mutations, this creates a significant gene-environment interaction, whereby cumulative low-dose diagnostic photon exposure ($\sim 17\text{mGy}$) particularly before 30 years of age, increases the risk of breast cancer. Similarly, patients with ATM mutations—most notably those with ataxia-telangiectasia—exhibit profound radiation sensitivity, placing them at a significantly higher risk of developing severe toxicities and secondary malignancies following radiotherapy. An analogous vulnerability is observed in individuals with Down syndrome, where repeated diagnostic imaging contributes additional radiation exposure to an already dysregulated and highly proliferative hematopoietic system, increasing susceptibility to leukemogenesis.

Conversely, loss of ATM or BRCA1/2 function within established tumors markedly enhances radiosensitivity, resulting in extensive genomic instability and mitotic catastrophe following photon irradiation. Proton therapy demonstrates a dual radiobiological profile. While its low-LET entrance dose reduces irradiation of healthy tissues and may lower secondary cancer risks in genetically susceptible individuals, LET increases substantially at the distal Bragg Peak. This region generates clustered DNA damage that strongly depends on ATM-mediated DNA end processing and BRCA1/2-directed HR for repair. Deficiencies in these pathways force repair through error-prone non-homologous end joining, thereby amplifying tumor cell killing and enhancing therapeutic efficacy.

High-LET neutron radiation (due to proton radiotherapy) produces dense and complex DNA lesions that overwhelm canonical DDR mechanisms and shift repair toward alternative pathways, generating characteristic structural rearrangements, inversions, and microhomology-mediated deletions. Trisomy 21 exhibits a striking tissue-specific paradox: increased chromosome 21 dosage promotes chronic overexpression of anti-angiogenic factors that may protect against radiation-induced solid tumors, while simultaneously increasing the vulnerability of hematopoietic progenitor cells to photon- and neutron-induced leukemogenesis.

Radiation-induced cancer risk and treatment response are highly dependent on the interaction between radiation quality and genetic background. While high-LET radiation can generate extensive chromosomal damage with reduced dependence on classical DDR pathways, proton therapy offers important clinical advantages by limiting normal tissue exposure while exploiting DNA repair deficiencies within tumors. These reports support the transition from generalized radiological protection models toward personalized risk assessment and genetically informed particle-based therapeutic strategies.

PTH-6 RANE: BRIDGING THE GAP BETWEEN RAPID GENERIC RESPONSE AND ACCURATE PLANT-SPECIFIC DECISION SUPPORT IN NUCLEAR EMERGENCIES

Author: Juan Carlos de la Rosa Blul | Co-Author: | Speaker: Juan Carlos de la Rosa Blul

Effective emergency preparedness and response (EPR) for nuclear and radiological events critically depends on the ability to support decision-making under severe time constraints while maintaining

sufficient physical realism. In current practice, operational capabilities tend to diverge into two distinct approaches: rapid but generic methods, based on predefined scenarios and simplified assumptions, and accurate but time-consuming approaches relying on detailed plant-specific modelling of accident progression, source term, and radiological consequences. This fundamental trade-off limits the effectiveness of early decision-making, when timely and reliable information is most needed.

This contribution presents the RANE (Radiological Assessment for Nuclear Emergencies) framework developed at the European Commission's Joint Research Centre (JRC), which is specifically designed to bridge this gap. RANE combines rapid, AI-enabled situation assessment with mechanistic, plant-specific modelling capabilities, enabling a progressive transition from early generic evaluations to physically grounded, facility-specific analyses within operationally relevant timescales.

The RANE workflow is structured into three integrated modules: (1) input and activation, (2) core radiological assessment, and (3) output-to-outcome transformation. The input module leverages machine learning and artificial intelligence techniques to rapidly capture, filter, and interpret heterogeneous data streams, including early notifications, plant characteristics (e.g. PRIS-based, EURDEP, etc.), and contextual information. This enables robust and timely identification and activation of plausible accident scenarios, even under incomplete, uncertain, or evolving conditions.

The core module performs plant-specific mechanistic calculations of accident progression, including thermal-hydraulic behavior, severe accident evolution, and source term estimation. These calculations rely on design-based surrogate models, tailored with plant-specific information such as reactor design, safety and mitigation systems, and relevant initial and boundary conditions affecting radionuclide releases. In addition, the core module computes atmospheric dispersion and deposition, enabling consistent dose projection assessments. By integrating accident progression and off-site consequence modelling within a unified framework, RANE ensures coherence between source term estimation and radiological impact evaluation.

A key feature of RANE is its ability to progressively refine assessments as new information becomes available, ensuring continuity between early rapid evaluations and subsequent high-fidelity analyses, and avoiding discontinuities in decision-making. The output-to-outcome module translates radiological results into structured and traceable recommendations for protective actions, explicitly linking projected consequences to generic intervention criteria. This supports transparent, defensible, and harmonized decision-making across different operational contexts.

The applicability of RANE is particularly relevant in complex and emerging scenarios, including multi-hazard and conflict-driven contexts, where uncertainties on initiating events and system performance challenge traditional approaches and are properly taken into account by RANE. By bridging the gap between rapid response and accurate plant-specific modelling, RANE provides a robust framework to support timely, consistent, and evidence-based decision-making in nuclear emergencies.

PTH-07 THE IMPACT OF INTER- AND INTRA- INDIVIDUAL VARIABILITY ON THE DNA DAMAGE RESPONSE TO IONISING RADIATION

Author: Hannah Mancey, Jochen Einbeck, Philip Davies, Stephen Barnard | Co-Author: | Speaker: Hannah Mancey

Phosphorylation of the ser-139 residue of the histone variant H2AX, which then forms γ H2AX, is an early cellular response to the induction of DNA double-strand breaks caused by ionising radiation, and can be detected and quantified by immunofluorescent staining under fluorescent microscopy (1). γ H2AX can be detected manually as foci, or using automated methods such as flow cytometry, both of which form a clear dose-response relationship (1). This method provides faster dose estimates than the 'gold standard' dicentric assay, in as little as 4 hours. However, dose estimates tend to be less accurate, with lower specificity of DNA DSBs to ionising radiation. Several other

factors are documented to cause DNA DSBs, including age, smoking status, genetics, and stress (2, 3), leading to variation in the DNA damage response both between and within people. This inter- and intra- individual variability is currently accounted for in dose estimation as overdispersion (4); however, no studies have directly measured or modelled these factors as part of a dose estimation procedure. This review aims to assess the impact of inter- and intra- individual variation on the DNA damage response to ionising radiation, and how this could affect dose and uncertainty estimation.

References

1. Simon Horn SB, Kai Rothkamm. Gamma-H2AX-Based Dose Estimation for Whole and Partial Body Radiation Exposure. *PLoS ONE* 6(9): e25113. 2011.
2. Perumal V ST, Raavi V, Basheerudeen SAS, Kanagaraj K, Chowdhury AR, Paul SF. Radiation signature on exposed cells: Relevance in dose estimation. *World J Radiol* 2015; 7(9): 266-278. 2015.
3. Hare BD, Thornton TM, Rincon M, Golijanin B, King SB, Jaworski DM, et al. Two Weeks of Variable Stress Increases Gamma-H2AX Levels in the Mouse Bed Nucleus of the Stria Terminalis. *Neuroscience*. 2018;373:137-44.
4. Einbeck J, Ainsbury EA, Sales R, Barnard S, Kaestle F, Higuera M. A statistical framework for radiation dose estimation with uncertainty quantification from the γ -H2AX assay. *PLOS ONE*. 2018;13(11):e0207464.

PTH-08 RADIATION PROTECTION CHALLENGES FOR THE LHC EXPERIMENTS IN LONG-SHUTDOWN 3

Author: Robert Froeschl | Co-Author: Bartosz Idzior, Davide Bozzato, Miguel Caballero-Pacheco, Tommaso Lorenzon | Speaker: Robert Froeschl

June 29, 2026 marks the start of Long Shutdown 3 that will last almost 4 years for the CERN Large Hadron Collider (LHC). During this period the LHC will be upgraded to the High-Luminosity LHC (HL-LHC) resulting in an increase in collision rate by a factor five to seven beyond the original LHC design value.

This increase of collision rate will translate into harsher radiation environments and high data rates for the LHC Experiments. The LHC experiments, especially the ATLAS and CMS experiments, will undergo major upgrades as well during Long Shutdown 3 to be able to take full advantage of these high collision rates, aiming for an increase of almost a factor of ten in integrated luminosity by the early 2040s.

A large number of detector components of various sizes will need to be decommissioned or refurbished and the upgraded detector components will then be installed in the underground experimental cavern during Long Shutdown 3. Decommissioned components will need to be transported requiring detailed radiological characterization. Prolonged interventions in high-residual radiation environments will take place to perform all these activities.

Advanced FLUKA Monte Carlo simulations have been performed to support the radiological optimization of these tasks, both in terms of dose to personnel and characterization and minimization of radioactive material. These simulations use dedicated simulation methodologies developed at CERN in the last years specifically for the preparation of Long Shutdown 3.

This contribution provides a comprehensive overview of the radiation protection studies in support of the activities in the LHC experiments during Long Shutdown 3. Radiological characterization of material and the associated zoning concepts as well as the dose estimation techniques are presented based on concrete example cases from the LHC experiments that illustrate the dedicated simulation methodologies developed at CERN.

The lessons learned during previous Long Shutdowns and from the preparation and the first months of Long Shutdown 3 are summarized.

PTH-09 BIOMARKERS OF RADIATION RESPONSE FOLLOWING CURCUMIN TREATMENT IN HUMAN PERIPHERAL BLOOD LYMPHOCYTES

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*Ionizing radiation induces a broad spectrum of biological responses that can be quantified using biomarkers relevant for radiation biodosimetry and radiation protection. Identification of agents capable of modifying these responses is important both for mitigation of normal tissue injury and for optimization of radiotherapy outcomes. In this study, we investigated the effects of curcumin (*Curcuma longa*), a plant-derived polyphenol with reported antioxidant and radiosensitizing properties, on biological markers of radiation-induced damage in human peripheral blood lymphocytes exposed to a clinically relevant dose of 3 Gy. Cells were pre-treated with curcumin at concentrations ranging from 0.1 to 50 µg/mL prior to irradiation. Radiation-induced biological effects were assessed using lipid peroxidation assays as indicators of oxidative stress, single-cell gel electrophoresis (comet assay) as a marker of DNA damage, and flow cytometry-based apoptosis analysis. Lower curcumin concentrations showed a tendency toward reduced radiation-induced damage, although the observed effects did not reach statistical significance. In contrast, higher concentrations significantly increased cytotoxic and genotoxic responses following irradiation. These findings demonstrate a concentration-dependent modulation of biomarkers associated with radiation exposure and cellular radiosensitivity. The observed differential effects suggest that curcumin may influence biological endpoints relevant for biodosimetric assessment and individual radiation response. Ongoing studies are evaluating whether concentrations that enhance radiation-induced effects in normal lymphocytes may also increase radiosensitivity in tumor cells while preserving the therapeutic ratio during radiotherapy.*

Acknowledgement: This research work was funded by the Scientific Grant Agency (Vedecká grantová agentúra, VEGA) of the Ministry of Education, Research, Development and Youth of the Slovak Republic, Grant No. 2/0082/23.

