



ISOE International Symposium

Helsinki, 16-17 June 2026



Programme & Book of Abstracts



Supported by





ISOE International Symposium

Helsinki, 16-17 June 2026

The European Technical Centre of the Information System on Occupational Exposure (ISOE) is pleased to organize, in collaboration with and the support of Fortum, Teollisuuden Voima Oyj (TVO) and the Radiation and Nuclear Safety Authority (SUK), the 2026 ISOE International Symposium on Occupational Exposure Management at Nuclear Facilities.

The Symposium will be held in Helsinki, Finland, from the 16th to the 17th of June 2026. It is co-sponsored by the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA).

The Symposium is targeted at all those concerned with radiological protection at nuclear power plants: radiation protection managers and staff members, maintenance and operation planners, contractors, exposed workers, regulatory body representatives and international organisations. It is also opened to research reactors and professionals from other nuclear fuel cycle installations sharing common radiological protection issues.

Dealing with occupational radiation protection at the design, operation and decommissioning stages of installations, as well as accident situations, this new meeting point of radiation protection professionals under the heading of ISOE will be a great opportunity to share, at the international level, experiences and practices favouring a continuous improvement of radiation protection.

Furthermore, the accompanying Technical Exhibition will give participants the opportunity to see the latest developments from industrial and commercial companies active in fields of radiation protection.

Prior to the Symposium, on Monday 14 June 2026, two meetings devoted to specific audiences have been organised:

- A Radiation Protection Managers meeting
- A Regulatory Body Representatives meeting

We are looking forward to welcoming you in Helsinki,

Caroline SCHIEBER

Head of ISOE-ETC

On behalf of the Programme Committee



ISOE International Symposium

Helsinki, 16-17 June 2026

PROGRAMME COMMITTEE MEMBERS

Lucie D'ASCENZO	ISOE ETC, CEPN – France
Laure-Anne BELTRAMI	ISOE ETC, CEPN – France
Eemeli HÄRMÄLÄ	Olkiluoto NPP – Finland
Johannes ISOKIVELÄ	Forsmark NPP – Sweden
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Hidenori YONEHARA	ISOE ATC, NSRA – Japan
Mitsuaki YOSHIDA	ISOE ATC, NSRA – Japan

CONFERENCE LANGUAGE

The conference language will be English.

SYMPOSIUM VENUE

The Symposium will take place at:

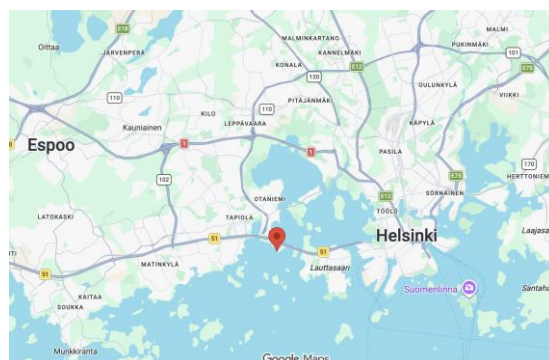
HANAHOLMEN - Swedish-Finnish Cultural Centre

Hanasaarenranta 5

02100 Espoo (Finland)

Website: <https://hanaholmen.fi/en>

Hanaholmen is located in Espoo, just outside Helsinki, on a small peninsula.





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DEDICATED MEETINGS – MONDAY 15 JUNE 2026

The ISOE Symposium will be preceded by two dedicated meetings devoted to specific audience.

If you wish to participate to one of those meetings, please contact the relevant person as indicated below for registration.

The registration to these meetings is free of cost.

Radiation Protection Managers Meeting

09:00 - 17:00	Location: Hanaholmen (Hanasaarenranta 5, 02100 Espoo) Room: Skiftnyckel <i>Contact-person:</i> Timo KONTIO, Loviisa NPP – timo.kontio@fortum.com
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Regulatory Body Representatives Meeting

09:00 - 17:00	Location: STUK (Jokiniemenkuja 1, 01370 Vantaa) Main entrance on Jokiniemenkatu 28. How to reach STUK: https://stuk.fi/en/how-to-reach-us <i>Contact-person:</i> Veli RIIHILUOMA, STUK – veli.riihiluoma@stuk.fi
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PROGRAMME

TUESDAY 16 JUNE 2026

08:30 - 09:00	Registration
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09:00 - 09:30	Opening Ceremony (ETC, Fortum, TVO, STUK)
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Session 1. International Recommendations and Guidelines

09:30 - 10:00	ICRP Review and Revision of the System of Radiological Protection: Where do we Stand? <i>Thierry Schneider (CEPN, France)</i>
10:00 - 10:20	The IAEA Safety Report on Health Surveillance of Workers Exposed to Ionizing Radiation <i>Jizeng Ma (IAEA)</i>
10:20 - 10:40	Enhancing Emergency Preparedness for Small Modular Reactors: A Graded Approach <i>Mike Webley (OECD/NEA)</i>

10:40 - 11:20	Coffee-break, Visit of Exhibition, Posters
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Session 2. RP Management

11:20 - 11:40	Digital Radiological Passbook Application Experience <i>Elena Pintado Alcoba (CSN, Spain)</i>
11:40 - 12:00	Enhancing the RP Workforce: by Incorporating International Training Standards, defining Junior Surveyor Pathways, and professionalizing the Decontamination Role <i>Franz Pedersen-Dambo (NUVIA Group, Canada)</i>
12:00 - 12:20	Demonstration of Radiological Digital Twin for Radiation Protection Operations and Personal Dosimetry <i>Borja Bravo, D. Campbell, J. Cady (EPRI, Ireland)</i>

12:20 - 14:00	Lunch Break
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Session 3. RP at Design Stage of NPPs - 1

14:00 - 14:20	Collection and Integration of Lessons Learned / Operating Experience from EPR Design Phases and First Operating Cycles <i>Sébastien Poirrier (EDVANCE, France)</i>
14:20 - 14:40	Optimisation of EPR2 Source Term at Design: Capitalisation of EPRs Cycles 1 & 2 Operating <i>Matthieu Longeot (EDVANCE, France)</i>

14:40 – 15:10	Synthesis of RPM Meeting and RB Meeting
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15:10 - 15:50	<i>Coffee-break, Visit of Exhibition, Posters</i>
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Session 4. Decommissioning and Waste Management

15:50 - 16:10	Feedback from the 18 th Meeting of the ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM) <i>Laure-Anne Boffa-Beltrami (CEPN, France), Benjamin Boussetta (EDF, France)</i>
16:10 - 16:30	TEPCO Fukushima Daiichi Nuclear Power Station: Status in 2025 and ALARA Measures <i>Toshikazu Suzuki (TEPCO, Japan)</i>

19:00	SYMPOSIUM DINNER AT HANAHOLMEN
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WEDNESDAY 17 JUNE 2026

Session 5. Source-Term Management

09:00 - 09:20	Effective RP and Chemistry Partnerships to Achieve Excellence in Operations & Plant Reliability <i>Bert Engstrom (Palo Verde NPP, USA)</i>
09:20 - 09:40	Overview of the Surface Contamination Measured through the EMECC Device into Primary and Auxiliary Circuits of the Pressurized Water Reactors (PWRs) Fleet in France <i>Thomas Jobert (EDF/DT, France)</i>
09:40 - 10:00	Nuclide Specific Measurements of Loops and Actions Taken Concerning Source Term Management at Loviisa NPP <i>Miska Hirvelä (Loviisa NPP, Finland)</i>
10:00 - 10:20	Ultrasonic Cleaning, a Promising Technology for Reducing Dosimetry <i>Rémi Bourdeloie, Edgar Moleiro (EDF/UNIE-GPEX, France)</i>
10:20 - 10:40	Source Term After Chemical Decontamination and Design Modification René Hoffmeister (Leibstadt NPP, Switzerland) <i>Distinguished paper from 2025 International ISOE symposium</i>

10:40 - 11:20 *Coffee-break, Visit of Exhibition, Posters*

Session 6. RP at Design Stage on NPPs - 2

11:20 - 11:40	CANDU MONARK™ Design Features Minimizing Collective Occupational Dose to ALARA <i>Serge Julien, N. Southam, J. Davidson (Candu Energy Inc., Canada)</i>
11:40 - 12:00	Standard Radiation Protection Design Sequence for New Nuclear Power Plants <i>Sébastien Poirrier (EDVANCE, France), Sonia Mallozzi (Framatome GmbH, Germany)</i>

12:00 - 14:00 *Lunch Break*



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Session 7. Job Experiences

14:00 - 14:20	Olkiluoto 3 – Insights to the First Two Outages of OL3 <i>Kalle Kari (Olkiluoto 3 NPP, Finland)</i> 🏆
14:20 - 14:40	Steam Generator Collector Work Contamination Management at Loviisa NPP <i>Sampo Ylisirnio (Loviisa NPP, Finland)</i>
14:40 - 15:00	Mitigation Solutions for Stress Corrosion Cracking Intervention <i>Julien Routtier (EDF DIPDE, France)</i>
15:00 - 15:20	Online Neutron Spectrum Measurement and Personal Dose Assessment inside the Reactor Based on a Single-Sphere Neutron Spectrometer <i>Bowen Sun, Zhihui Tang, Liye Liu, Zhen Wang (China Institute for Radiation Protection; Shanxi Key Laboratory for Radiation Safety and Protection; CNNC Key Laboratory for Radiation Protection Technology; Tsinghua University, China)</i> 🏆

15:20 – 16:00	Coffee-break, Visit of Exhibition, Posters
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Session 8. RP Events

16:00 - 16:20	Olkiluoto 3 – Unplanned Exposure to High Dose Rate during Crane Load Testing <i>Henri Jutila (Olkiluoto 3 NPP, Finland)</i>
16:20 - 16:40	Estimation of the Radiation Doses to Workers Caused by the Rupture of a Slightly Cooled Fuel in the Open Reactor Core <i>Pasi Karvonen (Loviisa NPP, Finland)</i>
16:40 - 17:00	Unexpected Skin Exposure at Decontamination Job <i>Janne Savolainen (Loviisa NPP, Finland)</i> 🏆
17:00 - 17:20	Overview of Evolution of Contamination Management at Loviisa NPP – Evolution of Trends and Actions taken to Reduce Contamination Events <i>Einari Mattila (Loviisa NPP, Finland)</i>

17:20 - 17:40	Distinguished Papers and Closure of the Symposium
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THURSDAY 18 JUNE 2026

TECHNICAL VISIT

A technical visit to the **Olkiluoto NPP** is organised (full day).

