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EDITORIAL

From a radiological point of view, the installations at the Nuclear European Research Centre (CERN) presents some specificities: size of the installations, number of components, radiation, time frame etc. If you would like to know more about the radiation protection challenges associated with accelerators and the practical management implemented by the Radiation Protection Group of CERN, go directly to **p. 2**.

Starting **p. 7** the Chair of the EAN provides a historic and combined view about the optimization principle based on recent publications (NEA, IRPA, …) and considers some difficult questions such as 'what is reasonableness?' 'what is ALARA culture?' and presents some of the (side) benefits of the application of the optimization principle.

Regulation is in place for the management of radon in public buildings and at the workplace (Psst: the EAN working group ALARA for radon at the workplace A-RAW has just concluded its work, check **p. 21**). Yet radon in domestic dwellings also requires attention. The French Institute for Nuclear Safety and Radiation Protection, and CEPN has produced an inventory of the territorial approaches engaged for the management of radon in homes to identify the challenges, the elements of success and draw several perspectives. More than 30 territories and approaches have been surveyed (**p. 12**).

There are several indications that the application of the ALARA principle could be improved in the fields of interventional radiology and in nuclear medicine (new radiopharmaceuticals). These elements are outlined on **p. 17** - justifying the planning of the EAN workshop 20 on these very same topics in 2023.

Finally on **p. 21** you will have a glimpse of upcoming EAN events and international events.

We hope you will enjoy this Newsletter, which is made possible through EAN Members support and contribution.

The EAN Newsletter Editorial Board: Mr. Sylvain Andresz, Mrs. Julie Morgan, Mr. Fernand Vermeersch and Mr. Pascal Croüail

(*P.S. do not hesitate to send your comments to the Board, cf. contacts* **p. 22**).

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Occupational radiation protection in the operation of accelerators at CERN

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Introduction

The CERN accelerator complex comprises an infrastructure of about 50 km of total beam line expanse with over 160 physics experiments that are all classified as Radiation Areas. Beside the Large Hadron Collider with its four main experiments ATLAS, CMS, LHCb and ALICE, CERN operates several experimental halls for fixed target experiments, a radioactive ion beam facility (ISOLDE), an Antiproton Decelerator (AD) facility and a spallation neutron source (nTof). Furthermore, several auxiliary facilities, such as radioactive laboratories and workshops as well as a Radioactive Waste Treatment Centre and radioactive waste interim storage facility support the research infrastructure. A schematic overview of CERN's accelerator and experimental complex is shown in Fig. 1

The Radiation Protection Group

Radiation Protection Management

The Radiation Protection (RP) Group of the Occupational Health & Safety and Environmental Protection Unit (HSE) is responsible for Radiation Protection at CERN, i.e., the protection of persons from potentially harmful effects of ionizing radiation linked to CERN's installations and activities. It achieves its mission by assessing and monitoring radiation hazards, defining protective measures and by ensuring the dose surveillance of personnel and the environment. Moreover, as part of the HSE Unit, the RP Group reports directly to the CERN Director General and approves activities generating ionizing radiation in compliance with CERN's Radiation Protection rules. As an intergovernmental organization CERN is subject to international law and establishes its own RP rules and procedures taking into account the legislation of its host states, as well European and international standards.