PTH-10 ABERRANT GRB10 EXPRESSION ASSOCIATED WITH PARTIAL DELETIONS OF CHROMOSOME 11 IN HIGH-LET CARBON-ION-INDUCED MOUSE THYMIC LYMPHOMAS

Author: Masaaki Sunaoshi | Co-Author: Erika Takahashi, Yoshiko Amasaki, Takamitsu Morioka, Kazuhiro Daino, Mayumi Nishimura, Yoshiya Shimada, Daisuke Iizuka, Shizuko Kakinuma | Speaker: Masaaki Sunaoshi

Background: High linear energy transfer (LET) radiation is known to induce more complex DNA damage than low-LET photon radiation such as X-rays, suggesting distinct mechanisms underlying carcinogenesis following high-LET exposure. Previously we demonstrated that mouse thymic lymphomas (TLs) induced by carbon-ion radiation showed a higher frequency of large genomic deletions than in gamma ray-induced TLs. However, carcinogenic mechanisms depending on radiation quality or LET remain poorly understood. In this study, we aimed to identify characteristic genetic alteration and the molecular mechanisms involved in TL development following high-LET carbon-ion irradiation.

Methods: TLs were induced in female B6C3F1 mice by whole-body irradiation with high-LET carbon-ion (1.6 Gy/fraction; mean LET: 60 keV/μm) once weekly for four consecutive weeks, starting at age 4-5 weeks. The induced TLs were analyzed for genome-wide loss of heterozygosity (LOH), copy number alteration, mutations in tumor suppressor genes, and comprehensive gene expression profiles to identify characteristic genetic alterations.

Results: TLs induced by fractionated high-LET carbon-ion irradiation frequently exhibited LOH on chromosome 11, encompassing the TL-associated gene **Ikzf1**, due to extensive genomic deletions in the paternal allele. Notably, TLs exhibiting LOH without **Ikzf1** alterations were observed at a relatively high frequency (16/39, 41.0%). RNA-sequencing and reverse transcription-PCR analyses of genes neighboring **Ikzf1** revealed marked upregulation of **Grb10** (17/39, 43.6%), an imprinted gene faintly expressed in the normal thymus. In **Grb10**-expressing TLs, enhanced interferon signaling, frequent **Pten** mutations, and activation of the PI3K-AKT-mTOR signaling pathway were suggested to promote cell proliferation and survival.

Conclusions: These findings indicate that extensive genomic deletions caused by high-LET carbon-ion irradiation may contribute to carcinogenesis by simultaneously disrupting multiple genes located in the deleted region, leading to aberrant signaling pathways that promote tumor development.

PTH-11 GLAUCOMA AND CATARACT INCIDENCE AMONG KOREAN RADIATION WORKERS: A NATIONWIDE HEALTH INSURANCE-LINKED COHORT STUDY

Author: Sang Ah Lee | *Co-Author:* Ari Lee, Dalnim Lee, Soojin Park, Gabin Lee, Songwon Seo, In Jeong Lyu, Minsu Cho, Eun Shil Cha | *Speaker:* Sang Ah Lee

Background Radiation exposure has been implicated in several ocular diseases, particularly cataract. However, evidence regarding the effects of chronic low-dose occupational radiation exposure on cataract and glaucoma remains limited. This study evaluated the incidence of glaucoma and cataract and their association with cumulative occupational radiation exposure among Korean radiation workers.

Methods This nationwide cohort study included 196,379 radiation workers enrolled in the Korean Radiation Workers Study (KRWS) with dosimetry records from 1984 to 2021. The cohort was linked with National Health Insurance Service claims data from 2002 to 2022. Eye lens doses were reconstructed from individual badge dose records using organ dose conversion coefficients. Incident glaucoma and cataract cases were identified using diagnostic, procedure, and examination codes from claims data to improve case ascertainment. Glaucoma was classified into primary open-angle, primary angle-closure, secondary, and other subtypes. Cataract was classified into senile and other cataracts; senile cataract was further subdivided into senile incipient cataract (e.g., posterior subcapsular and cortical cataracts) and nuclear cataract. Relative risks (RRs) and excess relative risks (ERRs) per 100 mGy were estimated using Poisson regression models with a 5-year lag, adjusted for age, sex, and calendar year.

Results During a mean follow-up of 13.7 years (mean cumulative eye dose 5.4 mGy), 5,636 glaucoma cases and 6,452 cataract cases were identified. No clear dose-response relationship was observed between cumulative radiation dose and the incidence of glaucoma, cataract, or their subtypes. In subtype analyses, elevated RRs were observed in some subtypes, including primary angle-closure glaucoma and other cataracts; however, no consistent dose-response trends were evident. ERR estimates per 100 mGy for overall glaucoma and cataract were -0.05 (95% CI -0.21 to 0.10) and 0.03 (95% CI -0.10 to 0.17), respectively.

Conclusion In this nationwide cohort of Korean radiation workers, chronic low-dose occupational radiation exposure was not clearly associated with glaucoma or cataract incidence. Although several subtype-specific associations were observed, no consistent dose-response relationships were evident. Continued follow-up is warranted to clarify potential risks associated with higher cumulative doses and longer latency periods.

PTH-12 CONSTRUCTION MATERIALS AND RESIDUES – INTRODUCING CROATIAN GEOTHERMAL DRILLING WASTE ISSUES

Author: Ivica Prlic, Zelimir Veinovic | Co-Author: Luka Pavelic, Branko Petrincic | Speaker: Ivica Prlic

Abstract: EU Member States are responsible for the safety, environmental and energy requirements applicable to buildings and other civil engineering constructions. Mineral materials that belong to group of Naturally Occurring Radioactive Material (NORM) residues, from mining and other industries, are under the “reuse” waste management policy increasingly utilized in manufacturing of building materials. Within the EU these materials are falling under the dual regulation of radiological safety standards Euratom Basic Safety Standards (Directive 2013/59/Euratom) which sets requirements for NORM in building materials and are to be integrated into the new Construction Products Regulation (EU) No 2024/3119 (CPR). It will be essential to add this information into a Digital Product Passport (DPP). DPP will be mandatory starting in 2026 serving as a basis for ensuring traceability, transparency, and access to essential information throughout the product's lifecycle including data on the composition, origin, carbon footprint, and reuse or recycling potential of each material reducing the environmental impact of the built environment. As Croatia has no such integrated standards this paper provides basic lessons learned during the reconstruction campaign of public educational and health buildings after the Zagreb and Petrinja earthquakes for which reconstruction permits the Radon protection Plan was legal obligation due to a National Recovery and Resilience Plan 2021-2026. financially supported by European Bank for Reconstruction and Development. As in many public buildings, following EU Green Deal Plan the green energy is to be utilized this paper covers the novelty research covering the possible NORM residues from geothermal heating sources like for the new National Children Hospital facility in Zagreb. The forming of a new “Geothermal Energy” regulation as well as a new Croatian Radon action plan which are in progress and it is to expect that those regulation packages will have a huge impact on research possibilities and practical solutions covering the Green Energy field regarding Climate Actions, having an enormous impact on reducing the NORM residues Rad Waste issues in Croatia and be a base for One Health housing and new construction materials development from industrial processes.

PTH-13 SCREENING FOR MOLECULAR SIGNATURES OF RADIOTHERAPY AND IMMUNE SYSTEM ACTIVATION IN BREAST CANCER: A SPATIAL MULTI-OMICS APPROACH APPLIED TO EX-VIVO CANCER SAMPLES

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Radiotherapy (RT) can enhance anti-tumor immune responses by increasing tumour immunogenicity and promoting immune-cell recruitment, potentially synergizing with immune checkpoint blockade. However, these effects are highly heterogeneous and reliable predictive biomarkers are still lacking. This gap is particularly evident in immunogenic breast cancer (BC) subtypes, such as triple-

negative (TNBC) and HER2-positive, where RT is an essential component of the therapeutic approach but its interaction with the tumor immune microenvironment (TIME) remains poorly understood.

We hypothesize that ionizing radiation induces highly localized, spatially heterogeneous transcriptional and immune remodelling within the TIME. The IMAGEOMICS Project (co-funded by the European PIANOFORTE partnership) aims to improve the benefit/risk ratio of BC radiotherapy, focusing on immune system activation by radiation. A work-package is dedicated to the identification of molecular changes in the tumor micro-environment after radiation, using high-throughput Spatial-Omics techniques.

To this aim, we will collect BC resections of patients undergoing surgery at Fondazione IRCCS Policlinico San Matteo (Pavia); from each tissue volume, two samples will be prepared: one irradiated with 5Gy-Xray, the other retained as control. Following irradiation, tissue samples will be maintained under controlled ex vivo culture conditions for 16-24h to allow development of early radiation-induced molecular and cellular responses. Samples will then be fixed and processed for Spatial Proteomics (Akoya platform) and Spatial Transcriptomics (10x Genomics Visium HD).

Spatial transcriptomics analysis will enable genome-wide profiling of gene expression while preserving tissue architecture. Sequencing data will undergo quality control, normalization, dimensionality reduction, and spatial clustering to define distinct cellular niches. Differential gene expression analysis between irradiated and control samples will be performed both globally and within spatially defined regions. Functional enrichment analyses (Gene Ontology, KEGG, Reactome, and Gene Set Enrichment Analysis) will be used to identify biological pathways associated with DNA damage response, cell death, inflammation, immune activation, and radioresistance. In parallel, spatial proteomics will be performed using a panel of 27 protein markers. Quantitative image analysis will be used to identify cell phenotypes, assess protein expression changes induced by irradiation, and characterize cell-cell interactions and tissue architecture. Spatial statistical approaches will further quantify immune infiltration patterns, neighborhood structures, and remodeling of the tumor architecture after irradiation.

By mapping these architectural shifts, this project aims to characterize radiation-induced immune dynamics and identify novel spatial biomarkers of early immunogenic response.