Please note that Olkiluoto NPP is about 3h30 by bus from Helsinki.

The bus departures and arrivals will be announced later on the ISOE Network website and to the registered participants. The participation is subject to availability as the visit is restricted to a limited number of persons.

HOW TO GET TO HANAHOLMEN CENTRE?

The Symposium will take place in Espoo, just outside Helsinki, on a small peninsula.

Public transportation:

- The walking distance from the nearest metro station “Koivusaari” is approximately 1.1 km.
- The bus stop along the Westway is circa 400 metres from Hanaholmen.

Public transport website: <https://www.hsl.fi/en>

Taxi:

- The taxi journey from the city centre of Helsinki to Hanaholmen will take approximately 10 minutes; from the airport it takes approximately 40 minutes.
- Please note that there is a risk of confusion, since there is a power station in East Helsinki called Hanaholmen, so be sure to ask the driver to take you to Hanaholmen Cultural Centre in Espoo.

REGISTRATION TO THE SYMPOSIUM

	Registration Fees	Online Registration
Participant	400 € (VAT Reverse charge)	Registration form
Commercial Booth	1400 € (VAT Reverse charge)	Booth Registration form

Payment of the fees must be done after online registration and receipt of the invoice.

Visit ISOE website: www.isoe-network.net for more information

BOOK OF ABSTRACTS



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Session 1. ICRP Review and Revision of the System of Radiological Protection: Where do we Stand?

Thierry SCHNEIDER
CEPN & ICRP

Initiated in 2021, the process of reviewing and revising the system started with a series of considerations to “keep ICRP recommendations fit for purpose” and the identification of “areas of research to support the system of radiological protection”. Preliminary consultations have proven that the current system is robust, but some clarifications and updates are needed to facilitate its application for protecting patients, workers, the public, and the environment against detrimental effects of ionising radiation exposure, without unduly limiting the benefits associated with the uses of ionising radiation.

Currently, more than 20 Task Groups are developing reflections to contribute to reviewing and revising the System. Among the topics under consideration are: reformulation of radiation health detriment and potentially including non-cancer diseases; the possibility of defining detriments for males and females of different ages; the framework for bringing together protection of people and the environment; improvements for the application of the three fundamental principles of justification, optimisation of protection and dose limit; and clarification of the exposure situations introduced in 2007.

The on-going work is largely developed in consultation with the relevant organisations and stakeholders with the aim to provide recommendations in the early 2030s addressing changes in science and society to remain fit for purpose.

This presentation will summarize the on-going work 5 years after the beginning of the reviewing and revising process, mainly focussing on topics of concern for managing occupational exposure.

Session 1. The IAEA Safety Report on Health Surveillance of Workers Exposed to Ionizing Radiation

Jizeng MA

International Atomic Energy Agency (IAEA)

Vienna International Centre, PO Box 100, 1400 Vienna, Austria, Email: j.ma@iaea.org

Health surveillance of workers exposed to ionizing radiation is an important part of radiation protection programme. It is required in the GSR Part 3 and detailed guidance is provided in the IAEA Safety Guide on Occupational Radiation Protection (GSG-7).

This safety report, revised by the International Atomic Energy Agency (IAEA) in collaboration with the International Labour Organization (ILO) and the World Health Organization (WHO), updates the 1998 IAEA SRS 5 to align with the current international standards, insights from Occupational Radiation Protection Appraisal Service (ORPAS) missions, and advances in workplace technologies. It provides comprehensive guidance based on frameworks such as the IAEA's GSR Part 3, ILO Conventions, and WHO recommendations, aimed at employers, occupational physicians, regulatory bodies, and workers to improve occupational radiation protection.

The report covers core topics including the nature of ionizing radiation, exposure pathways (external and internal), natural and artificial radiation sources, and associated health effects (deterministic and stochastic). It outlines radiation protection principles—justification, optimization, and dose limitation—with specific dose limits, constraints, and reference levels, as well as guidance for emergency workers. Global occupational exposure data across sectors (medical, industrial, nuclear fuel cycle, etc.) are presented, alongside risk assessments for radiation-induced cancer and non-cancer effects, supported by cohort studies and epidemiological evidence.

Key sections cover radiation protection programmes including area classification, local rules, exposure monitoring as well as health surveillance programmes, including pre-employment and periodic medical examinations, health records management, counselling, and arrangements for itinerant workers. Guidance is provided on the medical management of overexposed workers covering external exposure, contamination, and combined injuries, with emphasis on early detection, first aid, and referral to specialist care. Annexes offer scientific insights into the health effects of radiation and practical examples from countries such as China, the UK, Belgium, and Finland.

Focused on practicality and international compatibility, the report excludes hospital-based continuing care for emergency high-dose exposures. It remains an essential resource for standardizing health surveillance practices and ensuring the health of workers occupationally exposed to ionizing radiation worldwide.

The report is at the final stage of submission for publication.

Session 1. Enhancing Emergency Preparedness for Small Modular Reactors: A Graded Approach

Mike Webley
OECD NEA, France
Mike.WEBLEY@oecd-nea.org

The Nuclear Energy Agency's (NEA's) Committee on Radiological Protection and Public Health (CRPPH) assists member countries in the implementation and ongoing revision of the system of radiological protection. The Expert Group on Emergency Preparedness for Small Modular Reactors (EGEPSMR) is exploring how a graded approach can be applied to emergency planning, ensuring that protection strategies are appropriately tailored to the unique characteristics and deployment scenarios of SMRs. The EGEPSMR continues the work of the Task Force on SMRs (TFSMR) which was established to assess and report on whether there are areas of added value for CRPPH-led work concerning radiological protection issues of SMRs. The presentation will share the TFSMR publication and recommendations, and the work of EGEPSMR to design and carry out a survey to determine whether the implementation of existing emergency preparedness and response (EPR) requirements adequately cover SMRs and the identification and implementation of a graded approach on protection strategies for emergencies.

Session 2. Digital Radiological Passbook application experience

Elena Pintado Alcoba, Nuclear Safety Council (CSN) from Spain
Email address: elena.pintado@csn.es

The **Digital Radiological Passbook (CRAD)** initiative, led by the **Spanish Nuclear Safety Council (CSN)**, represents a significant advancement in the modernization of radiological protection systems in Spain. This project replaces the traditional paper-based radiological monitoring document—used since 1990—with a secure, cloud-based digital platform designed to enhance the traceability, accessibility, and efficiency of radiological exposure tracking for external workers operating in controlled areas.

The radiological passbook was developed in response to the need for systematic monitoring of radiation doses received by external personnel working in environments with ionizing radiation exposure. It is grounded in the regulatory framework established by **Royal Decree 1029/2022** and further defined by **Safety Instruction IS-01 (2001)**, which outlines the structure and content of the radiological passbook. The digital transformation of this system is part of the CSN's broader strategic plan for digitalization and innovation in regulatory oversight, aligning with national and European objectives for digital public services.

CRAD offers numerous **benefits** that significantly enhance radiological protection management. The **administrative processes** for companies and nuclear or radiological facilities have been streamlined and optimized, reducing paperwork and minimizing manual data handling. Authorized stakeholders now have real time, secure access to individual exposure data, which improves responsiveness and supports more informed decision making. **Regulatory oversight** has also been strengthened, enabling the CSN to monitor compliance and analyze exposure trends more effectively. Additionally, the system ensures interoperability with other digital platforms within the radiological protection ecosystem, facilitating seamless data integration and reporting.

Development of the application was carried out between Q4 2022 and Q1 2023, followed by structured pilot trials. The first pilot, conducted during the Trillo NPP refueling outage (May–June 2023), involved five external companies and approximately 40 outside workers. The second pilot, during the Ascó NPP refueling outage (Nov–Dec 2023), expanded the scope of testing and validated system performance under operational conditions. Following these trials, the CRAD entered a progressive rollout phase in January 2024, extending adoption to all facilities and selected permanent contractors.