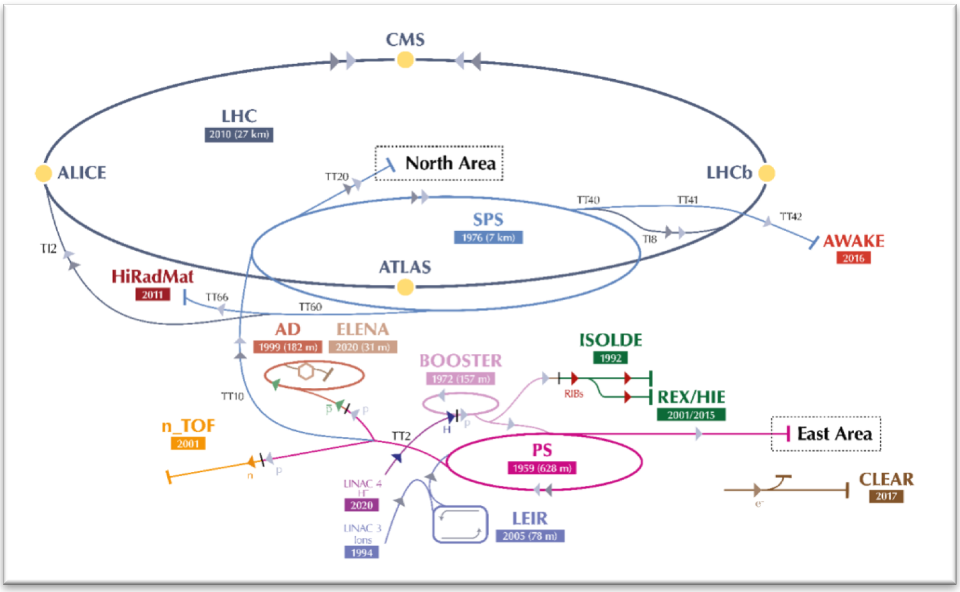

Figure 1: Schematic representation of CERN's accelerator and experimental complex.

Signed in 2010, the Tripartite Agreement on Radiation Protection and Radiation Safety between CERN and its host states, France and Switzerland, provides the current legal framework to discuss CERN wide radiation safety and radiation protection issues. This fully transparent and collaborative partnership implicates the host states authorities, ASN (France) and OFSP (Switzerland). It stipulates that the host state authorities review and agree to the methods used by the organization in the assessment of radiological risks to workers and the environment and homologate, among others, RP rules and documentation related to safety and protection against ionizing radiation of its installations. It is achieved through regular discussions and Joint Visits in which the authorities verify that CERN complies with host states, EU and international standards in matters of Radiation Protection and Radiation Safety.

Instrumentation

The personal dose monitoring of its over 10000 Radiation Workers is achieved by means of an electronic Direct Ion Storage (DIS) dosimeter for photon and beta radiation combined with a passive CR39 solid state nuclear track detector for neutron dose recording. The DIS dosimeters are read out monthly by their users via a network of 65 reader stations allowing for a timely follow-up of personal doses (see Fig. 2). The annual dose statistics demonstrate that radiological risks as CERN are generally very low with more than 90% of the annual individual doses being lower than 100 µSv. Moreover, over the past seven years no Radiation Worker received more than 2 mSv annual dose, reflecting the success of a formalized ALARA approach that has become integral part of the CERN safety culture. The CERN dosimetry service is accredited in Switzerland according to ISO 17025

Figure 2. Left panel: Electronic personal dosimeter DIS-1 with integrated neutron dosimeter. Right panel: Reader station.

Procedures

The optimization of practices involving ionizing radiation at CERN is formalized by rules and procedures for the entire life-cycle of a facility or experiment, from design, planning and operation to the final dismantling. So-called "ALARA Levels", based on estimated individual and collective doses, facilitate and standardize the optimization process by prescribing the optimization actions to be undertaken depending on the results of the radiological risk assessment. They range from activities with very low radiological risks that are a priori considered as optimized (Level 1), over those that require a formally approved work-and-dose-planning (Level 2) to activities where either the estimated individual dose exceeds 1 mSv or the estimated collective dose exceeds 5 person-mSv (Level 3). Planning of the latter activities requires a review by an ALARA Committee with final approval given by the CERN Director for Accelerators and Technology.