PTH-14 THE MONITORING FOR INTAKES OF RADIONUCLIDES IN GERMANY: PRESENTATION OF THE REVISED GUIDELINE

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In Germany, 21 approved internal dosimetry services offer in-vivo and in-vitro methods for the monitoring of workers for intakes of radionuclides. Approx. 1300 individuals are subject to this monitoring and they receive approx. 3800 measurements per year. Beside these measurements at internal dosimetry services, monitoring of airborne radionuclides at the workplace is conducted under the responsibility of the employers, currently only for confirmatory monitoring because of a lack of demand for this method for individual monitoring, though.

A guideline, which was revised in 2025, regulates the implementation of the monitoring for occupational intakes of radionuclides in Germany. It defines a threshold for the annual effective dose, expressed as the so-called likely committed effective dose, of 1 mSv, above which routine monitoring is required. The calculation of the likely committed effective dose is based on the handled activity and incorporation factors. It deviates in the details of the incorporation factors

from international standards because of a lack of verifiability from primary literature. For applications in nuclear medicine, specific incorporation factors based on recent literature are tabulated. Regarding the monitoring of persons of childbearing potential, an assessment of the equivalent dose for the uterus and if required a monthly monitoring are prescribed. The guideline demands a minimum quality assurance programme of the approved monitoring services, which adapts parts of the extensive requirements of an accreditation selectively for the specifics of internal dosimetry. For workplace monitoring, technical requirements, in particular quality-assurance procedures, are also specified. Regarding the dose assessment, a reference method and several individual methods are described, with the investigation threshold for switching to individual methods corresponding to an effective dose of 6 mSv during the calendar year. For the reference method, standard assumptions (inhalation, AMAD 5 µm for workplaces, 1 µm for emergency workers with environmental exposure) are applied.

The German system of monitoring for intakes of radionuclides contributes to a variety of the United Nations' Sustainable Development Goals (SDG):

The continuous development of monitoring methods in internal dosimetry services along or even ahead of novel nuclear applications contributes to a safe and also lawful conduction of these applications. This refers to novel applications in nuclear medicine, current methods in nuclear decommissioning, research with novel radionuclides etc. and is one of many requisites for innovation in these fields (SDG 9).

The definition of minimum requirements for monitoring intervals, detection limits etc. together with the interaction of various monitoring methods for different radionuclides leads to a comprehensive monitoring for incorporation risks and establishes trust in safe working conditions at nuclear workplaces (SDG 8).

With clearly defined criteria in which cases internal monitoring is required and how it is conducted, all involved stakeholders (licensees, public authorities and internal monitoring services) take decisions in a predictable way and act accountably. Therefore, the existence of a national guideline on the monitoring of intakes of radionuclides constitutes the foundation for effective and accountable institutions in this field (SDG 16).

PTH-15 EXCESS ABSOLUTE AND RELATIVE RISKS OF CANCER MORTALITY AMONG KOREAN RADIATION WORKERS FOLLOWING PROTRACTED LOW-DOSE OCCUPATIONAL RADIATION EXPOSURE

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BACKGROUND: Evidence on cancer mortality associated with occupational radiation exposure has been derived predominantly from large Western nuclear worker cohorts such as INWORKS and the UK National Registry for Radiation Workers, in which excess relative risk (ERR) has been the primary measure of dose-response association. Evidence from East Asian populations remains limited despite potential differences in baseline cancer mortality rates that may influence absolute risk estimates. In addition to ERR, excess absolute risk (EAR) provides complementary information by quantifying the absolute increases in mortality per unit dose, which may be relevant for evaluating the public health impact of occupational radiation exposure. This study estimated both EAR and ERR for cancer mortality among Korean radiation workers using organ-specific absorbed doses.

METHODS: A national cohort of 164,445 Korean radiation workers was linked to the National Vital Statistics Registry (1992-2020) and the National Health Insurance Service (NHIS) database for

covariate information. The cohort contributed 2,542,610 person-years, during which 1,038 cancer deaths were recorded. Cumulative organ-specific absorbed doses (Gy) (1984-2021) were estimated from recorded occupational doses using ICRP dose conversion coefficients and used as exposure metrics. EAR and ERR were estimated using Poisson regression models with a 10-year lag for solid cancer and a 2-year lag for leukemia, adjusting for sex, attained age, calendar year, and lifestyle (smoking and alcohol drinking) and socioeconomic factors available from NHIS data.

RESULTS: Participants were predominantly male (84.1%), with a mean follow-up of 15.5 years. Mean cumulative colon and red bone marrow doses were 5.36 and 4.66 mGy, respectively. For solid cancer mortality, the EAR was 0.002 excess deaths per 100,000 person-years per Gy (95% CI: -2.00 to 2.00), and the corresponding ERR per Gy was 1.81 (95% CI: -3.11 to 6.73). Site-specific analyses showed no statistically significant dose-response associations, although stomach cancer had the highest ERR estimate (16.37, 95% CI: -4.65 to 37.39). No significant associations were observed for solid cancer or any specific cancer site examined.

CONCLUSIONS: No statistically significant dose-response associations were observed for cancer mortality in this nationwide cohort of Korean radiation workers exposed to protracted low-dose radiation. This study provides both excess absolute risk (EAR) and excess relative risk (ERR) estimates for cancer mortality in an Asian occupational cohort. Although positive point estimates were observed for some cancer sites, particularly stomach cancer, these estimates were imprecise, with wide confidence intervals, and should be interpreted with caution. The wide confidence intervals likely reflect the relatively low cumulative dose and limited numbers of cancer deaths observed in this cohort. Continued follow-up will be important to improve the precision of risk estimates.

PTH-16 POTENTIAL IMPACT OF PATIENT CARE INVOLVEMENT RATIO ON OCCUPATIONAL RADIATION EXPOSURE IN CARDIOVASCULAR INTERVENTIONAL RADIOLOGY

Author: Tomoko Kuriyama | Co-Author: Go Hitomi, Takashi Moritake | Speaker: Tomoko Kuriyama

In interventional radiology (IR), nurses are generally considered to receive lower radiation doses than physicians. However, their exposure risk is difficult to evaluate uniformly because nurses have greater mobility, and their proximity to the patient—who is the primary source of scattered radiation—varies depending on their procedural role. In IR procedures performed without general anesthesia, patients are more likely to experience discomfort or distress. Nurses therefore play a critical role in promptly detecting changes in patient condition, communicating these to physicians, and alleviating both physical and psychological burden. In addition, nurses perform a wide range of tasks, including patient assistance and maintaining procedural workflow. These task-related behaviors may also influence positioning within the procedure room, which is a key determinant of occupational radiation exposure. This study aimed to analyze how task allocation within cardiovascular IR teams affects nurses' intra-procedural positioning and its implications for radiation protection.

A questionnaire comprising 53 items on the working environment and duties of nurses engaged in cardiovascular IR was developed. A survey was conducted over a 10-month period from February 2023 targeting certified expert radiological technologists for angiography and intervention (Ex-RT) accredited by the Japan Professional Accreditation Board of Radiological Technologist for Angiography and Intervention. Among the 53 items, 21 were used for analysis. Nineteen tasks potentially performed by nurses during cardiovascular IR were classified into five categories based on the primary responsible profession, including nurse-dominant, nurse-physician shared (e.g., assessment of consciousness level), and multidisciplinary collaborative tasks. For seven nurse-physician shared tasks, the ratio of physician-performed to nurse-performed tasks (P/N ratio) was

calculated for each institution to evaluate patterns of involvement. Group comparisons were performed using the Mann-Whitney U test and χ^2 test.

Responses were obtained from 78 of 434 institutions. In institutions with higher nurse involvement (P/N ratio < 1.0 , $n = 31$), nurses were more frequently positioned near the patient's head. In contrast, in institutions with higher physician involvement (P/N ratio > 1.0 , $n = 19$), nurses were more likely to work near the patient's feet or outside the procedure room ($p < 0.05$). Additionally, institutions with higher nurse involvement tended to have fewer hospital beds than those with higher physician involvement ($p = 0.107$).

For nurse-physician shared tasks, complementary functioning between the two professions was commonly observed. The P/N ratio was influenced by institutional structure, which in Japan is closely associated with hospital size (i.e., number of beds). Smaller hospitals tended to have lower P/N ratios, reflecting greater nurse involvement. Nurses' positioning strongly affects both access to clinical information and potential radiation exposure. Positioning near the patient's head allows acquisition of critical clinical information and facilitates rapid response to changes in patient condition but may involve closer proximity to the source of scattered radiation. Conversely, positioning near the patient's feet may reduce radiation exposure due to greater distance from the irradiation field and shielding by physicians. These findings suggest that task allocation and team organization should be considered alongside radiation protection strategies to optimize both patient care and occupational safety in IR settings.

PTH-17 BETA IRRADIATION FACILITY BSS 2: AN UPDATE

Author: Rolf Behrens | Co-Author: Phil Brüggemann, Jürgen Roth, Niclas Schwertfeger, Patrik Kramer | Speaker: Rolf Behrens

Introduction: The irradiation facility for beta radiation, Beta Secondary Standard BSS 2, has been developed and continuously improved by PTB [1] and is commercially available [2]. For several years, it has been in worldwide use to perform irradiations with calibrated beta sources traceable to PTB in terms of the operational quantities in radiation protection.

Main characteristics of the BSS 2, including its most recent hard- and software update:

1. beta sources ^{147}Pm , ^{85}Kr , $^{90}\text{Sr}/^{90}\text{Y}$, and $^{106}\text{Ru}/^{106}\text{Rh}$ with mean energies from (0.07...1.2) MeV;
2. operational quantities $H_p(0.07)\text{S}$, $H_p(3)$, $H'(0.07)$ and $H'(3)$;
3. dose rates of $\sim (10\ldots1000)$ mSv/h;
4. PTB-traceable dosimetry in accordance with ISO 6980-1, -2 and -3:2023;
5. fully software-controlled irradiation of dose and dose rate;
6. sensors for all parameters relevant for the dose (rate), such as radio nuclide, beam-flattening filter, angle of radiation incidence, distance, ambient conditions etc.;
7. ISO rod and slab phantom;
8. recent addition of energy reduced $^{90}\text{Sr}/^{90}\text{Y}$ radiation field (0.54 MeV instead of 0.8 MeV) [3].

Conclusion: The BSS 2 remains a modern and fully quality assured irradiation facility for beta radiation.