The official release in September 2024 initiated a three-year transition period, during which paper-based passbooks remain valid until 30 September 2027. As of December 2025, current rollout data indicate substantial adoption: 5,235 digital passbooks are active across 227 companies. The transition rate from paper to digital format has reached 81%, reflecting widespread acceptance among nuclear power plants and contractors.

In conclusion, CRAD constitutes a scalable, modernized infrastructure that strengthens radiation safety governance, reduces administrative complexity, and supports advanced analytical functions. Its deployment marks a decisive step toward the digital transformation of radiation protection practices.

Session 2. Enhancing the RP Workforce: by Incorporating International Training Standards, defining Junior Surveyor pathways, and professionalizing the Decontamination Role

Franz Pedersen-Dambo, Director, Radiological Protection Services

NUVIA Group, France

Email address: franz.dambo@nuvia.com

Bio: RP Experience from PWR, BWR, Magnox, AGR, CANDU reactors in multiple countries.

Resource shortage

There is a shortage of qualified radiation protection technicians in most mature nuclear markets, particularly among senior personnel.

At the 2024 ISOE North American Symposium in Clearwater, USA, during the Plenary Remarks from the Honourable David A. Wright, U.S. NRC Commissioner, data presented on attrition among RPTs available and willing to work outages reveal a critical imbalance between training and retention. Between Fall 2018 and Fall 2021, Junior RP Technicians (JRS) experienced an attrition rate of approximately 42%. Although intensive training programmes successfully replaced these individuals, maintaining a stable total number of junior technicians. Even after training efforts, the net attrition was 37% in the available Senior RP Technician (SRS) workforce over that same three-year period. It was also mentioned that the remaining senior pool faces significant demographic challenges, with many already at or nearing retirement age.

Such high turnover, even among juniors, creates a significant experience gap. As the departing juniors are also amongst those close to reaching senior-level skills, replacing them with entry-level juniors disrupts the natural development pathway.

Three key takeaways:

- The Revolving Door (Junior Level): The industry trains staff (42% attrition met by training to maintain the pool size), but it isn't retaining them long enough for that training to take full effect.
- The Broken Pipeline: The "middle" of the workforce is vanishing, resulting in fewer qualified candidates ready to advance into senior roles.
- The Net Drain (Senior Level): The 37% decline in seniors represents a lasting loss of expertise that training alone cannot remedy.

Although this trend is less evident in Europe, a similar pattern continues.

Some of the impact of shortages can be mitigated by leveraging the offset peak seasons in Europe and North America, as well as by utilizing other international resources.

Although the US regulatory framework is moving away from cumulative and five-year dose averages, it is important to remember that these practices are not yet industry standards. Most utilities still maintain internal Administrative Control Levels (ACLs) that closely follow ICRP recommendations.

However, this regulatory change introduces a "latent risk." As the senior workforce continues to decline—evidenced by a 37% net reduction of SRS personnel between 2018 and 2021—the temptation for utilities to exploit these higher limits to fill immediate staffing gaps will grow. We face a potential crisis: a transition that could happen quickly once a few major utilities start diverging from international norms to maintain outage schedules.

This divergence forms a two-way barrier to mobility:

- Outbound Constraints: US-based radiation protection technicians who adopt higher limits might be disqualified from projects in international markets (e.g., Canada or Europe) that strictly enforce ICRP-aligned 5-year averages.
- Inbound Resistance: International radiation protection technicians might hesitate to support US outages, fearing that a single high-dose year in the USA could harm their ability to work in their home markets.

Training Standards

One challenge is the wide variety of qualifications, which often requires already qualified resources to undergo additional, time-consuming training that mainly confirms their existing qualifications rather than enhancing their knowledge; therefore, there is a need for more internationally standardized training and evaluation criteria.

The wide variation in training generally exists between countries, but even within a country, qualifications can differ from one site operator to another, making the radiation protection technician less mobile. If a Radiation protection technician is limited to local work and there isn't enough work to sustain their livelihood, skilled workers may leave the industry. Power plant operators with only a few reactors are especially vulnerable — not only is there a risk of lacking access to resources, but managing proficiency and maintaining qualifications becomes very challenging. Additionally, if the industry shifts to include a mix of many small, one- or two-unit SMR sites, having a flexible workforce to develop competency levels will become even more essential.

If we examine the USA as an example

Historically, the nuclear industry encountered significant logistical bottlenecks during outages. Supplemental contract technicians had to be repeatedly retrained and re-evaluated on core RP tasks whenever they arrived at a new site, resulting in thousands of wasted person-hours.

EPRI, in collaboration with industry, tackled this issue by establishing a universally accepted baseline for core radiological protection tasks, transferring training responsibilities from individual power stations, and creating a truly portable workforce.

The Three Key Pillars

- Unified Procedures (NISPs): The industry agrees on standardized operating procedures for essential, universal tasks such as operating standard survey instruments and controlling HRA access.
- Portable Evaluations (STEs): Technicians complete standardized written and practical exams based on those procedures. Passing scores are recorded in a central, industry-wide registry that any host utility can verify instantly, preventing duplicate testing.
- Vendor Pre-Qualification (AP3): After formal evaluation and approval, third-party workforce providers and contractors are authorized to conduct these standard assessments prior to deployment. Technicians arrive on-site fully qualified for their baseline tasks.

The EPRI framework demonstrates that standardizing the fundamentals is effective. By establishing a common baseline, individual sites only need to train additional staff on rare, site-specific anomalies.

Although achieving a fully international standard at this stage, especially in procedures due to varying regulatory requirements, is unrealistic, it is still possible to align with the core principles of radiation protection, which are based on international standards. This can likely be accomplished by adopting a foundation from one of the higher training standards. While it may not be entirely aligned, this approach would still facilitate more seamless and effective bridging training and could substantially assist newer nuclear nations in adopting higher standards. Overall, this strategy would better support the industry's performance, even if these resources remain domestically focused.

Simulated source systems have significantly improved and are now practically usable for creating realistic scenarios. This enhances our ability to better prepare junior personnel for fieldwork and to train senior staff for high-hazard tasks, such as using simulated point sources with simulated instruments and EPDs. Many of these systems also provide various unbiased evaluations that help standardize and ensure the quality of practical assessments. For example, VIZRAD Frisk allows for an unbiased assessment of the area frisked, speed, and distance.

Junior tasks

Utilities often request highly experienced senior personnel even for tasks that junior surveyors could manage because senior resources are more versatile. The lack of entry-level tasks limits juniors' opportunities to advance into senior roles. Even within the same country, the tasks a junior is permitted to perform may vary from site to site. It is also important to rotate the tasks juniors undertake to encourage their eagerness to

learn and prevent complacency. We also need to remember that the experience of a seasoned junior, even if they have not yet become a senior, differs from that of a new junior, and a tiered approach could be considered.

We, as an industry, need to define junior roles more clearly so they can be deployed sooner and assigned more meaningful tasks.

Decontamination

Decontamination is often viewed as a basic entry-level cleaning task. Many markets have bundled decontamination services into facility management and civil maintenance, performed by resources that spend most of their time maintaining non-contaminated areas and items with minimal radiation knowledge. Improper decontamination can easily spread contamination and pose a significant internal hazard.

Decontamination can be highly sophisticated with specialized tools, but it is often linked to understanding contamination and how it spreads, especially when used in simple daily tasks.

For example, we often see a fast-food restaurant quickly wipe the table with the same cloth in a circular motion, catching some of the dirt but also spreading and diluting it until the stains are no longer visible. If this method were used in a radioactive contaminated environment, it has a high potential to spread contamination. Proper decontamination is one-way, from clean to dirty. It involves regularly turning and folding the cloth to use the clean side and changing it frequently to prevent spread and cross-contamination.

Maslin cloths have a slightly oily surface, are static when stretched, and are very effective at collecting dry dust. Ammonia-based window-cleaning products are sometimes used to loosen spots on exterior surfaces and can often be a good choice for this purpose. However, using them together is not advisable, since the maslin cloths are not very absorbent, and you don't get the proper effect when they are used incorrectly. Unfortunately, this is a common issue, and this ineffective decontamination method results in unnecessary waste.

There are several examples of skilled decontamination operatives removing contamination hazards, preventing their spread, and reducing delays on the critical path

A few examples.

During refurbishment projects, moving shielding flasks often impacts the critical path. We have observed cases where improper decontamination of the flasks caused significant delays, and we have also seen how deploying dedicated, highly skilled decontamination operatives who follow proper methodology and use solvents appropriately when needed can help keep the schedule on track.

Decontamination of the reactor pool and cavity during refuelling outages often impacts the critical path, and we have observed better results and shorter durations when using more experienced, senior decontamination operatives.

The decontamination background has, in many cases, established a solid foundation for developing a well-rounded radiation protection technician with a strong understanding of contamination management, often exceeding the requirements expected of a junior radiation protection technician.

Rather than combining decontamination with facility management services, it is crucial to professionalize decontamination operatives and integrate them into the radiation protection organization. Besides defining the required skills and offering proper training, this method also expands the recruitment pool for future RPTs.