Upgrade of the internal beam dump of the Super Proton Synchrotron (SPS) accelerator

A recent example for optimizing the design of accelerator components is the upgrade of the internal beam dump of the Super Proton Synchrotron (SPS) accelerator during the last Long Shutdown 2 (LS2, 2019-2020). Figure 3 (left panels) shows the old unshielded beam dump and a contour plot of calculated residual dose rates that were typical for cool-down times of one week. Any work in its vicinity required extended accelerator stops for radioactive decay and had to be carefully planned due to dose rates in the order of several mSv/h. Moreover, cables passing by in the vicinity of the dump experienced radiation damage, despite a concrete wall placed in between cable trays and dump (see in Fig. 3 on top left picture). While the wall was providing some protection of the cables against radiation from the dump, it made any replacement of them very difficult and time consuming. Thus, during LS2 this dump was replaced by a fully shielded and optimized dump at a location of the SPS that provided sufficient space (see Fig. 3, panels on the right side). Residual dose rates are now lower by at least two orders of

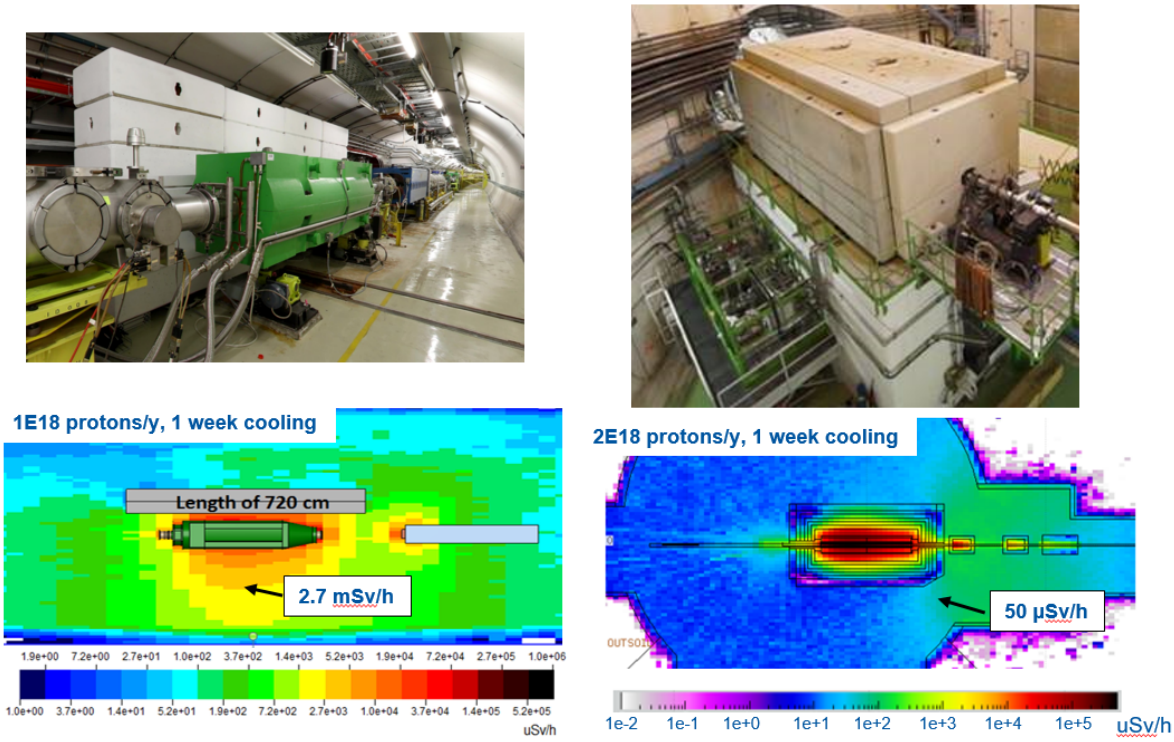

Figure 3: Beam dump of the SPS prior to its upgrade and residual dose rates after one week of cooling (left panels) and after its upgrade in LS2 (right panels).

magnitude allowing more efficient operation and lower doses to personnel.