References:

- 1: [PTB's website][1]
- 2: [Eckert & Ziegler Strahlen- und Medizintechnik AG: www.ezag.com][2]
- 3: [R. Behrens 2024 JINST 19 P07003][3]

[1]: <https://www.ptb.de/cms/en/ptb/fachabteilungen/abt6/fb-63/information/results-of-research.html#c38376>

[2]: <https://www.ezag.com/de/produkte/isotope-products/isotrak-calibration-sources/instruments/beta-secondary-standard-2-bss-2/>

[3]: <https://iopscience.iop.org/article/10.1088/1748-0221/19/07/P07003>

PTH-18 TRAINING ACTIVITIES WITHIN THE PROJECT GUIDERADPROS TO SUPPORT A BETTER IMPLEMENTATION OF ISO 4037

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The GuideRadPROS research project (22NRM07) ran for three years until June 2026. An important part of the project was the organisation of training activities and development of training material to make standards on radiation protection dosimetry more accessible to users.

The central part of the training activities was the development of e-learning material on the main aspects of setting up reference radiation fields according to ISO 4037 and calibration of radiation protection doseimeters. It was developed in four steps:

- 1. At first, a questionnaire was sent to stakeholders including NMIs, DIs, SSDLs through networks such as EURAMET, TC-IR, EMN RP and the IAEA SSDL network. The aim was to identify the training needs of calibration laboratories.*
- 2. Based on the answers, lectures were prepared and presented to 30 project partners and stakeholders in an online workshop on 30 September and 1 October 2024. With help of the feedback from the audience, the lectures could be further refined.*
- 3. Subsequently, a training course was held at the Greek Atomic Energy Commission (EEAE) in Athens from 20 to 22 May 2025 for users of the ISO 4037 standard. The course combined theoretical lectures and hands-on training with discussion rounds and got very positive feedback from the participants.*
- 4. The material was then refined to serve as e-learning resources, which were published on the BIPM's e-learning platform in spring 2026.*

The training is structured in four parts: Introduction, Establishing the calibration setup, Spectrometry and Calibration process and end-user needs. It includes lectures, videos and supporting material, and is accessible to registered users of the BIPM e-learning platform. Further information can be found under <https://zenodo-rdm.web.cern.ch/records/20440076>.

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PTH-19 TOWARDS CONSISTENT X-RAY FIELDS: IMPROVING THE REQUIREMENTS FOR BEAM PARAMETERS AND VALIDATION IN ISO 4037

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Objectives: The GuideRadPROS research project (22NRM07), which ran for three years until June 2026, had two aims: to make radiation protection dosimetry standards fit for the present and future, and to make these standards more accessible to users. With regard to ISO 4037, this was achieved by improving the standard by investigating maximum allowable deviations for beam parameters and validation procedures, leading to consistent requirements, and by investigating the dosimetry validation procedure.

Methods: Two measurement campaigns were conducted: in the first campaign, six participating laboratories tested the requirements on beam parameter (tube potential and filter thickness) and on half-value layers (HVL) using spectrometry, SpekPy spectral model calculations and full Monte Carlo simulations. The second campaign involved four partners testing the dosimetry validation method through a comparison study of the measured conversion coefficients using secondary standards for K_a , $H_p(10)$ and $H^*(10)$. In both cases, the radiation qualities N-30, N-40, N-60 and H-60 were chosen as representative test cases.

Results: The results across the participating laboratories, and across the different methods were consistent. It was found that the requirements for beam parameters and HVL in ISO 4037 need updating at least for the four investigated radiation qualities, and in most cases a relaxation is possible. The use of SpekPy for consistent calculation for all ISO 4037 radiation qualities was validated.

The dosimetry validation method was found to work well, except at low energies, where the ionisation chamber's energy dependence is too high.

Conclusions: In the next step, new maximum allowable deviations for the beam parameters and HVL will be calculated by SpekPy calculations for all ISO 4037 radiation qualities. This will improve the standard by creating new, mutually consistent requirements for the upcoming update.

Acknowledgements: The project 22NRM07 GuideRadPROS has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

PTH-20 RADIATION AWARENESS AND OCCUPATIONAL CONCERNS AMONG NURSES WORKING WITH IONISING RADIATION - A DANISH SURVEY

Author: Malene Roland Vils Pedersen, Theresa Junker, Charlotte Abrahamsen, Sally Alsted Nørgaard, Helle Precht, Pernille Lund Hansen, Karen Brage | Co-Author: | Speaker: Karen Brage

Background: Nurses increasingly work in clinical environments involving ionising radiation (IR), yet little is known about their radiation protection knowledge, training, and occupational concerns in a Danish context.

The aim of this study was to investigate Danish nurses' knowledge, perceptions, practices, and concerns related to occupational IR exposure.

Methods: A national cross-sectional survey was conducted among Danish nurses working in environments involving IR. The survey included items on demographics, radiation protection training, self-reported knowledge of dose limits, use of protective measures, pregnancy-related workplace adjustments, and occupational concerns. Data was analysed using descriptive statistics as well as chi-square and Fisher's exact tests. Free-text responses were summarised thematically.

Results: A total of 498 nurses participated. Most respondents had received radiation protection training (72.7%); however, training was brief (median 1 hour), and follow-up education varied considerably. Only 16.4% reported knowledge of the occupational dose limit and 9.9% of the dose limit for pregnant workers. Dosimeter use was reported by 58.1% of respondents.

Concerns regarding radiation exposure affecting personal health, fertility, and children's health were reported by 20%, 13%, and 13% of respondents, respectively. Nurses younger than 40 years reported significantly greater concern regarding all three outcomes ($p < 0.001$).

Radiation protection training was associated with greater perceived preparedness, higher self-reported knowledge, increased dosimeter use, and more consistent use of protective measures.

Conclusions: Radiation protection training, knowledge, and protective practices varied considerably among Danish nurses working with IR. More structured and regularly updated radiation protection education is needed to strengthen occupational radiation safety.

PTH-21 DOSE MODELLING FOR OCCUPATIONAL EXPOSURE ASSESSMENT IN MAINTENANCE ACTIVITIES ON LARGE OIL & GAS COMPONENTS CONTAINING NORM RESIDUES

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Objectives/Background: Within the framework of an Italian research project on the radiological assessment of exposure to NORM in the oil and gas sector, jointly promoted by INAIL and Eni SpA, the present study aimed to develop a dose model for the assessment of occupational exposure during maintenance activities on large oil and gas components containing NORM residues. In particular, the work addresses a relevant exposure scenario associated with the handling and maintenance of process equipment where naturally occurring radionuclides may accumulate at enhanced activity concentrations. The study aligns with Sustainable Development Goals related to health protection, decent work and industrial innovation (SDG 3, SDG 8 and SDG 9).

Methods: Maintenance activities were assumed to be predominantly characterized by external gamma exposure arising from NORM-bearing matrices accumulated within process equipment. The assessment focused on large components typically encountered in oil and gas installations, such as tanks and separators containing sludge and scale deposits.

Modelling was performed using the MicroShield code, and field measurements collected on actual industrial equipment used as a reference to validate the calculations. Results: Operational experience and radiometric surveys indicated that ^{226}Ra is the radionuclide most frequently observed at elevated activity concentrations in NORM residues owing to its preferential accumulation in process deposits. Consequently, the external exposure assessment was primarily derived from the measured ^{226}Ra activity concentrations, serving as a representative and conservative indicator of the radiological conditions associated with the maintenance activities examined.

Conclusions/Implications: The developed model provides a practical and technically sound tool for the radiological assessment of workers involved in maintenance operations on large oil and gas components. This approach supports the characterization of occupational exposure scenarios, contributing to more robust radiation protection assessments and sustainable management strategies in the NORM oil and gas sector.

PTH-22 DEVELOPMENT OF A PROTOTYPE ACTIVE AREA DOSEMETER BASED ON DOSEPIX PIXEL DETECTORS FOR CONTINUOUS AND PULSED PHOTON RADIATION FIELDS

Author: Jürgen Roth | Co-Author: Felix Lehner, Florian Beisser, Hayo Zutz, Oliver Hupe, Rolf Behrens | Speaker: Jürgen Roth

Accurate active area monitoring in photon radiation fields with widely varying dose rates and pulse structures remains a challenge for conventional radiation protection instrumentation. This work presents a prototype for an area dosimeter based on four Dosepix hybrid photon-counting pixel detectors. These detectors consist of an energy-resolving integrated circuit (IC) specifically designed for dosimetric applications and bump bonded to (16 x 16) pixels on a 300 µm silicon sensor.

The performance parameters in continuous and pulsed radiation fields are presented. The instrument's dose response to the ambient dose equivalent $H^*(10)$ is characterized in various ISO 4037 photon reference radiation fields and shows compliance between 20 keV and 6 MeV and for pulse dose rates up to 100 Sv/h with the limits stated in IEC 60846-1 for area dosimeters. Within a smaller range of energies and dose rates, the application of the directional dose quantities $H'(3)$ and $H'(0.07)$ are also demonstrated as well as the application in stray radiation fields.

In conclusion, the presented prototype demonstrates the potential of multi-detector pixel spectrometry for area monitoring in challenging radiation environments. The combination of spectrometric information and radiation protection dosimetry provides a promising approach for future area dosimeters intended for applications in research facilities, industrial irradiation environments, and especially in pulsed radiation fields, e.g. such as those used in medical applications.

PTH-23 HYBRID X-RAY DARK-FIELD AND FLUORESCENCE IMAGING FOR LOW-DOSE MOLECULAR IMAGING

Author: Xiaolei Yan, Kunal Kumar | Co-Author: Cecilia Riani, Muna Abboush, Axel Boese, Christoph Hoeschen | Speaker: Xiaolei Yan

*Background: Molecular medical imaging is a cornerstone of modern diagnostics, enabling early disease detection and personalized therapy. However, current *in vivo* imaging modalities often face a trade-off between radiation dose and image quality. Achieving high sensitivity together with adequate spatial and temporal resolution frequently requires prolonged acquisition times and increased radiation exposure. Therefore, there is a growing need for imaging approaches capable of molecular targeting with high spatial resolution at reduced radiation dose.*

Methods: To address these limitations, this proof-of-concept study presents a hybrid imaging approach integrating X-ray Dark-Field Imaging (DFI) and X-ray Fluorescence Computed Tomography (XFCT). DFI, characterized by high sensitivity to microstructural alterations at low radiation dose, was employed to identify targeted regions of interest (ROIs) and provide structural guidance. Subsequent XFCT acquisition was restricted to DFI-guided ROIs to localize molecular nanoprobe

with improved efficiency. By limiting high-dose fluorescence acquisition to selected regions rather than performing full-volume scans, this approach aims to reduce radiation exposure while maintaining molecular imaging capability.

The integrated benchtop system was designed around a shared microfocus X-ray source and includes a photon-counting detector for DFI, an energy-resolving spectrometer for XRF detection, and a motorized positioning platform for automated tomographic acquisition. A custom switchable collimator enabled rapid transition between wide-field DFI illumination and pencil-beam XFCT acquisition.