Conclusion

Given the severe shortage of highly specialized skills, expecting a single approach to close the resource gap is unrealistic. Instead, we should adopt a multistage approach, and therefore:

We, as an industry, need to enhance the RP Workforce by further incorporating international training standards, defining Junior Surveyor pathways, and professionalizing the Decontamination Role.

Session 2. Demonstration of radiological digital twin for radiation protection operations and personal dosimetry

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Currently, most radiation protection (RP) tasks for the collection of radiological data at nuclear power plants and subsequent analyses to inform radiation protection, source term management, and/or ALARA planning are typically conducted manually. RP organizations need to leverage technologies that provide remote/automated radiological measurements, enable remote execution of RP tasks, and facilitate data management and analytics. Technological solutions may exist to address elements of the issue; however, these solutions may not be well known yet or fully developed for widespread implementation in the industry.

The main objective of this study is to explore the implementation of digital twins combined with advanced data analytics at real sites to optimize radiation protection operations in nuclear power plants, evaluating the various ways a digital twin can be applied to optimize and enhance radiation protection operations, automated ALARA planning, personal dosimetry, training, etc., highlighting the importance of technological innovation to improve radiation management in nuclear power plants. The research has been conducted through pilot demonstrations at different sites, utilizing advanced scanning, data processing, and simulation technologies to create a digital twin of the plant's radiological environment. The methodology included the integration of real-time data and the simulation of operational scenarios to enhance ALARA planning, shielding optimization, and operational efficiency, as well as to estimate worker doses in various operations.

The results obtained demonstrate the potential of digital twins to improve radiation mapping, the estimation of actual worker doses or simulated doses in different scenarios and shielding optimization. Additionally, challenges and opportunities for the future development of digital twins were identified. In conclusion, this work highlights the importance of digital twins in enhancing the safety and efficiency of radiation protection operations in nuclear power plants, offering valuable insights for their practical implementation and continuous development.

KEY WORDS: RADIATION PROTECTION, DIGITAL TWIN, ALARA, DOSIMETRY, INNOVATION, AUTOMATION

Session 3. Collection and integration of lessons learned / operating experience from EPR design phases and first operating cycles

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Abstract

The design work, commissioning and first operating cycles of EPRs worldwide have yielded a significant number of lessons learned (LL) and operating experience (OPEX) feedback.

LL and OPEX are highly valuable for improvement and optimization of new reactors design, e.g. to rearrange some parts of buildings to ease future operations (logistics, etc.), to perform a tailored radiation shielding specification based on a calculation / measurement benchmark or to verify the accuracy of flux and dose rate design estimations in the reactor building during power operation.

This presentation will focus on the collection and integration of lessons learned and operating experience regarding radiation protection aspects, from EPR design phases and first operating cycles (Flamanville 3, Olkiluoto 3, Taishan 1 & 2).

First, the collection process will be explained (workshops, networks, on-site technical visits).

Then, the integration in the new reactors design will be discussed, highlighting the benefits of design improvements for the project and for the future operator with illustrative examples on topics like sizing of radiation shielding structures or integration of operators' constraints and organizational aspects.

Keywords

New Nuclear Power Plants, lessons learned, optimization, measurements, design calculations, OPEX, logistics

**Session 3. Optimisation of EPR2 Source Term at Design: Capitalisation of EPRs Cycles 1 & 2
Operating Experience**

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EDVANCE and EDF perform radiation protection design engineering studies for the EPR2, model that is envisaged for the renewal of the French nuclear fleet. In this frame, activities aimed to optimise EPR2 source term at design stage are key to reduce as much as possible future workers radiation exposure during inspection and maintenance intervention and to improve availability (and therefore the economic performance) of the plant. Source term optimisation is also important because associated design features reduces radiation and contamination levels throughout the plant, whereas shielding or ventilation design features will benefit only locally.

Besides recalling the mechanisms of production of source term and their impact on radiation field in the radiation controlled area, the presentation has 3 main objectives.

The first objective is to present EDF Radiation Protection (RP) Strategy and Guidelines. For example, optimisation of source term at design involves:

- Materials choice with low impurities (i.e. likely to be activated in the core), surface finishing;
- Systems design to ensure optimisation of chemical conditioning and purification of primary fluid at all plant states and equipment design for monitoring of radionuclide activities and dose equivalent rates (DER);
- Optimised chemistry procedures (e.g. cold shutdown) in normal operations rules.

The second objective is to present EDF-EDVANCE approach to apply EDF Guidelines of optimisation of source term during the EPR2 design. This implies the definition of an EPR2 designer-operator work program ([Com' S02-3 at 2024 UE ISOE Conf](#)) for which illustrations (non-exhaustive) are given below:

- An R&D program (tripartite EDF, Framatome and CEA) is related to the development of OSCAR code (including calibration with measurements). At EPR2 design stage, this code carries out predictive studies of surface contamination in circuits by varying parameter such as material choice, cold shutdown chemistry procedure or primary water purification strategy;
- Through its network with EDF, EDVANCE collected operating experience (OPEX) of Cycle 1 EPR (OL3, FA3 and TSN1-2) which consists first of « measurements of "RP data" (DER and surface contamination) & "Chemistry/Radiochemistry data" » and second of elements of context with operating parameters of the cold shutdown. Capitalisation of these OPEX for EPR2 is forecast, i.e. to provide recommendations such as optimal "passivation during hot functional tests", optimal "cold shutdown procedures" and optimal "purification strategy" based on intercomparison between EPRs (OL3 and FA3).

The final objective of the presentation is to present illustrations of capitalisation on EPR2 of first elements of EPR OPEX (dose rates, surface and volume activities and spectra measurements); namely, some EPR2 design optimization to reduce source term and to mitigate source term's impact.

Keywords

Source term, design, operating experience, chemistry, operation procedures, decontamination

¹ EDVANCE (an EDF SA and Framatome subsidiary) is a key entity for Engineering, Procurement, Construction and Commissioning of EPR2 Nuclear Islands.

Session 4. Feedback from the 18th meeting of the ISOE Working Group on Radiological Protection Aspects of Decommissioning Activities at Nuclear Power Plants (WGDECOM)

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Decommissioning of nuclear power plants is a subject of growing importance for the nuclear industry. During decommissioning of NPPs, economics, technical and organizational challenges are encountered and only few feedbacks are collected and shared at the international level to deal with these challenges.

In November 2014, ISOE (Information System on Occupational Exposure, www.isoe-network.net) decided to establish a new working group dealing with occupational radiological protection during decommissioning activities at NPPs, the WGDECOM. The objective of this working group is to improve the sharing of operational RP data and experience for NPPs in all stages of decommissioning.

The 18th meeting of the WGDECOM will be organized in France from 31st of March to 3rd of April.

During the meeting there will be two site visits:

- Two decommissioning units of Saint Laurent A NPP
- Chinon A NPP:
 - o Visit of two units in decommissioning
 - o Visit of prototype installation for graphite treatment.

In addition of these visits, two days of meetings will be organized with at least one topical session.

This presentation will focus on the outcome of this meeting.

Session 4. TEPCO Fukushima Daiichi Nuclear Power Station: -Status in 2025 and ALARA Measures-

Toshikazu Suzuki

Tokyo Electric Power Company Holdings, Decommissioning Company, Japan

Following the ocean release of treated water, the dismantling of 12 empty tanks in the J9 area—part of the nearly 1,000 ALPS treated water tanks—was completed over approximately seven months. Work continues on dismantling 9 adjacent tanks in the J8 area. And the Unit 3 Fuel Debris Retrieval Facility is planned for construction in this combined J8 and J9 area.

The 2025 treated water releases occurred as planned, totaling seven releases. During this period, the tritium concentration in seawater remained below the detection limit (approximately 10 Bq/L using rapid measurement methods) throughout the year within the 20 km coastal zone. Meanwhile, within 3 km of the coast, levels ranged from several tens of Bq/L up to a maximum of 61 Bq/L. This was less than one-tenth of the 700 Bq/L level at which TEPCO would halt releases and remained well below the WHO drinking water standard of 10,000 Bq/L. The rapid measurement method involves directly measuring filtered seawater using a liquid scintillation counter. While its sensitivity is lower than that of precision measurement methods, it offers the advantage of reducing the analysis period from several months to just a few days.

The first fuel debris retrieval from Unit 2 in November 2024 was followed by a second retrieval in April 2025, conducted closer to the center of the PCV. A representative sample from the second retrieval measured approximately 5 mm × 4 mm with a total mass of 0.187g and exhibited a gamma-ray dose rate of 0.3 mSv/h. Gamma-ray spectroscopy detected the following nuclides: ²⁴¹Am, ^{154/155}Eu, ¹²⁵Sb, ¹³⁷Cs, and ⁶⁰Co. Here, the presence of ²⁴¹Am confirmed the material as nuclear fuel debris. The remaining amount of ¹³⁷Cs, much of which volatilized during the accident, was small. Meanwhile, surface element analysis by SEM-WDX detected only U, Fe, Ni, Cr, Zr, and O at all locations, confirming the primary composition consists of nuclear fuel (U), cladding tubes (Zr), and structural materials (Fe, Ni, Co). Compared to the first analysis, elements such as Si, Ca, and Al, which originate from insulation layers and seawater, were not detected. This suggests that materials present within the RPV may have contributed relatively more significantly during the debris formation process.