The design of the new beam dump was supported by extensive Monte Carlo simulations of various radiological quantities (material activation, residual dose rates, activation of air and cooling water) with the FLUKA code [1,2] as shown, for example, by the contour plots in Fig. 3. Among others, the results of such simulations help in selecting construction materials with low activation properties that later reduces not only doses to personnel but also the costs for final radioactive waste disposal. In order to avoid time-consuming repetitive calculations for different materials the in-house developed code ActiWiz [3] is typically used for material optimization studies. It allows folding of calculated particle fluence spectra with inhouse pre-calculated nuclide yields as well as production cross sections from evaluated data libraries for any material and energy. Since decades, such detailed Monte Carlo simulations with the FLUKA code are integral part of the design and operation of any accelerator and experiment at CERN with significant radiological impact and, thus, FLUKA calculations are also one of the methods agreed by the CERN host state authorities.

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Radiation protection procedures and specificities of CERN

As mentioned earlier, any work of ALARA Levels 2 and 3 requires an optimized work-and-dose-planning. At CERN, it is fully integrated into the general web-based tool for safety risk assessments and co-activity planning (Intervention Management Planning and Coordination Tool, IMPACT), also allowing for electronic approval signatures by the Radiation Protection and Radiation Safety Officers. During works in areas where dose rates exceed 50 µSv/h (so-called Limited Stay and High Radiation Controlled Areas) the received dose is monitored, in addition, by means of an electronic operational dosimeter with alarm functions. The dosimeter has to be read out immediately after the work on the same day using one of the 65 reader stations from where the dose is transferred automatically into a database. Another web-based tool (OpeDosi) provides a user-friendly and timely comparison of estimated and received doses in order to immediately identify anomalies and stop the work for an inquiry in case of significant deviations from the planned doses. The success of the ALARA procedure was once again demonstrated during LS2, for example, by the fact that for none of the works classified as ALARA Level 3 neither the approved maximum individual nor the collective doses were exceeded and that all individual doses stayed within the CERN dose objective of 3 mSv received over 12 consecutive months.

The size of CERN's facilities (c.f., circumference of the LHC accelerator of 27 km) and its operational requirements pose also challenges to the radiological classification of activated components and to their classification for transport. For example, every year around 20000 activated components are measured by

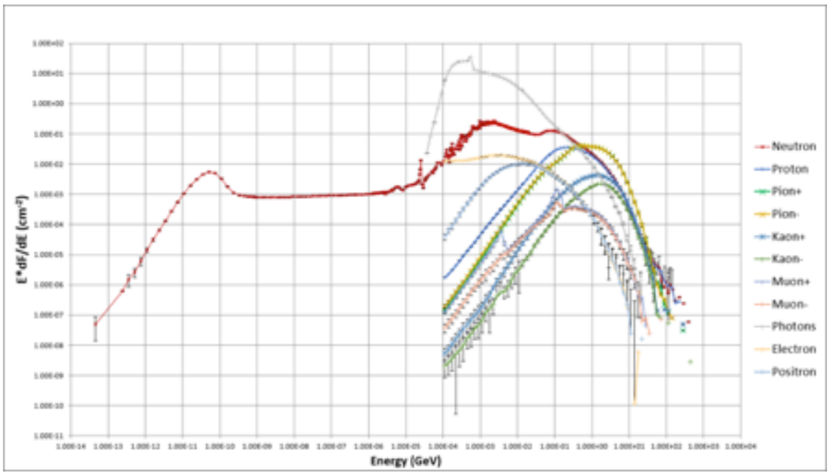

Figure 4: Example of particle fluence spectra encountered around CERN's high energy particle accelerators and experiments. The spectra of charged hadrons are cut at 100 keV by the particle transport threshold in the simulation.