Results: A compact hybrid imaging platform enabling co-registered XFCT and DFI acquisition was successfully developed and implemented. The system architecture integrates orthogonal imaging geometries on a unified sample stage, allowing both modalities to operate from a shared radiation source. The custom collimation mechanism enabled dynamic beam adaptation for multimodal operation and demonstrated the technical feasibility of integrated DFI-guided XFCT acquisition.

Conclusion: This proof-of-concept study demonstrates the successful development and integration of a hybrid XFCT-DFI imaging platform with shared-source acquisition and unified tomographic operation. The proposed architecture establishes the feasibility of combining structural and molecular imaging and provides a foundation for future low-dose, high-resolution molecular medical imaging applications.

PTH-24 MONTE CARLO EVALUATION OF MULTIPLEXED X-RAY FLUORESCENCE IMAGING UNDER IN VITRO AND IN VIVO CONDITIONS FOR BREAST CANCER HETEROGENEITY

Author: Muna Abboush | **Co-Author:** Christoph Hoeschen, Kunal Kumar, Melanie Fachet, Xiaolei Yan | **Speaker:** Muna Abboush

The heterogeneity of breast cancer remains a challenging aspect in the precise diagnosis, characterization, and assessment of tumor response to treatment. The metallic nanoparticle (NP)-based X-ray fluorescence (XRF) imaging represents a promising molecular imaging modality capable of delivering both high spatial resolution and high sensitivity. Upon excitation by an external X-ray source, functionalized NPs, that selectively accumulate in tumor tissue through targeted labeling, emit fluorescence signals. The fluorescence signals are detectable by energy-resolving detectors and used to reconstruct a three-dimensional map of tumor distribution. Although XRF is particularly promising for accurate cancer localization, characterization, and treatment monitoring, several fundamental limitations still hinder its clinical implementation. Principally, XRF requires powerful near-monochromatic X-ray sources, such as synchrotrons, to achieve high signal-to-noise ratios (SNR) while maintaining high spatial resolution. In addition, the detection sensitivity of conventional benchtop X-ray tubes is not sufficient at nanoparticle concentrations relevant for *in vivo* applications. Both the limited accessibility to synchrotron facilities and the low detection sensitivity at *in vivo* relevant concentrations reflect two major issues in XRF imaging clinical translation.

To address these aspects, here, we utilized Monte Carlo simulations to study the suitability of different metallic nanoparticles as candidate contrast agents for breast cancer imaging, specifically for tumor heterogeneity characterization, under *in vitro* and *in vivo* mimicking conditions. A polychromatic benchtop X-ray source, namely a microfocus tube (X-RAY WorX XWT-225-XC) operating at 150 kVp with 3mm Sn filter was investigated using the Geant4 toolkit. The simulations modelled a pencil beam setup, cadmium telluride (CdTe) detectors, and a voxelized digital breast model derived from real patient breast computed tomography images. Gold (Au), gadolinium (Gd), and hafnium (Hf) NPs were embedded within the digital breast model and tested for their minimum detectable concentrations under *in vitro* and *in vivo* imaging scenarios. The

simulation results indicate that the *in vitro* imaging configuration demonstrates a notable sensitivity increase when compared to the *in vivo* case, showing an approximate order of magnitude increase. Further, the simulated detected fluorescence signals indicate that K-shell gadolinium (Gd-K α), K-shell hafnium (Hf-K α), and marginally K-shell gold (Au-K α) XRF emission lines could represent potential contrast elements for simultaneous, multiplexed NP detection, required for heterogeneity characterization in breast cancer.

PTH-25 MECHANISMS OF RADIATION-INDUCED BREAST CANCER INDUCTION: ROLE OF SEX HORMONES AND OBESITY

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*Introduction: Puberty is a radiosensitive stage for radiogenic breast cancer, and early menarche strongly increases risk regardless of exposure age. The mechanisms remain unclear, but obesity promotes early menarche. This study tests whether the obesity hormone leptin alters the *in vitro* radiation sensitivity of breast cells grown with female sex hormones.*

Methods: Normal breast epithelial cells MCF10A were treated for total 4 weeks with oestrogen (E2; 10 nM) and progesterone (P; 10 nM), each for one week (E2-P-E2-P) to mimic hormone levels during the menstrual cycle. Leptin (L; 6.25 nM) was added alone or in combination with sex hormones and radiation. γ -radiation (3.4 Gy) was delivered either acutely prior or after the treatment with hormones (0.65 Gy/min) or chronically (5 mGy/h). Cell proliferation was monitored continuously. After treatment, DNA damage was analysed by γ H2AX foci. Production of reactive oxygen species was measured using dihydrorhodamine 123. Chromosomal aberrations were analysed by FISH. Gene expression of selected genes was measured by RT-qPCR.

Results: Preliminary data on the cumulative population doublings showed a decreasing trend of cell growth co-treated with sex hormones and leptin. The strongest effect was seen after acute exposure. γ H2AX foci results suggest a possible higher DNA damage in cells treated solely with E2/P, while leptin-treatment appears to inhibit the focus frequencies. A similar inhibiting effect of leptin was observed for gene expression.

Conclusion Preliminary data indicate the effect of hormones and leptin alone/in combination in response to radiation on multiple levels. Since the experiments are ongoing, more results will be presented during the meeting.

Acknowledgment: This work was supported by Swedish Radiation Safety Authority and PIANOFORTE Partnership.

PTH-26 EVALUATING γ -H2AX ASSAY PERFORMANCE FOR SENSITIVITY, VARIABILITY, AND IMPLICATIONS FOR BIODOSIMETRY

Author: Lindsay A. Beaton, Alyssa Tarnocai, Kevin Pham, Samantha Fancy, Xavier Courcelles, Kris Lyons, Danicia Flores, Ruth C. Wilkins | Co-Author: | Speaker: Lindsay A. Beaton

Objectives/Background: The detection and quantification of biological responses to ionizing radiation is a key factor in biodosimetry. While cytogenetic assays provide robust dose estimation, molecular assays such as the γ -H2AX assay offer advantages for rapid detection of DNA damage and

early biological response assessments. Recent work has demonstrated the feasibility of γ -H2AX using imaging flow cytometry (IFC) as a high-throughput biodosimetry tool [1]. However, the performance of this assay across varying dose ranges, assay conditions, and in relation to complementary biomarkers remains insufficiently characterized.

Methods: In this study, γ -H2AX foci formation was assessed using IFC across radiation doses ranging from 0 to 4 Gy. Emphasis was placed on the low dose range (up to 0.5 Gy), evaluating signal response, inter-sample variability, and signal-to-background discrimination. Replicate samples were analyzed to assess reproducibility and short-term stability. Additional biomarkers, including 53BP1, BAX, and p53, were evaluated for comparative performance across a broader dose range.

Results: The γ -H2AX-IFC assay demonstrated a dose-dependent response within the studied range; however, variability and overlap with background signal in the low dose range affected dose discrimination under certain conditions. Contributing factors included biological heterogeneity and experimental variability. In contrast to prior IFC-based findings, 53BP1, BAX, and p53 exhibited limited or inconsistent dose-responses across 0 to 4 Gy under the conditions tested. Repeatability assessments indicated stable signal measurements over several weeks, with low variation (up to 6% across 1-5 Gy). These results indicate that biomarker performance is strongly dependent on dose range and assay context, with reduced sensitivity observed at lower exposure levels.

Conclusions/Implications: This work extends prior IFC-based γ -H2AX biodosimetry studies by examining assay performance beyond initial validation, highlighting important constraints related to sensitivity, variability, and marker selection. These findings contribute to defining the practical capabilities and limitations of γ -H2AX and complementary biomarkers within integrated biodosimetry frameworks for radiation protection and emergency response.

[1] Hassan, E. M., Puzantian, B., Mayenburg, J. M., Li, M., Rashid, M., Wilkins, R. C., & Beaton-Green, L. A. (2026). Application of an imaging flow cytometry γ -H2AX assay for biodosimetry using supervised machine learning. *International Journal of Radiation Biology*, 102(7), 796-805. <https://doi.org/10.1080/09553002.2025.2536108>

PTH-27 MONTE CARLO-BASED CHARACTERIZATION OF A NEW 450 kV X-RAY IRRADIATION FACILITY AT PTB

Author: Khadijeh Rezaee Ebrahimsaraee | **Co-Author:** Hayo Zutz, Miroslav Zboril, Steffen Ketelhut | **Speaker:** Khadijeh Rezaee Ebrahimsaraee

Objectives: A new 450 kV X-ray irradiation facility has recently been commissioned at PTB to enhance the existing photon reference radiation infrastructure used for radiation protection dosimetry, calibration services and reference radiation field development. This work presents the commissioning status of the facility and a Monte Carlo-based characterization of its radiation field properties. A detailed MCNP6 model was developed to investigate beam profile characteristics, field dimensions and key irradiation field parameters relevant for future dosimetric applications.

Methods: A detailed MCNP6 model of the new 450 kV X-ray irradiation facility was developed, including the X-ray source, collimation system, shielding components and irradiation geometry. Simulations were performed to investigate the lateral beam characteristics for different source diameters. Beam profiles were evaluated in terms of field width, full width at half maximum (FWHM), flatness, symmetry, penumbra width and out-of-field transmission. In addition, the influence of irradiation conditions on the absorbed dose in the monitor chamber was investigated. The simulation results were compared with analytical calculations where applicable.

Results: The simulations showed that the investigated irradiation geometries provide well-defined beam profiles with excellent flatness and symmetry in the central field region. The source diameter was found to mainly affect the penumbra width and the effective beam diameter, while the core field remained largely stable. The out-of-field transmission was low for all configurations. A comparison between analytical estimates and MCNP6 results showed good agreement for the core field width and effective beam diameter.

Conclusions: The simulations demonstrated excellent beam flatness and symmetry for all investigated irradiation geometries. The influence of source size on the penumbra and effective beam dimensions was quantified, and good agreement was obtained between analytical calculations and MCNP6 results. The developed model provides a sound basis for the ongoing characterization of the new 450 kV X-ray irradiation facility at PTB.

Acknowledgment: The authors sincerely thank Jürgen Roth, Christian Fuhg and George Winterbottom for their outstanding technical assistance throughout this work. Their support in the preparation and operation of the experimental equipment, precise measurements, and facilitation of data acquisition was invaluable and is greatly appreciated.