For Unit 1, where the R/B roof collapsed during the hydrogen explosion, a large movable cover was installed to cover the entire roof. This serves as a countermeasure against radioactive dust dispersion for the upcoming debris removal work required for fuel removal from the spent fuel pool on the operating floor. The cover consists of eight blocks weighing 38 tons to 103 tons per block and was installed atop the roof using a large crane.

On the other hand, progress was made in organizing solid waste stored on site, such as debris and felled trees, with shielding installed where necessary. Additionally, the release of ALPS treated water into the ocean reduced direct radiation from the tank clusters. However, the ambient dose rate at the site boundary remains largely unchanged from previous years. The readings at monitoring post MP-6, located in a position less susceptible to direct radiation and skyshine radiation, are the lowest at approximately 0.3 µSv/h. Even at the highest point, MP-4, readings remain stable at approximately 1.0 µSv/h. Continuous dust monitors are installed near each MP. Airborne radioactive concentration (β nuclides) has remained below the detection limit of 1×10⁻⁶ Bq/cm³. Furthermore, no α particles originating from artificial nuclides have been detected.

At Fukushima Daiichi, internal exposure measurements involve screening examinations every three months using a plastic scintillation chair-type whole-body counter (WBC). If the specified counter reading is exceeded, body radioactivity measurements are conducted using a NaI(Tl) scintillation standing-type WBC. For work in environments containing actinides other than fuel debris, where ¹³⁷Cs is typically present, internal intake is assessed via quarterly WBC screening if no alpha contamination is detected on the full-face mask surface. In fiscal year 2024, there were no cases of internal intake exceeding 2 mSv (Recording level). The average external exposure dose was 2.08 mSv and the maximum external exposure dose was 16.8 mSv. As a result, the total number of radiation workers during the same fiscal year was 11,909, and the collective dose was 24.73 person-Sv.

Session 5. Radiation Protection Success Through Cross-Department Teamwork

Bert Engstrom
Palo Verde Generating Station
Radiation Protection Manager

Radiation Protection (RP) achieves its strongest results when it operates as a fully integrated partner with other station work groups.

This presentation highlights how coordinated efforts among **Chemistry, Maintenance, Operations, and Work Management** directly contribute to safe, efficient, and ALARA-focused performance.

RP success is not limited to one department. Chemistry ensures accurate radiological chemistry data, Operations maintains plant stability and respects radiological boundaries, Maintenance executes work with radiological awareness, and Work Management aligns scheduling and planning to support ALARA strategies.

Together, these groups create a culture where radiation safety is a shared responsibility.

Session 5. Overview of the surface contamination measured through the EMECC device into primary and auxiliary circuits of the Pressurized Water Reactors (PWRs) fleet in France

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This presentation will provide an overview of the surface contamination measured into primary and auxiliary circuits of the Pressurized Water Reactors (PWRs) fleet in France.

Surface contamination by activated corrosion products (ACP) is the main contributor to maintenance doses and dose rates in PWRs. Thus, the measurement of this contamination is one of the key factors to reduce radiation fields. The characterization of the radiological situation of units, as well as a better understanding of the contamination mechanisms through the analysis of the data collected, will allow to implement the adequate radiation protection measures. Gains will be provided both at the design stage of new reactor development and during operation of existing plants.

In this presentation we will mainly focus on Co-58, Co-60 and Ag-110m deposited activities, gathered with the EMECC measurement device, designed by the CEA and equipped with a High Purity Germanium detector to allow accurate gamma spectrometry measurements. The first part of the presentation will be dedicated to display the results of the EMECC measurement campaigns and to propose an analysis of the contamination evolution observed on the 3 reactor series since the startup of the plants. In the second part, we will describe the data treatment applied to the EMECC measurements to identify correlations between the surface contamination in different parts of the primary circuit and design or operating parameters – such as zinc injection, pH, steam generator tubing alloys, load follow operation... The first results will be presented. Last, the ongoing work about machine learning experiments regarding the EMECC data will be depicted.

Session 5. Nuclide specific measurements of loops and actions taken concerning source term management at Loviisa NPP

Miska Hirvelä
Loviisa NPP

Nuclide specific HPGe measurements have been made at Loviisa NPP steam generator rooms since 1993. This covers the LO2 primary circuit decontamination in 1994.

Measurements are made from three loops and steam generators. First loop at both units has eight exact measurement points, which gives a good mean value estimation about the surface contamination level on loop oxide layer and the changes can be compared to previous years. Conversion coefficients are used convert kBq/cm² to mSv/h and the dose rate trends show favorable development.

Co-60 has been reducing on both units for the last 30 years due to very strict cobalt requirements. After the replacement of the primary pump sealings for antimony free ones in 2012-2014 the Sb-122 and Sb-124 levels started to reduce and Sb-124 is no longer the most dominant nuclide causing the dose rate. Ag-110m has been one remarkable nuclide at LO2 for the last decade and Plant has established a working group to solve the origin of silver and to find out methods to dispose the source of inactive silver. Some actions are made in recent years and probable sources have been identified. At the same time the relative part of the dose rate caused by silver and the absolute amount of silver in surface contamination has reduced.

The dose rate value from loops have lowered on both units from the beginning value around 0,4 mSv/h to current 0,1 mSv/h. Also steam generators and some heat exchangers have had the same development in contamination levels than loops. All of this has had a huge effect to personnel collective doses.

Session 5. Ultrasonic Cleaning, a Promising Technology for Reducing Dosimetry

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ABSTRACT

One of the main challenges for EDF in the upcoming years, is to reduce the collective and individual dosimetry of our workers. To address this, a strategic purpose is the management of “hot spots”, mainly composed of ⁶⁰Co particles, which can generate significant dosimetry at a workstation or increase the dose rate in the vicinity. To mitigate the impact of these “hot spots”, the use of in situ ultrasonic decontamination technologies is one of the levers that can be implemented at French nuclear facilities. This non-intrusive technology is based on the clamping of transducers controlled by a central unit to pipes facing the “hot spots” and applying an ultrasonic mechanical wave at an optimal frequency and power. In this way, it removes the irradiating particles and evacuates them by the driving force of the fluid circulating in the pipe to a filter or sump. Recent tests using this technology have been implemented on nuclear island vent and drain system of two EDF power plants and have shown to be remarkably effective. Today, EDF’s objective is to extend the use of this technology to circuits classified as important for safety (RCS, CVCS, RHR, etc....).

Keywords: Ultrasonic cleaning, “hot spots”, Decontamination, Qualification tests.

Session 5. Source term after chemical decontamination and design modification

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Distinguished Paper at 2025 ISOE International Symposium (Weihai, China).

Since the implementation of HWC/OLNC in 2008, KKL has experienced an increase of collective radiation exposure (CRE) and source term. Average dose rates in the Drywell had nearly doubled between 2008 and 2021. Already in 1992, the recirc pump housings and recirc pipes were identified as major Co-source term contributors due to the high content of stellite and the corrosion rate. In 2005, a decision was made to replace part of the recirc pipes and pumps as part of a life extension project. Several measures concerning the ALARA impact like Stellite replacement in the steel used in pipes, pumps and valves, chemical decontamination of the recirc system and adjacent RHR system and the replacement of the flow control valves by an adjustable speed drive were included in the project's scope, together with the electropolishing of new surfaces. The project was executed in a 7-month outage in 2021 and only started after a chemical decontamination that removed 1.27 TBq (34.3 Ci) of gamma emitters, and achieved an average decon factor of 17. The accrued dose for the whole outage in 2021 was 3434 Pers.-mSv (343 p-rem). The chemical decontamination saved an estimated 3 Pers.-Sv. The measures taken to reduce CRE and source term had the following effects in the subsequent outages in 2022, 23, 24, 25 and 26: the saved dose is estimated around 700 Pers.-mSv (70 p-rem). Also, for the first time since 2008 the average Co-source term decreased steadily, currently 61% lower than at its all-time high in 2017, and still 51% lower compared to the 2021 level. The recontamination of the recirc system was much lower compared to the start-up years in the 1980's, most likely due to the electropolishing of surfaces and the improved source term in the reactor water. Dose rate increase on the recirc system reached equilibrium after 5 cycles and is still lower than pre-HWC/OLNC. At this point in time, it is still too early to make a final assessment, but the totality of all measures already ensures a reduction of the collective dose in the order of a low 3-digit Pers.-mSv per 3-year average, always assuming that workload stays relatively stable at current levels.

Session 6. CANDU MONARK™ Design Features Minimizing Collective Occupational Dose to ALARA¹

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Over the past several decades, Canada's nuclear industry has been continuously improving the CANDU®² reactor technology, from various large-scale reactor designs to new systems and features that improve the performance of reactor output, lifespan, and reliability. This has culminated in the CANDU MONARK™³ 1,000 MWe class Gen III+ reactor which builds upon the designs of existing CANDU plants in Ontario and overseas, as well as the Enhanced CANDU 6®¹ and ACR-1000®¹. The CANDU MONARK is a natural uranium fueled, heavy water moderated and cooled pressure tube reactor. Its design benefits from the proven principles and characteristics of the CANDU 6 design and the extensive knowledge base of CANDU technology gained over many decades of operation and incorporates modern plant designs.