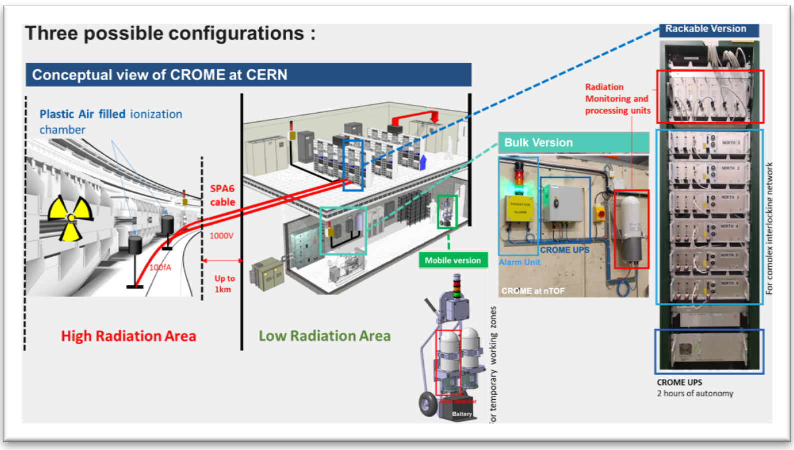

Figure 5: Overview of CROME configurations with conceptual views of the versions for high and low radiation areas and well as pictures of detectors and racks installed around CERN's accelerators and experiments.

RP technicians and about 1000 radioactive transports are performed. The huge number of components as well as their variety in material types, sizes and shapes, along with short-delay times as needed by an efficient facility operation, make detailed individual radiological characterization analyses often impossible. Thus, procedures were developed that allow conservative classifications via dose rate measurements. The approach is based on extensive studies with FLUKA and ActiWiz that define, for example, under which conditions an object can be classified as non-radioactive by means of a dose rate measurement with a BGO detector. Similarly, radioactive transports can be classified according to the United Nation's "*Accord relatif au transport international des marchandises Dangereuses par Route*" (ADR) by dose rate measurements. Here, in addition, the entire process from transport request, over classification, packaging, issuing related documents, controls and reception are automatized and integrated into web-based tools for traceability of radioactive items (TREC) and business processes for requesting, classifying and approving transports (EDH).

While many CERN accelerators are located underground (e.g., the LHC at about 100 m below ground) and personnel protection of surface facilities and experiments is often based on passive means (i.e., shielding), the online monitoring of prompt radiation is still a legal requirement to prove the efficiency of the protection measures. Therefore, the CERN RP Group operates a radiation monitoring system that has to cover mixed particle fields (protons, neutrons, pions, photons, etc.) with energies over 16 orders of magnitude (from thermal energies to TeV) and pulsed time structures from nano-seconds to seconds. Figure 4 shows an example of particle energy spectra around CERN's high energy particle accelerators and experiments.

In order to meet these challenges with state-of-the-art technology an in-house development of a new generation of radiation monitoring electronics (CERN Radiation Monitoring Electronics, CROME) is gradually replacing all currently used systems that date back to more than 20 years ago. It exists in three configurations, two of them for fix-installed monitors in either high radiation areas with electronics deported to shielded areas (rack version) or low radiation areas with the measurement electronics directly attached to the detector itself (bulk version). The third version is designed for mobile measurement stations on trolleys often used for punctual dose verifications during facility commissioning. Figure 5 shows an overview of the different CROME versions.

Conclusion

As outlined in this article, research and development of innovative solutions are vital to an efficient occupational radiation protection in the operation of high-energy particle accelerators. It includes both the development of powerful multi-purpose Monte Carlo codes for radiological studies (e.g., FLUKA) as well as of analytical tools for fast and comprehensive assessments (e.g., ActiWiz). Processes and procedures have to be automatized as much as possible using web-based tools, distributed dose readout systems as well as dose analysis and statistics tools. Fast dose rate measurements with hand-held instruments supported by comprehensive studies can provide a very efficient and sufficiently accurate characterization of activation for material classification and transport.

At the same time, a modern and efficient ALARA approach would not be possible without having established a related safety culture with support of the ALARA concept by everyone involved, including all hierarchical levels. Moreover, the design of high-energy physics accelerators typically extends over several decades during which radiation protection legislation evolves. Thus, design studies have to anticipate changes in legislation in order to avoid expensive retrofitting of the installations. At CERN, this was considered, for example, during the design of the LHC by using the most restrictive nuclide-specific activation limits recommended by international bodies at the time (e.g., IAEA, European Commission). Decades later, when the LHC had started operating, many of these limits have entered national laws.