PTH-28 NATURAL OCCURRING RADIONUCLIDES IN HIGH-ALTITUDE AEROSOLS AT SIERRA NEVADA (GRANADA, SPAIN)

Author: Pilar Santos Cárdenas | Co-Author: Essaid Chham, Fran Pinero-García, Mari Ángeles Ferro-García | Speaker: Fran Pinero-García

High-mountain environments are among the most sensitive regions for detecting changes in atmospheric composition, long-range transport, and aerosol-climate interactions. Their elevated position, reduced boundary-layer influence, and direct exposure to free-tropospheric air masses make them exceptional natural observatories for studying the behaviour of atmospheric radionuclides. In the western Mediterranean, Sierra Nevada (Granada, Spain) stands out as a unique high-mountain system where contrasting air masses from the Atlantic, the Mediterranean, and North Africa converge. Generating strong variability in aerosol loading, mineral dust inputs, and deposition processes.

In this context, the present study investigates the atmospheric deposition of ^{210}Pb , ^{226}Ra , ^{230}Th , ^{232}Th , ^{234}U and ^{238}U above 2500 m in Sierra Nevada mountains, providing a comprehensive assessment of radionuclide behaviour in a high-mountain Mediterranean environment. By combining radionuclide measurements with air masses study, this work contributes to a deeper understanding of the atmospheric processes that shape radionuclide variability in the western Mediterranean basin in high-altitude background.

^{210}Pb , U and Th radionuclides were detected with activity concentration higher than the minimum detectable activity in all the samples analyzed, while ^{226}Ra was detected in the 80% of the samples. The activity concentration of ^{210}Pb ranged between 130 - 660 $\mu\text{Bq}/\text{m}^3$ with an average activity concentration of $390 \pm 140 \mu\text{Bq}/\text{m}^3$. ^{226}Ra , U and Th radionuclides ranged between 0.3 - 4.7 $\mu\text{Bq}/\text{m}^3$ with a mean value of $2.6 \pm 1.1 \mu\text{Bq}/\text{m}^3$ for ^{230}Th ; $2.0 \pm 1.1 \mu\text{Bq}/\text{m}^3$ for ^{226}Ra , 1.3 ± 0.7 for ^{232}Th and ^{234}U ; and $1.1 \pm 0.6 \mu\text{Bq}/\text{m}^3$ for ^{238}U . The results showed an isotopic disequilibrium in the ^{238}U decay series. Furthermore, the results clearly identify the Mediterranean basin and the north African continent as potential source of the naturally occurring radionuclides detected at high-altitude in the southeast of Iberian Peninsula, being highly influenced by Saharan dust intrusions.

PTH-29 ECRAD: ONE RING TO BIND THEM ALL

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The ICRP Vancouver call for action highlights the need to strengthen and sustain expertise in response to the shortage of radiation protection professionals. This shortage in the workforce can threaten the safe use of radiation and diminish public trust. Moreover, the highly specialized niches in the field of radiation protection, originated originating from its interdisciplinary and diverse nature, present challenges in building and sustaining a network for early career scientists. Although there are some successful networks (e.g. MEENAS and IRPA) out there, an initiative to bind together and promote collaboration and knowledge exchange among the different networks in radiation protection is still missing.

ECRad (Early Career in Radiation Protection) began in 2024 to bridge the gap between various existing networks in the field of radiation protection. It has successfully conducted three in-person meetings supported by the PIANOFORTE partnership under the European Early Career Researcher and Professional Networking Activities Grant Call. Two of those meetings were organized during the ERPW (Rome 2024 and London 2025).

*In 2025, ECRad conducted an online survey that collected responses from 47 Early Career Scientists (ECRs) in Radiation Protection across Europe (Degenhardt et al., *Radiation and Environmental Biophysics*, 2025). The main takeaway messages were: ECRs seek more in-person networking, mentorship, and for their voices to be heard. A majority of respondents were uncertain whether an additional network was necessary, suggesting that a new network may add limited value compared to existing ones. For this reason, ECRad does not aim to be a new network, but an initiative to connect the existing networks across Europe and to promote peer support, knowledge exchange, and collaboration among ECRs.*

Currently, ECRad has established a group of core members, from PhD candidates to young professionals in radiation protection within Europe. Through its LinkedIn page (with 290 followers), members can present their work and discuss ideas. With regular meetings and events, members stay connected and learn about recent developments in radiation protection, as well as opportunities related to conferences, training, mentorship, funding, and career development. ECRad plans to keep activities on a 'low-maintenance' approach and to integrate alumni members to address the challenge of building a long-lasting network which stretches beyond just the early career phase.

PTH-30 DOSE-DEPENDENT MULTI-OMICS SIGNATURES OF RADIATION-INDUCED MEDULLOBLASTOMA IN PTCH1^{+/−} MICE

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*Background: Early-life exposure to ionizing radiation is an established risk factor for pediatric brain tumors, including medulloblastoma (MB). However, the dose-dependent molecular mechanisms linking radiation exposure to tumor initiation and tumor heterogeneity remain incompletely understood. This study investigated low- and high-dose γ -irradiation in the *Ptch1^{+/−}* mouse model of Sonic Hedgehog-driven MB to identify early cerebellar alterations and tumor-associated molecular programs relevant to radiation-induced cancer risk.*

*Methods: *Ptch1^{+/+} mice were exposed at postnatal day 2 to 0.1 or 2 Gy y-rays and monitored longitudinally for MB development. Tumor incidence, latency, and burden were assessed and integrated with genome-wide DNA methylation profiling, proteomic analyses, and transcriptomic profiling to characterize dose-specific molecular responses in the cerebellum and in radiation-induced tumors.*

Results: Radiation increased MB incidence in a dose-dependent manner. Exposure to 2 Gy significantly increased tumor burden and reduced latency, whereas 0.1 Gy increased tumor risk without affecting tumor onset. Methylome profiling revealed progressive dose-dependent epigenetic remodeling, with broad developmental and transcriptional regulatory changes after high-dose irradiation and more limited signaling-associated alterations after low-dose exposure. Proteomic analyses identified common proliferative programs together with dose-specific biological contexts: low-dose irradiation was preferentially associated with regulatory, transport, and selected immune-related pathways, while high-dose exposure was linked to chromatin organization, DNA replication, nucleotide metabolism, and RNA-associated processes. Radiation-induced MBs displayed transcriptional architectures distinct from spontaneous tumors and differed according to radiation dose. Although the methylomic, proteomic, and transcriptomic layers involved largely distinct genes and pathways, they converged on qualitatively distinct dose-associated biological programs. Cross-omics functional concordance increased with radiation dose, indicating greater integration of molecular responses following high-dose irradiation.

Conclusions: Independent methylomic, proteomic, and transcriptomic analyses converged on the same biological conclusion, defining dose-specific molecular states associated with radiation-induced MB. These findings provide a biological framework linking early cerebellar remodeling to tumor heterogeneity. This integrated multi-omics approach may improve understanding of pediatric radiation risk and support future tumor stratification strategies.

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PTH-31 LINPASS: A VERSATILE PASSIVE NEUTRON DOSIMETER FOR CLINICAL, INDUSTRIAL AND AEROSPACE RADIATION PROTECTION

Author: Benedetta Brusasco | Co-Author: Alfredo De Blas Del Hoyo, Ariel Tarifeno-Saldivia, Francisco Calviño Tavares, Guillem Cortes Rossell, Maria Amor Duch Guillen, Roger Garcia Sanchez | Speaker: Benedetta Brusasco

Reliable neutron dosimetry remains a critical, unresolved challenge across different sectors, where conventional passive systems often fail to deliver accurate, traceable integral dose measurements. In healthcare, proton therapy and FLASH radiotherapy generate secondary neutron fields over a wide energy range within extremely short time frames, where existing dosimeters often under-respond in pulsed or in high-dose-rate regimes. In the nuclear energy sector, dosimetry within Nuclear Power Plants must accurately cover neutron energies ranging from thermal to several MeV, operating reliably in harsh environments with limited access for maintenance, all while meeting increasingly strict regulatory requirements for traceable dose assessment. In aerospace, crews and space mission personnel face extended exposure to high energy cosmic neutrons, yet few lightweight passive dosimeters are currently optimized for long-duration missions where power or maintenance are unavailable. Crucially, no commercially available passive neutron dosimeter currently offers full metrological traceability, highlighting a significant gap in reliable dose monitoring across these domains.

To overcome these shortcomings, The LINrem project (<https://www.linrem.tech/>), a Spanish initiative, has produced a suite of innovative solutions for ambient neutron dosimetry, including

the patented active dosimeter LINrem, with sensitivity up to 10 MeV, and the extended-range LINremext, responsive up to 10 GeV and specifically designed for hadron therapy facilities[1]. Building on the LINrem technology, this work introduces its passive counterpart: the LINpass.

LINpass is based on ThermoLuminescent Detectors (TLD) enriched with ^6Li and ^7Li , embedded in the LINrem moderator. This design ensures a broad neutron energy response from thermal up to GeV, an optimized $\text{H}^*(10)$ response and accurate performance in pulsed and high-dose-rate fields (e.g. FLASH) where active systems suffer from saturation and pile-up. Being fully passive, lightweight and portable, LINpass requires no power supply nor associated electronics, simplifying deployment and reducing maintenance. These features make it suitable for routine occupational and area monitoring in hospitals and accelerator facilities, for distributed deployment in Nuclear Power Plants, and for aviation where reliability over long periods is essential. Its complementary integration with active dosimetry systems further enables hybrid monitoring strategies combining real-time and cumulative dose assessment, while international patent protection consolidates its competitive position across multiple sectors.

Preliminary validation campaigns were conducted in diverse neutron environments, including reference neutron fields, intercomparisons at the CERN High Energy Neutron Source (CERN), and a dedicated campaign at a clinical proton and hadron therapy facility, focusing on LINpass performance in realistic environments.

Overall, the preliminary results are encouraging and support the suitability of LINpass as a reliable, traceable passive neutron dosimeter across these diverse radiation environments.

[1] Tarifeno-Saldivia, A., Calvino, F., De Blas, A., Brusasco, B., Casanovas-Hoste, A., Cives, A. M., ... & Pavez, C. (2024). Ambient dosimetry in pulsed neutron fields with LINrem detectors. *Radiation Physics and Chemistry*, 224, 112101.