The CANDU MONARK is designed to meet the International Commission on Radiological Protection (ICRP) fundamental objectives of radiation protection and comply with Canadian Nuclear Safety Commission (CNSC) regulatory requirements for radiation protection for plant operating staff and the public, including CNSC regulations for keeping radiation exposures As Low As Reasonably Achievable (ALARA), taking into account social and economic factors.

During the CANDU MONARK design phase, a design improvement program was developed to minimize the collective occupational dose and public dose based on the ALARA approach, taking into consideration of technology advancement, the specific design features, operation and maintenance issues, and lessons learned from the operation of CANDU Nuclear Power Plants. The evolutionary CANDU MONARK design features significant radiation exposure control improvements based on the latest technology and industry best practices with respect to the limitation of potential doses and the minimization of radionuclide production at source for all phases of the CANDU MONARK life cycle.

The presentation will focus on design aspects of the CANDU MONARK that contribute to minimize occupational radiation exposures to ALARA. As a result, it reduces collective occupational dose below the target defined by the Institute of Nuclear Power Operations (0.6 person-Sv/a).

¹ As Low As Reasonably Achievable (ALARA) taking into account social and economic factors.

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³ CANDU MONARK is a trademark of Candu Energy Inc., an AtkinsRéalis company.

Session 6. Standard radiation protection design sequence for new Nuclear Power Plants

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Abstract

When designing a new Nuclear Power Plant (NPP), the considerations about radiation protection (RP) of workers involve a wide range of requirements which are either inherited from the applicable referential (e.g. RP design rules) or derived from design assessments (e.g. radiation transport simulations, comprehensive 3D mock-up review).

Furthermore, radiation protection plays an important role in the early design phases of a NPP, particularly in the context of system design, material selection, and layout supporting optimization of RP and cost reduction.

RP requirements shall be defined all along the successive design phases of a NPP project to support its key milestones, and the verification of good implementation of such requirements shall be performed before the plant is built, commissioned and transferred to the operator. Therefore, the definition and the implementation of RP requirements in the design of a product (e.g. building layout, fluid system components) require strong and efficient interfaces between project stakeholders.

The standardization of products (building civil structures, door types, valve technologies), which serves various goals such as reduction of construction time and industrial performance, is also a source of challenge in terms of RP requirements and needs to be accounted for in the RP design work supporting a new NPP design.

Main radiation protection activities are performed several times during design phases to follow the progress of product design until the maturity level for construction is reached. These activities consist in ensuring the compliance with the regulatory framework and the good implementation of RP optimization principles in various ways:

- Assessments of dose rates and radiological zoning in rooms of nuclear buildings,
- Sizing of radiation shielding structures (e.g. main civil structures, doors),
- Optimization of layout (e.g. room arrangement, system routing),
- Contributions to the arrangement of contamination control areas for workers and equipment,
- Space reservation for inspection or maintenance activities during plant operating life, foreseeing decommissioning and dismantling activities as well.

Assessments and comparative analyses promote and support the early detection of new radiological risks in the design phases, identifying areas of improvement for an appropriate consideration of radiological constraints.

This presentation will introduce the context and goals of the standardization of the radiation protection design sequence of activities and associated interfaces, with examples from ongoing design phases of EDF NPP projects. It will also outline the importance of data management, standardization of design rules, standardization of engineering methods including modelling (codes, tools, digital thread).

Keywords

New Nuclear Power Plants, standardization, design rules, methods, requirements, interfaces, data

Session 7. Olkiluoto 3 – Insights to the first two outages of OL3 (EPR reactor type)

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Overall presentation about first two outages of the OL3 EPR reactor. Doses received and exposure conditions, source term, work phases with special RP topics and special events happened planned and unplanned during these first two outages.

Session 7. Steam Generator collector work contamination management at Loviisa NPP

Ylisirnio Sampo
Loviisa NPP, Finland

Loviisa NPP design type is VVER-440, which means it has horizontal steam generators (SG). Loviisa NPP also has a steel containment building that is not typical for a VVER-440. To keep the steel containment structure in rational size, the primary components (SGs and primary circuit) had to be built in a significantly smaller space than in the typical VVER-440 design.

Along the years, works done at the steam generator hot leg and cold leg collectors have been known to spread contamination inside and outside the shoeboundaries/contamination areas set up for the works, as the limited space makes it difficult to contain the contamination in the designated area. It wasn't until mid 2010's that it was recognized that eddy current testing (ECT) done for the heat exchanger tubes was likely to be the main reason for the contamination events at the work area.

The type of probe pusher-pullers used in ECT in Loviisa's steam generators are inserted into the collector, and probe-manipulator sticks out from the collector to about 1.5 m height. At the end of the manipulator is a cable-roll that spins. It was noticed that the spinning roll can spew contamination to the surroundings in the work area. To counter this, a "tent" is build around the collector and a local HEPA-filtrated ex-haust ventilation is built inside the tent, as near the collector as possible. Discussions and planning for designing a vacuum system to be inserted directly to the probe pusher-puller, similar to those found in vertical steam generator ECT are underway with the ECT company.

Session 7. Mitigation solutions for stress corrosion cracking intervention

Julien ROUTTIER
EDF/DIPDE

Stress corrosion cracking is a phenomenon that appeared in France in 2021 in pressurized water reactors (PWRs). The phenomenon has spread across several plants and affects some systems connected to the primary circuit. Once the causes were identified, solutions for replacing the affected piping were developed in record time, and innovative radioprotection actions were implemented, such as the full robotization of cutting, beveling, and welding operations on piping. Finally, preventive solutions have been considered and are currently being implemented to limit the need for replacement work

Session 7. Online Neutron Spectrum Measurement and Personal Dose Assessment inside the Reactor Based on a Single-Sphere Neutron SpectrometerBowen Sun^{1,2,3,*}, Zhihui Tang^{1,2,3,4}, Liye Liu^{1,2,3}, Zhen Wang^{1,2,3}¹China Institute for Radiation Protection, Taiyuan, China; ²Shanxi Key Laboratory for Radiation Safety and Protection, Taiyuan, China; ³CNNC Key Laboratory for Radiation Protection Technology, Taiyuan, China;⁴Department of Engineering Physics, Tsinghua University, Beijing, China

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Neutron spectrum measurements and personal dose evaluations inside the reactor is of great significance for guiding the radiation protection of staff, and also provides source-term data for conducting neutron activation analysis within the reactor. At present, rem meters are commonly used for dose assessment inside reactors, but the results are strongly affected by the spectral shape and thus carry large uncertainties. Multi-sphere neutron spectrometers can derive neutron dose from the measured spectrum and give more reliable dosimetry result; however, the set comprises several moderating spheres, is rather bulky, and requires frequent sphere changes during measurement, making the procedure cumbersome.

The SP80 neutron spectrometer is a new-generation instrument whose geometry incorporates only a single neutron sphere. 80 active thermal-neutron detectors are embedded at different positions inside the sphere, arranged along 8 radial depths and 14 azimuthal directions. The spectrometer performs spectrum unfolding through 8 input channels, covering the range from thermal neutrons up to 19 MeV. The spectrometer has been tested with isotopic sources such as ²⁵²Cf: the deviation of integrated fluence rates from the reference value is within 5 %, and the angular response of integrated fluence rates does not exceed 2 %. Compared with multi-sphere systems, the spectrometer can acquire the neutron spectrum in a single exposure, the result can be monitored on-line. A neutron-direction reconstruction algorithm based on the maximum-likelihood method has also been developed, allowing directional information to be derived from detector counts.

Neutron measurements were performed at multiple locations inside the reactor with both the SP80 single-sphere spectrometer and a multi-sphere spectrometer. Neutron energy spectra were unfolded and the personal dose equivalent $H_{p,slab}(10,0^\circ)$ was determined based on the fluence-to-dose conversion coefficients provided in *ICRP Publication 74 (1996)*. Relative to the multi-sphere results, the single-sphere spectrometer yielded integrated fluence rates that was 16 %–38 % higher and personal dose rates that was 9 %–32 % higher; the mean energy agreed within one order of magnitude but were systematically lower. The discrepancies are ascribed to the single-sphere spectrometer being positioned only 30 cm above the floor, whereby ground-scattered neutrons made a significant contribution. Directional information was derived from the single-sphere neutron-spectrometer measurements; however, the neutron field inside the reactor is complex and not strictly unidirectional, so the result represents an averaged neutron incidence direction and can serve as a basis for more accurate subsequent personal-dose assessment.

Keywords: neutron spectrometry; neutron dosimetry; single-sphere neutron spectrometer

Session 8. Olkiluoto 3 – Unplanned exposure to high dose rate during crane load testing

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We had at OL3 in the summer of 2024 event where workers were exposed to high dose rate. Exposure was unplanned since in the work it was planned to use dummy fuel assembly. FA dummy to be used was assigned by the fuel work coordinator. However, after related misunderstandings, confusion with instructions and lack of technical and administrative barriers another dummy was used than originally assigned. This dummy had irradiated control rod inside of it which caused the exposure when the dummy FA with the RCCA was lifted from the pool. Electronic dosimeters warned the workers about high dose rate and after that the load was lowered back to the pool. Consequences were that the highest dose received for an individual was 0.04 mSv and collective dose 0.07 manmSv, so the actual doses were well under reportable limits. ***However, the potential doses for four contractor individuals were high.***

I believe this is a good example of unplanned exposure event where the related root causes etc. are good to present for a wider audience so that others can prevent similar events.