Aspects of radioactive waste minimization and elimination have become increasingly important for an efficient operation of high-energy accelerators and experiments, not only due to its significant cost impact but also due to increasing awareness within society and its importance in the public acceptance of large-scale accelerator projects. CERN is pioneering also in this field but further discussions are not within the scope of this article. ■

Optimization of protection, the Cornerstone of Radiation Protection

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Introduction

In this paper, an overview of the application of the optimization principle in radiation protection and in safety and well-being as a whole is provided. It illustrates how the optimization principle, including the concept of reasonability, is almost de-facto is embedded in the holistic all-hazard approach in prevention and protection for the worker, the public and the patient involving a multi-disciplinary approach.

To begin with, it is important to remind on the benefits and the risks of the application of ionizing radiation. The discovery of X-rays by Wilhelm Röntgen at the end of 1895 and radioactivity a year later by Becquerel opened new opportunities for scientific research, technical and medical applications of ionizing radiation. The discovery opened opportunities to further explore and understand the structure and nature of matter, improve materials, generate energy, diagnose, understand and treat diseases.

The usefulness of ionizing radiation has also a downside as the deleterious effects of ionizing radiation became rapidly apparent under the form of deterministic and stochastic health effects.

It became clear, already in the early days of exploring the use of ionizing radiation that there was a need to manage the risks associated with it, to ensure the benefit from its use.

Basic principles of radiation protection

ICRP took on the task in 1928 to developed recommendations on the subject. These evolved over the years based on the expanding scientific knowledge and gathered knowledge on the health effects by other organizations. The recommendations resulted in the 3 basic principles of radiation protection, recalled in ICRP publication 103 (2007) [1], formulated on the basis of the linear non-threshold dose-effect relationship model. These recommendations are the foundations of the basic safety standard (Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards IAEA GSR part 3), adapted and translated worldwide into national regulations.

The principles of radiation protection are:

- Justification: show that there is more benefit than harm in using the ionizing radiation
- Optimization: aim to keep doses as low as reasonably achievable taking into account economical and societal factors
- Dose limits: keep stochastic effects tolerable and avoid deterministic effects.

Optimization

Respecting the dose limits assures that the probability of stochastic effects occurring is deemed to be tolerable. The optimization process strives to further reduce the risk to an acceptable level given the economic and societal factors, or as we further will develop, taking into account the prevailing circumstances.

The wording to address optimization has evolved over the years, as represented in the table below. We see an evolution from "reduce to the lowest possible level" to "as low as reasonably achievable economic and societal factors being taken into account". Today, ALARA and "optimization principle" are synonymous [2].

The optimization process, is a decision-aiding tool, and aims to arrive at an acceptable level of exposure that takes into account the elements defining the prevailing circumstances. Based on the description given in ICRP 101b (2006) [3] and ICRP 103 (2007) [1], the following can be identified:

- Exposure situation: Planned, Existing and Emergency
- Economic factors: Value for money of the protection means, or the efficiency of the radiation protection measures
- Societal factors: Value for society, the use of resources, based on good governance, optimal use of societal resources
- Other risks: Industrial risk, well being
- Technical elements: Conditions, preconditions that influence the implementation of the radiation protection measures
- Processes and procedures: The RP measures can be influence by the specific processes and procedures
- Judgements: dialogue and involvement with the stakeholders.

The question that can be immediately raised is: what is a reasonable; acceptable level of risk, how safe is safe enough?
Before exploring this further it is important that the optimization or the ALARA process is performed in a structured way in a deliberative process. A methodology for the ALARA process is given in the European ALARA practical guidebook [2] further developing the ALARA process presented in "ALARA- from theory towards practice" [4]. The process is a methodology for evaluating and selecting radiation protection actions in order to reduce the magnitude of the individual exposure, the number of people exposed and the likelihood of potential exposure of the workers, public and patients to a level as low as reasonably achievable.
The different steps, the all hazard approach and the attention to the involvement of the different stakeholders support a comprehensive deliberative process (Figure 1).