PTH-32 LOW-DOSE X-RAY EXPOSURE ALTERS FIBROBLAST AND MONOCYTIC CELL RESPONSES ACCORDING TO RADIATION DOSE AND BIOLOGICAL FACTORS INCLUDING AGE, SEX, AND IMMUNE STATUS

Author: Lena Janz | Co-Author: Laura Ruspeckhofer, Tom Unterleiter, Thomas Weissmann, Michael Rückert, Stefanie Corradini, Udo S. Gaipf, Lisa Weissmann | Speaker: Lena Janz

Background: Demographic heterogeneity among radiation-exposed individuals necessitates personalized strategies in radiation protection and cancer therapy. Sex- and age-dependent differences in cellular and immune responses are increasingly recognized but remain underrepresented in current radiological risk models and therapeutic concepts. Fibroblasts (FB), and monocytic cells, such as macrophages (MPH), and osteoclasts (OC) are central regulators of collagen turnover, bone metabolism and inflammation that all play a role in low-dose radiotherapy (LDRT) as well as in radiotherapy (RT) in cancer treatment and normal tissue responses. We thus investigated sex- and age-specific radiation responses of these cell types after low-, intermediate- and high-dose X-ray exposure in vitro, corresponding to doses that are important in radiation protection, LDRT and individualized treatment of solid tumors.

Methods: Experimental data were obtained using primary murine cells from wild-type C57BL/6NRj mice of both sexes at 6, 14, and 52 weeks of age. MPH and OC were isolated from bone marrow of the hind limbs, while FB were obtained from digested skin, lung, and ear tissue. MPH subtypes (M-CSF/GM-CSF, LPS, IFN γ , IL4, IL10) and OC (M-CSF, RANKL) were differentiated via cytokine stimulation, and TNF- α was used to induce a pro-inflammatory state in FB and OC. RT was applied using 100 kV X-rays at single doses ranging from 0.1 to 2 Gy; OC were additionally exposed to

fractionated regimens. Cell type-specific endpoints included cell death, surface marker expression, ELISA, arginase and collagen assays, qPCR, phagocytosis, and differentiation assays.

Results: We observed an age-dependent switch to an anti-inflammatory MPH phenotype by overall alteration of secreted proteins and surface markers in male-derived MPH and especially triggered by 0.5 Gy irradiation in female-derived MPH through decreased levels of iNOS, IL-1 β , IL-23, and IL-15. Whereas the resorptive phenotype of OC is triggered especially by higher doses in female-derived OC and age, cell stress and secreted TRAP of male-derived OC are more radioresistant. In addition, we observed sex-specific differences e.g. in secreted IL-6 and TNF- α of inflamed-like OC, thus a resorptive-oxidative phenotype in female-derived OC at doses of 1 and 2 Gy. Pro-inflammatory MCP-1 is found to be induced by increasing dose in both, OC and FB regardless of the inflammatory status. In male-derived FB, we observed increased levels of the proteins MMP-3, MCP-1, TGF- β , IL-6 and CXCL1 in the inflammatory type compared to the healthy FB, and an age-dependent rise especially in CXCL1. On surface marker level, healthy FB show a higher matrix-remodelling character (FAP) by 1 and 2 Gy that declines with aging, while inflamed-like FB have a constant fibrotic type (α -SMA) at 0.3 and 0.5 Gy.

Conclusions: Our data demonstrate context-dependent sex- and age-specific radiation responses in monocytic and FB cells, affecting MPH polarization, OC resorption and FB matrix remodelling across clinically and radiobiologically relevant dose ranges, often in dependence of the inflammatory background mimicked by TNF- α stimulation. These findings underscore the need for further research to integrate sex and age as key variables in radiation protection, LDRT concepts and individualized radiotherapy planning. Supported by the German BMFT (TOGETHER, 02NUK073).

PTH-33 DISTRIBUTION OF PATIENT DOSES IN MOST COMMON DIAGNOSTIC PROCEDURES FROM COMPUTER TOMOGRAPHY AND ANGIOGRAPHY IN GEORGIA: INITIAL RESULTS

Author: Davit Nadareishvili, Salome Kiparoidze, Ketevan Jariashvili | Co-Author: | Speaker: Davit Nadareishvili, Salome Kiparoidze

Medical imaging plays a crucial role in the early diagnosis and management of diseases. Computed tomography (CT) and interventional angiography are among the most widely used diagnostic modalities, providing essential clinical information but also contributing significantly to patient exposure to ionizing radiation. Although the benefits of these procedures generally outweigh the associated risks, optimization of radiation protection remains a fundamental principle of good clinical practice. The International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) recommend the establishment and use of Diagnostic Reference Levels (DRLs) as an important tool for optimizing patient radiation doses while maintaining diagnostic image quality. Establishing national DRLs requires reliable data on patient dose distributions from routine radiological procedures. To date, no comprehensive study of patient radiation doses has been conducted in Georgia, and national DRLs have not yet been established. The aim of this study was to evaluate the distribution of patient radiation doses from the most common CT and angiography procedures performed in Georgia, providing baseline data to support the future establishment of national DRLs and optimization of radiation protection practices.

A multicenter observational study was conducted in selected hospitals across Georgia. Computed tomography (CT) and angiography systems were identified using a database created by us, based on data provided by the National Regulatory Body. Frequently performed diagnostic procedures were selected, and dose data were collected from 20-30 adult patients of standard body size for each procedure. For CT examinations, CTDI and DLP were recorded. For angiography DAP, fluoroscopy

time, number of acquired images, and cumulative air kerma were collected. Data were analyzed using the IAEA methodology and standardized software tools to characterize patient dose distributions and support future establishment of national Diagnostic Reference Levels (DRLs).

Patient radiation doses showed substantial variability between hospitals and examination types. Typical values and the 75th percentile were determined for CTDI, DLP, DAP, and Cumulative Air Kerma for each procedure. The findings provide the first national baseline dataset on patient dose distribution in Georgia and identify procedures requiring optimization of radiation protection.

The distribution of patient radiation doses demonstrated variability across imaging procedures and healthcare facilities, highlighting opportunities for dose optimization. The established baseline dataset represents an important first step toward the implementation of national Diagnostic Reference Levels and the harmonization of radiation protection practices in Georgia.

PTH-34 ESTIMATES OF RELATIVE BIOLOGICAL EFFECTIVENESS FOR A AND B PARTICLES DERIVED FROM EPIDEMIOLOGICAL STUDIES

Author: Mark P Little | Co-Author: Harry M Cullings, Nobuyuki Hamada | Speaker: Mark P Little

Objectives: The effectiveness of one type of radiation relative to another type of radiation at causing a specified biological effect, referred to as its relative biological effectiveness (RBE), is of some interest to radiological protection. In this paper we shall concentrate on human data for RBE for cancer endpoints.

Methods: We shall assess data on cancer mortality and incidence in various groups receiving mostly internal emitter exposure, and excess relative risks/Gy are compared with matched subsets of the Japanese atomic bomb survivor incidence cohort as a reference. Risks are examined separately for low- and high-linear energy transfer exposures. We use standard meta-analytic methods, and confidence intervals (CI) for ratio estimates derived from Fieller's theorem.

Results: For β -particle exposure, the RBE is ~ 2.2 for all solid cancer and leukaemia (derived from seven studies) and ~ 1.0 for thyroid cancer (derived from six studies). Depending on adjustments made for effects of dose and dose rate there is variation in RBE for all solid cancer and leukaemia by about 50%, with much less variation shown for thyroid cancer. For radon-associated α -particle exposure, the RBE is 25.6 to 42.1 (derived from five studies) for lung cancer depending on which group of miners is used; for plutonium-associated α -particle exposure to the lung, the RBE is ~ 6.8 to ~ 8.0 (derived from a single study). If liver cancer plutonium-associated α -particle data is added (one extra study) to the radon-associated lung cancer data the α -particle RBE becomes 20.9 or 30.4 depending on which group of miners is used. There is considerable sensitivity, by a factor of 10, to the assumed value of Gy/working level month for studies of α -particle exposure from radon relating to lung cancer. Nevertheless one cannot be entirely confident that our estimates relate to the limiting low dose maximal RBE (RBEM) for either type of radiation or endpoint.

Conclusions/Implications: Compared with wR of 20 for alpha particles (ICRP Publication 103) and RBE of 7-11 (without adjustment of DREF) for radon and plutonium lung cancer (ICRP Publication 150), our RBE for radon-associated α -particle exposure to the lung is slightly higher, but that for plutonium-associated α -particle exposure to the lung is much the same. However, given the uncertainties our estimates are not inconsistent with these ICRP values. This work has been submitted to the *International Journal of Radiation Biology*.

PTH-35 FETAL RADIATION DOSE IN CT PELVIMETRY: A PILOT STUDY FROM NORTHERN MOROCCO.

Author: Maher El Fassi | Co-Author: Zakaria Tahiri, Mohammed Essendoubi, Gaston Katoyo, Saad Tatari, Siham Rachidi Alaoui | Speaker: Maher El Fassi

Objectives/Background: CT pelvimetry is frequently used in obstetric practice, typically near term, to evaluate fetal-pelvic compatibility before delivery, notably in cases of suspected cephalopelvic disproportion or prior cesarean section, and can directly influence the choice of delivery mode. Although clinically valuable, the examination exposes the fetus to ionizing radiation, making optimization of radiation protection a priority, particularly given the heightened radiosensitivity of fetal tissue. This pilot study aimed to assess fetal radiation doses delivered during CT pelvimetry and to identify practical strategies for dose optimization in routine clinical practice.

Methods: A retrospective observational study was conducted at the University Hospital Center (CHU) of Tangier, which serves as the principal public-sector referral center for CT pelvimetry in the northern region of Morocco, including all examinations performed at the center between May 2023 and May 2025. For each examination, acquisition parameters and dose metrics, including the volume computed tomography dose index (CTDIvol) and dose-length product (DLP), were collected, and fetal doses were estimated. Dose distributions were compared with international diagnostic reference levels (DRLs) to assess compliance and identify the main sources of dose variability.

Results: Seventy-three CT pelvimetry examinations were analyzed. The mean CTDIvol was 1.42 mGy, and the mean DLP was 46.82 mGy·cm. Estimated fetal doses ranged from 0.68 to 3.72 mGy, with a mean of 1.53 mGy. Substantial inter-operator variability in acquisition parameters was observed, reflecting inconsistent adherence to the standardized protocol in a subset of cases. Several optimization opportunities were identified, including reducing the scanned anatomical length, adjusting tube current, and adopting low-dose protocols without compromising diagnostic image quality.

Conclusions/Implications: This pilot study highlights notable variability and occasionally avoidable increases in fetal radiation dose during CT pelvimetry. Reinforcing adherence to the existing acquisition protocol and systematically applying dose-reduction strategies are essential to strengthen fetal radioprotection while preserving the diagnostic value of the examination. These findings support the development of targeted training and quality-assurance measures for CT pelvimetry, with relevance extending beyond the single-center context of this pilot study and informing future quality-improvement initiatives.