Session 8. Estimation of the radiation doses to workers caused by the rupture of a slightly cooled fuel in the open reactor core

Pasi Karvonen
Loviisa NPP

Loviisa NPP operates two VVER-440 units with spent fuel stored in pools located in the spent fuel storage facility adjacent to the auxiliary building of unit 2.

In 2025, two operational events involving spent fuel assemblies occurred. The first incident took place in January in the spent fuel storage pool, where a fuel assembly used as an extension for a control rod was accidentally dropped due to an unsuccessful disconnection from the gripper. The second event occurred during the annual outage in the reactor building, when a fuel absorber slipped from the gripper and fell onto the top of fuel assemblies in the loading pool. Fortunately, neither event resulted in fuel rupture nor posed any radiological hazard to personnel or the environment.

However, the internal investigation of the latter event concluded that, in the worst-case scenario, the fuel absorber could have fallen directly into the open reactor core. Given the approximate 10-meter maximum fall distance, the possibility of fuel rupture at the reactor core could not be entirely ruled out.

This prompted further consideration of the potential radiological consequences for plant personnel were such an event to occur in the future.

In this presentation, the results of a preliminary dose assessment to personnel addressing a hypothetical event involving a fuel rupture at the open reactor core are introduced, and radiation safety aspects of such a scenario are discussed. As further analyses to obtain more accurate and less conservative insight of the issue are still underway, this presentation is based on simplified assumptions and conservative modelling approaches used during the initial event investigation to characterize the potential severity of the scenario.

Session 8. Unexpected Skin Exposure at Decontamination Job

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During Loviisa nuclear power plant unit 1 outage worker got unexpected skin exposure from working in the decontamination center. The equivalent dose to the skin was estimated to be 82,7 mSv. The event led to changes in working arrangements for decontamination, and personnel contamination monitor usage. Radiation protection organization also developed better guidelines on how to function in case of contamination on skin and acquired better equipment for removing and capturing hot particles from skin and hair.

The events started in the decontamination center where worker was decontaminating reactor cavity cleaning equipment. Decontamination job was done in a open pressure washing pool with a pressure washer. At some point worker got contamination to the hood of his protective overall. Contamination moved to the workers head when undressing from the protective overalls. At the main shoe boundary contamination was detected based on a medium alarm from personnel contamination monitor, and the actions for removing the contamination begun. During the measurements, contamination was recognized to be a small discreet radioactive particle or so called "hot particle". Capturing the particle was difficult so the RP instructed the worker to take a shower. Before showering, RP conducted dose rate measurements from the active particle situated in the person's hair/top of the head at different distances. After two sets of showering the radioactive particle was not detected anymore via handheld contamination metering devices. Personnel contamination monitor measurements were also clean after showering. The showering area was screened with handheld contamination meters but the particle could not been found and thus was not recovered for further investigations.

Skin exposure was calculated with Varskin 4.0 software and the equivalent dose to the skin was estimated to be 82.7 mSv. This accounts for 16.5% of the annual skin dose limit of 500 mSv. Var-skin calculations were based on the estimations of the radioactive particle activity, exposure time and distance from skin. Estimated total activity for the radioactive particle was 207 kBq determined with Microshield software. Nuclide distribution for the Microshield calculations were acquired from the initial smear samples from the reactor cavity. Most dominant nuclides were Nb-95, Cr-51 and Zr-95 covering up to 72 % of the total activity.

The event was classified as a radiation safety deviation by the Radiation and Nuclear Safety Authority of Finland. In Loviisa NPP the event was processed as Operating Experience investigation. Based on the investigation OE report was composed.

As a result of the event and investigation, following corrective actions were made:

- better decontamination instructions concerning decontaminating the reactor cavity cleaning equipment
- identified the process systems and jobs with elevated risk of contamination with radioactive particles
- at exiting the RCA personnel contamination monitor measurements will be carried out bareheaded after working in full PPE or without a helmet
- made better guidelines for radiation protection technicians on how to operate in case of skin contamination (hot particle)
- acquired better equipment for removing and capturing a distinct radioactive particle

This paper deals with the background leading to the unexpected skin contamination, how the situation was handled and what was the aftermath.

Session 8. Overview of evolution of contamination management at Loviisa NPP – evolution of trends and actions taken to reduce contamination events

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RTM860TS personnel contamination monitors that could collect and store measurement data were installed to Loviisa NPP in 2005. This made it possible to start gathering statistics and setting goals for continuous improvement of personnel contamination control. Statistics have also helped in identifying work packages and -sites with the most contamination events so appropriate actions could be made to reduce contamination events.

Over the years few upgrades have been made to the monitors, including radon compensation and installing of small item boxes to reduce "unnecessary" contamination events. Certain plant modifications to reduce contamination in the primary circuit are also visible in the statistics.

The presentation explains and visualizes the effects of different modifications and actions to the personnel contamination statistics.

Poster 1. Investigation of field calibration method for krypton-85 noble gas monitors

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Fourth-generation reactors, represented by molten salt reactors, produce large amounts of radioactive materials during operation, including fission products and actinide elements. Among these, gaseous radionuclides account for more than 43% of the total radioactivity, mainly including fission products of volatile metals, noble gases, and iodine isotopes. Relevant laws and regulations require that the levels of effluents from nuclear facilities should be monitored and reported regularly. ⁸⁵Kr and ¹³³Xe are the main radioactive noble gas nuclides. Radioactive noble gas monitors are bulky, difficult to disassemble, and continuous operation. Absolute measurement method and standard are complex, unsuited for on-site calibration.

In order to solve the problems of on-site calibration and improve the value transfer system for noble gas, China Institute for Radiation Protection (CIRP) has been established on-site calibration device for noble gas monitors. The on-site noble gas activity concentration standard device was based on gas diffusion theory. The main standard instrument was krypton-85 noble gas, tracing from National Physical Laboratory(NPL). A series of ampoules of different volumes were used for preparing the activity concentration of noble gas. Temperature, pressure, decay, volume and the other factors were considered in evaluation of uncertainty. In order to evaluate the stability and reliability of the device, some on-site experiments and comparisons were finished. The device can provide krypton-85 activity concentration between $1.0 \times 10^5 \text{ Bq} \cdot \text{m}^{-3}$ and $1.0 \times 10^{10} \text{ Bq} \cdot \text{m}^{-3}$, the relative extend uncertainty of 6.8%-9.0% ($k=2$). The activity concentration of main standard instrument is $3.38 \times 10^{10} \text{ Bq} \cdot \text{m}^{-3}$, and the standard uncertainty is 2.22%. The comparison error is less than 3% between HPGe measurement method and gas diffusion method. Besides, the device meets the requirements of JJF 1979-2022 calibration specification for radioactive noble gas monitors. The experiments for NGM series manufactured by Mirion Tech. Inc instruments represent that the activity concentration response nonlinear is less than 9.7% between $1.0 \times 10^8 \text{ Bq} \cdot \text{m}^{-3}$ and $1.0 \times 10^{10} \text{ Bq} \cdot \text{m}^{-3}$. The calibration factor is between 0.73 and 1.42. The on-site calibration device is an important supplement for noble gas value transfer system in China.

In the future, the device will be further modified to expand the range of activity concentration and to reduce the relative extend uncertainty.

Key words: Krypton 85; noble gas monitor; on-site calibration; value transfer

Poster 2. Research on the On-line Monitoring System for Tritium in Gaseous Effluents from Nuclear Facilities

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In recent years, tritium, as a key radionuclide of concern in the source term of gaseous effluent discharge, has attracted increasing attention in the field of radiation monitoring and protection at nuclear facilities. At present, the measurement methods for tritium in gaseous effluents from nuclear facilities mainly include two categories: offline sampling measurement and on-site online measurement. Although the method of offline sampling combined with laboratory measurement has high accuracy, it is relatively complex to operate and has obvious hysteresis, failing to capture transient emissions or early accident signals. This study aims to establish a tritium online monitoring system based on high-sensitivity detectors and high-efficiency pretreatment modules, so as to achieve the technical goal of on-line, stable and efficient measurement of low-concentration tritium in gaseous effluents from nuclear facilities.

Developing an automated pretreatment unit based on Nafion membrane separation and high-efficiency precious metal catalytic oxidation, so as to achieve efficient separation and conversion of HTO and HT. And developing a backend measurement system based on the flow gas proportional counter to achieve efficient and rapid measurement of HTO samples. A tritium on-line monitoring system is developed through systematic integration, with its performance test and optimization completed. This system features a rational layout, stable operation, as well as excellent reliability and applicability, and is capable of achieving minute-level data updates. Under specific experimental conditions, the separation efficiency of the separation module and the conversion efficiency of the catalytic oxidation module of this system both exceed 90%, and its tritium detection limit is below the magnitude of 10^3Bq/m^3 .