PTH-36 BALANCING RISKS IN PREGNANCY: A SURVEY OF CLINICIAN PERCEPTIONS OF FOETAL CT RADIATION AND MODIFIABLE PREGNANCY RISK FACTORS

Author: Emer Kenny, John Legge, Paddy Gilligan, Seán Cournane | Co-Author: | Speaker: Paddy Gilligan

Objective / Background: Foetal radiation doses from computed tomography (CT) are typically well below deterministic effect thresholds; however, concerns regarding radiation risk may influence clinicians' referral decisions and delay clinically indicated imaging during pregnancy. A previous review by our group demonstrated that the estimated childhood cancer risk associated with a 10 mGy foetal CT dose (odds ratio ≈ 1.4) is comparable to, or lower than, reported risks associated with several common modifiable maternal exposures, including smoking, alcohol consumption, obesity, and poor air quality. Despite this, it remains unclear whether referring clinicians appreciate these relative risks or how they compare CT radiation risk with other pregnancy-related

risk factors and clinical interventions. This study evaluated clinicians' perceptions of foetal CT radiation risk in the context of modifiable and clinical pregnancy risk factors.

Methods and Materials: An anonymous online survey was distributed to clinicians who refer pregnant patients for imaging across multiple hospital sites in Ireland. The survey assessed knowledge, risk perception, and clinical decision-making relating to foetal CT radiation in comparison with common pregnancy-related risk factors, including maternal smoking, alcohol consumption, caffeine intake, obesity, and selected clinical interventions. Participant demographics, including clinical specialty and years of experience, were collected to explore differences in responses between groups.

Results: Preliminary findings suggest that clinicians overestimate the risks associated with foetal CT radiation when compared with evidence-based risk estimates and other established pregnancy risk factors. Variations in risk perception across specialties and experience levels are presented, highlighting opportunities to improve clinician education, risk communication, and evidence-based imaging decision-making during pregnancy.

PTH-37 AMBIENT DOSE EQUIVALENT RATE OF TERRESTRIAL GAMMA RADIATION IN GERMANY

Author: Robert Schnell | Co-Author: Nicole Klasen, Sven Seidensticker | Speaker: Robert Schnell

The dose rate of terrestrial gamma radiation is primarily generated by radionuclides of the uranium/radium decay series, the thorium decay series, and the radionuclide K-40 in soils. Beginning in the 1990s, a survey was conducted across parts of Germany to measure the terrestrial dose rate. This project has recently been continued to provide comprehensive data on the spatial distribution of natural radionuclides and the resulting terrestrial dose rate, with the goal of achieving coverage across the entire territory of Germany. The objective of this study is to reliably assess radiation exposure from natural radioactivity and to present its spatial distribution through detailed maps that are publicly accessible.

The determination of terrestrial gamma dose rate is carried out using two methods, allowing for effective cross-verification. The first method involves in-situ ambient dose rate measurement at selected locations across Germany. Using measurement devices that were characterized for their response to terrestrial gamma radiation and to cosmic radiation, as well as accounting for device background, the dose rate of the terrestrial gamma radiation can be calculated. The second method involves gamma spectrometric analysis of a soil sample collected directly from the location where the ambient dose rate measurement was performed. The specific activity of relevant decay series and radionuclides are determined and then converted into an ambient dose rate using appropriate conversion coefficients.

In previous measurement campaigns, approximately 23% of Germany was covered by gamma spectrometric analysis of soil samples. Future campaigns are planned to ensure comprehensive coverage of the entire country.

Maps illustrating the spatial distribution of natural radionuclides in the state of Bavaria will be presented. Additionally, it is demonstrated that the methodology used in previous measurement campaigns is consistent with current measurements, confirming that the method can continue to be applied.

A measurement-based dataset on terrestrial dose rates from natural sources is essential for assessing environmental radioactivity and thus strengthens radiation protection in Germany.

The data obtained can be made available under the IFG (Informationsfreiheitsgesetz).

This project contributes to Sustainable Development Goal 3.

PTH-38 **OpenSLM: A WEB-BASED PLATFORM FOR STOCHASTIC MODELING OF AEROSOL DEPOSITION IN THE HUMAN LUNG**

Author: Dalma Günter, Gábor Albrecht, Veronika Groma, Péter Fűri, Árpád Farkas, Werner Hofmann, Balázs G. Madas | Co-Author: | Speaker: Dalma Günter

Objectives / Background: Inhaled aerosols can pose significant health risks depending on their deposition patterns within the human airways, making accurate estimation essential for both public health and environmental risk assessment. The Stochastic Lung Model (SLM) addresses this need by incorporating individual anatomical variability and realistic breathing behaviours. The model has been extensively applied in studies investigating the respiratory deposition and dosimetry of radioactive aerosols, as well as other airborne pollutants such as particulate matter and nanoparticles. The model has been applied in more than 60 scientific publications (approximately one-third addressing radiation protection applications), but until recently its use was largely limited to the developer institutions. While several lung deposition models are available, the lack of an accessible implementation of the Stochastic Lung Model (SLM) has limited its broader application.

Methods: To broaden access to advanced respiratory deposition modelling, we developed OpenSLM, a FAIR-oriented, freely accessible reference implementation of the Stochastic Lung Model. OpenSLM is a web-based platform designed to make this modelling tool available to researchers, healthcare professionals, and other interested users by enabling aerosol deposition simulations through customizable input parameters, including particle and breathing characteristics. Implemented in Rust language for computational efficiency and equipped with a user-friendly web interface, the platform provides downloadable results detailing both regional and airway generation-specific deposition patterns.

Results: The project successfully delivered a publicly available web platform featuring detailed documentation, user-friendly input handling, automated simulation workflows, and downloadable results. Since its release, OpenSLM has been tested and applied by both Hungarian and international researchers in aerosol and respiratory research, demonstrating its usability and scientific value across multiple application areas.

Conclusions / Implications: OpenSLM contributes to SDG 3 by supporting research on aerosol deposition in the respiratory tract, thereby improving the understanding of inhalation exposure, air pollution impacts, and inhalation-based therapies. Also contributes to SDG 9 by providing a FAIR-oriented, freely accessible digital research infrastructure that broadens access to advanced respiratory deposition modelling and fosters innovation through open and reproducible computational tools. The presentation will introduce the underlying model and demonstrate the capabilities of the OpenSLM web platform.

PTH-39 **2ND INTERNATIONAL WORKSHOP ON STUDIES OF URANIUM MINERS AND URANIUM PROCESSING WORKERS – SUMMARY, CONCLUSION AND IMPACT**

Author: Nora Fenske, Veronika Deffner, Tonia Ludwig, Peter Scholz-Kreisel, Michaela Kreuzer | Co-Author: | Speaker: Nora Fenske

Objectives / Background: Uranium miners and uranium processing workers are exposed to several occupational risk factors including ionizing radiation and dust. Main established health effects of

occupational exposure due to uranium mining are lung cancer by radon and silicosis by silica dust. Studies of uranium miners provide a substantial epidemiologic basis for assessing health risks from radiation exposure, particularly radon, and for informing radiation protection and occupational health and safety. To support interdisciplinary exchange on current research and developments on health risks from radiation in studies of uranium miners and uranium processing workers, the Federal Office for Radiation Protection (BfS) organized an international workshop in Munich, Germany, from 16th June to 18th June 2026. The objective of this contribution is to provide an overview on the scientific findings and the related impact.

Methods: The workshop was designed as an on-site event, but online participation was also possible. It mainly consisted of invited talks by experts in the respective field, and of selected contributed talks based on an abstract submission process. The first day of the workshop was dedicated to “Three decades of health research based on German uranium miners studies: results, impact, outlook”.

Results: Altogether, almost 50 persons participated on-site and almost 50 persons online in the workshop. Professional backgrounds of the international participants from all over the world were very interdisciplinary, but mainly from the field of radiation epidemiology. The first day of the workshop acknowledged 30 years of German “Wismut” uranium miners studies. In 1996 the large Wismut uranium miners cohort study started (running now for 30 years) and in 2008 the Wismut biobank was established. Findings on biological and health effects among former Wismut employees were presented. The impact of these results was discussed in a panel with various stakeholders. The second day of the workshop was dedicated to recent findings on health effects within the large worldwide Pooled Uranium Miners Analysis (PUMA) and the international Pooled Analysis of Uranium Processing Workers (iPAUW). Other topics were occupational exposures beyond radiation, such as silica dust, and mining beyond uranium mining. On the third day, methodological and dosimetric aspects of uranium miners and workers studies (e.g. regarding exposure and dose uncertainties) were discussed, and were followed by the final session addressing relevance and impact of results of the studies for radiation protection.

Conclusions / Implications: Recent findings from uranium miners studies have provided a valuable contribution to an improved quantification of the radon-related lung cancer risk, which is relevant, among other topics, for radon dose conversion. Given the large uncertainties, results of the epidemiological approach are quite consistent with those of the dosimetric approach. The large pooled data sets provided no convincing evidence that radon causes other diseases than lung cancer. However, for some causes of death, small excess risks due to radon were observed. Therefore, further follow-up of single cohort studies and pooling projects is important to increase precision of risk estimates and detect late health effects, particularly regarding more recent working periods with contemporary occupational exposures.

PTH-40 X-RAY MACHINES IN CROATIA – QUALITY CONTROL ASSESSMENT

Author: Suzana Bedić | **Co-Author:** | **Speaker:** Suzana Bedić

Background: The study presents some observations about the state of the x-ray machines in Croatia in relation to the legal requirements.

Methods: Findings are based on two-years experience of regular work as a radiation protection professional associate during which the author has conducted quality control of over three hundred x-ray machines of various kinds, used in both medical and non-medical settings. The tests performed are those required by the Croatian regulatory bodies as a basis for mandatory monthly and yearly quality control, as listed in Appendices three to twelve of the relevant Regulation². In particular, the equipment used consists of RTI Piranha meter and standard quality control

phantoms such as Computed Tomography Dose Index phantom, blocks of PMMA and ETR phantom for image control of medical radiography systems.

Results: Of more than three hundred x-ray machines checked, there was only one case of a permanent ban of use of a medical unit due to exceeding the permitted limits of deviation from the set parameters. There was no case of image quality of medical radiological systems not satisfying the legal requirements. Also, there was no case of a voltage of a mammography x-ray unit deviating from the set value by more than 2 kV, i.e. all the units checked satisfy this legal requirement.

Additionally, there were a couple of temporary bans of use of x-ray units due to minor technical issues noticed during annual check. Such issues were easily resolved by professional technicians and units are checked again and allowed for use.

Conclusions / Implications: We conclude that an overall state of the Croatian x-ray machines used in medical and non-medical settings is satisfactory and almost all equipment has its relevant parameters way within the legal bounds. There are no widespread quality issues which might raise concerns over patient and worker safety.

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