The development of an on-line tritium monitoring system for gaseous effluents from nuclear facilities helps address the technical challenge of on-line, stable and efficient measurement of low-concentration tritium in gaseous effluents, and overcome the limitations of traditional offline sampling and measurement methods in terms of timeliness and adaptability. Meanwhile, it fulfills the demand for on-line monitoring of low-concentration tritium emissions from nuclear facilities, providing certain technical support and guarantee for tritium monitoring and accident emergency response of nuclear facilities.

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Poster 3. Correlation Analysis Methodology for Radiation Dose Assessment in Biological Species under Specific Environmental Conditions

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The assessment of biological radiation dose relies on the specific concentrations and distribution patterns of radionuclides within both the environment and organisms. Environmental conditions, biological species, and radionuclide types collectively influence the deposition, transfer, and accumulation of radioactive substances. This study, focused on a specific Gobi Desert ecosystem, involved a comprehensive survey within an 80-km diameter area to document animal and plant species, their distribution, and population densities. Based on this inventory, representative organisms were selected for analysis. Animal samples (including Ruddy Shelduck, dragonflies, free-ranging small fish, and grazing sheep) were collected from various tissues (bone, muscle, internal organs). Plant samples (common grass, reeds) and three environmental media (soil, water, sediment) were also collected.

The Spearman's rank correlation method was employed to analyze the correlative relationships between the average concentrations of radionuclides (e.g., ^{60}Co , ^{137}Cs) in different tissues and organs of resident organisms, which had reached an approximate equilibrium with the long-term contaminated environment. Analyses were conducted under five distinct scenarios: 1) all media and organisms contaminated, 2) soil only, 3) water only, 4) sediment only, and 5) inter-species relationships only (excluding environmental media).

Establishing these correlations helps to clarify the pathways of radionuclide impact on the ecosystem. The application of Spearman's method allows for extrapolation to similar organisms with strong correlations based on limited sampling and measurement data. The results provide a crucial technical reference for estimating radiation doses to biota in data-sparse environments. In this specific Gobi study, the results of the biological correlation analysis, ranked in descending order of correlation strength, are presented in Table 1.

Table 1. Spearman's Rank Correlation Analysis Results between Organisms and Media in a Specific Environment (Ordered by Priority)

Sample & Corresponding No.	Soil	Water	Sediment
1 (Shelduck Muscle)	5, 7, 2, 3	5, 6	5, 7, 2
2 (Shelduck Bone)	1, 3, 5, 7	1, 3	1, 3, 5, 7
3 (Shelduck Viscera)	6, 1	6, 1	1
4 (Dragonfly)	1, 9	1, 9, 8	1, 9, 8, 12
5 (Dragonfly Larvae)	7, 1, 2	1, 7	7, 1, 2
6 (Free-ranging fish)	3, 1	3, 1	3, 1
7 (Common grass)	5, 1, 2	1, 5	4, 6, 1, 2
8 (Reed)	9, 4	9, 4, 2	9, 12, 4, 2
9 (Grazing sheep)	8, 4	8, 4, 2	8, 12, 4
10 (Soil)	None (Self)	—	—
11 (Water)	—	None (Self)	1
12 (Sediment)	—	9, 8, 4, 2	None (Self)

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Poster 4. Case Studies on Robot-based Radiation Mapping Solutions for Radiation Protection

Erika Suzuki (Gamma Reality Inc.), Utility Partner (to be confirmed)

As the nuclear industry evolves to support both the existing commercial fleet and the deployment of next-generation advanced reactors, there is a growing need for innovative tools that enhance radiation protection, operational efficiency, and worker safety. This presentation explores the integration of multiple advanced technologies—spanning 3D radiation mapping, data fusion, robotic platforms, and decontamination solutions—to address the complex challenges of radiation survey and control during operations and decommissioning.

The combined deployment of multiple technologies enables a holistic approach to radiation protection that maximizes the benefits that these technologies can provide. Together, they deliver measurable benefits including significant dose reduction, improved personnel safety, increased efficiency of routine and emergent operations, enhanced data quality for decision-making, and reduced time spent in radiological areas. These integrated solutions are helping to modernize radiation protection practices across the nuclear sector, driving both near-term performance gains and long-term sustainability for current and future reactors.

This presentation will feature case studies and lessons learned from deploying robotic radiation mapping technologies at an operating nuclear power plant. Drawing from real-world deployments, it will highlight how mobile, robot-mounted sensing systems have been used to perform radiological surveys in areas that are difficult, time-consuming, or higher dose for personnel to access. The discussion will address practical considerations such as deployment workflows, data interpretation, integration with existing radiation protection programs, and human-machine teaming. These experiences illustrate both the immediate benefits—such as dose reduction, improved efficiency, and enhanced situational awareness—and the broader lessons that can inform future adoption of robotic radiation mapping across the current nuclear fleet and emerging advanced reactor designs.

Poster 5. Mirion Connected Electronic Dosimetry & Vision 2030

Laurent Marco & Henri Michel
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Over the past years, the nuclear industry has improved dramatically the safety and security of workers. The current situation supporting a growing interest in nuclear energy as a cleaner alternative to traditional fossil fuels restarts the reactors innovation and the entire industry capacity. Many countries are exploring and investing in next-generation nuclear technologies, such as small modular reactors (SMRs), new facilities and advanced reactor designs. This development is associated with a renewal of health physics, especially new capacities of connectivity, automatization, and communication. These digitalization process will lead to a full integration and optimization approach, in order to extend the current level of safety and security, either production gain.

From last 25 years, Mirion Technologies supported the reduction of the radiation exposures and enhanced the security by implementing different innovation in the radiation protection as remote monitoring, enhanced DMC capacities (alarms, DMC features, etc..). Nowadays, a new strategical approach is performed by introducing the connectivity & integration into the DMC. The presentation will introduce the new Connected Mirion Electronic Dosimetry solution, values propositions associated, benefits and advantages with use cases application. In addition, we will illustrate some recent developments regarding product integration, data management, and data analysis with our dose management solution. Finally, we will propose the Mirion vision for electronic dosimetry following industry evolution.

Keywords

Electronic connected Dosimetry Solution

Poster 6. Mirion Telemetry Ecosystem & Vision 2030

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Over the past years, the nuclear industry has improved dramatically the safety and security of workers. The current situation supporting a growing interest in nuclear energy as a cleaner alternative to traditional fossil fuels restarts the reactors innovation and the entire industry capacity. Many countries are exploring and investing in next-generation nuclear technologies, such as small modular reactors (SMRs), new facilities and advanced reactor designs. This development is associated with a renewal of health physics, especially new capacities of connectivity, automatization, and communication. These digitalization process will lead to a full integration and optimization approach, in order to expand the current level of safety and security, production gains.

From last 25 years, Mirion Technologies supported the reduction of the radiation exposures and enhanced the security by implementing different innovation in the telemetry as remote monitoring, enhanced connectivity integration. Nowadays, a new strategical approach is performed by introducing connectivity into the telemetry network. The presentation will introduce the new Telemetry Mirion solution, values propositions associated, benefits and advantages with use cases application. In addition, we will illustrate some recent developments regarding our Orion RTLS Real Time Location Solution, data management and data analysis with the new Vital platform and the supervisory application - SV1. Finally, we will propose the Mirion vision for telemetry & monitoring following industry evolution.

Keywords

telemetry solution, monitoring & dosimetry solution

Poster 7. Monitoring the Amount of Nuclide-Specific Activities on Primary Circuit Surfaces of Nuclear Power Plants – The Finnish Regulator’s View on Key Considerations

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This presentation explains the reasons why nuclear power plants should monitor nuclide specific activity levels on primary circuit surfaces. The international requirements related to these measurements will be summarized, followed by an overview of the requirements in current Finnish legislation. Future challenges associated with possible new reactor types will also be discussed.

According to the requirements issued by STUK, the nuclear facility shall have an As Low As Reasonably Achievable (ALARA) action programme to keep the occupational doses low. The programme shall include both short-term and long-term plans and measures to limit the doses of occupationally exposed workers. The accumulation of radioactive material on the primary circuit systems has a major impact on the radiation levels inside the power plant. The action programme shall therefore take into account for example the source term and the chemistry conditions that mitigate corrosion.

Furthermore, STUK’s requirements state that the generation and spreading of radioactive substances at a nuclear facility shall be limited in accordance with the optimisation principle of radiation protection. Corrosion, activation, and the migration of substances that significantly affect occupational exposure shall be kept low by selecting suitable materials and structures, and by using appropriate surface treatments, chemical conditions, and purification systems.

STUK’s requirements also state that the amount of surface activity on primary circuit surfaces shall be monitored on a nuclide specific basis. Fixed contamination and activated corrosion products on these surfaces can significantly increase local gamma dose rates, particularly during maintenance and outage periods, when the majority of occupational radiation exposure typically occurs.

Monitoring nuclide specific activities in the primary circuits of nuclear power plants is a key component of ALARA programmes and other measures aimed at minimising occupational doses. Once the dominant nuclides present on these surfaces are identified, their source terms can be determined and appropriate corrective actions taken. Regular measurements provide timely information on the condition of the primary circuit and on evolving radiation levels, enabling early initiation of necessary mitigation measures. Nuclide-specific information is also valuable, if the nuclear plant is considering system decontamination measures.

Key words: nuclide-specific activities, primary circuit, ALARA program, regulatory requirements

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