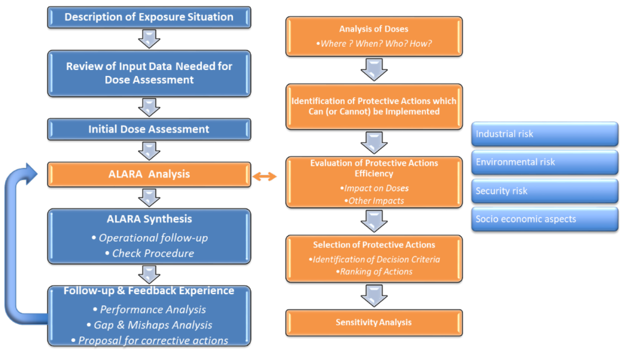

Figure 1. Steps in the ALARA process.

The process starts with the definition of the problem leading up to a first dose evaluation before optimization. This is followed by a detailed analysis to identify protective actions to further reduce collective and individual dose.
In the process we clearly identify the factors that influence the final selection of radiation protection actions and evaluate them with regard to their impact.

The structured process enables the evaluation of the effectiveness of the radiation protection measures and the key factors that determine the decision. Using this structured way makes the process transparent for the different key users and stakeholders. The process can benefit from the use of Cost Benefit Analysis to evaluate the value for money aspects (cost efficiency) and/or can use other quantitative techniques such as multi-attribute utility analysis that can accommodate value for society (good governance optimal use of societal resources, ethics).

ALARA Culture

It is important to understand that the optimization process can only be fully successful when this is embedded in safety culture of which radiation safety culture and ALARA culture are a subset. The following elements can be identified as the components of a good safety culture:

- Engaging with all parties involved in the activity
- Implementing appropriate education and training
- Maintaining an environment supporting a questioning attitude, openness and challenge
- Learning and sharing from experience
- Strong commitment from the leadership
- Integration of the above commitments into a clear management system

Elements of the ALARA culture are clearly attitude and behaviour, risk awareness and the involvement of stakeholders.
To illustrate, on the left of Figure 2, an example of the stakeholders involved in a planned exposure situation is sketched and on the right, the graphic extends to a broader set of stakeholders identified by the EAN working group on ALARA culture [5], each having their specific contribution to the practical implementation of optimization.

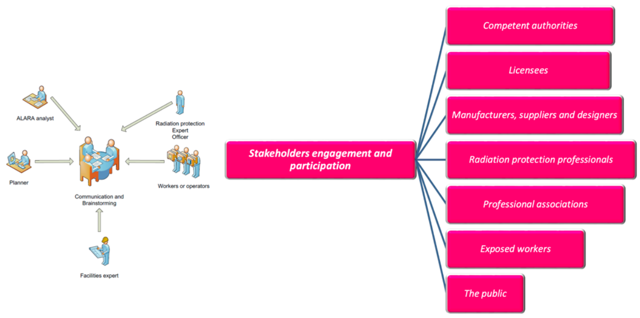

Figure 2. Stakeholders

An important element in establishing safety culture and in engaging in effective deliberative process is education and training. A good understanding of the risk and risk awareness is necessary, understanding the science where it is based on and understanding the risk perception by all the stakeholders.
Dialogue is essential in the process and must also be based on the clear representation of the elements used to arrive at the selected protection measures to achieve the acceptable risk level and determine the residual risk.

Reasonableness

The question remains on what is reasonable (acceptable) and has been explored by ICRP in its publication 138(2018) [6] on the ethical basis of the radiation protection system. This has led to defining the pursuit of reasonableness as "the permanent quest depending on the prevailing circumstances in order to act on knowledge and experience, to do more good than harm (beneficence/non-maleficence), to avoid unnecessary exposure (prudence), to seek fair distribution of exposure (justice), and to treat people with respect (dignity)". The question of reasonableness was also further explored by IRPA [7] an NEA/CRPPH [8].
IRPA came to principal factors that underpin, contribute to the aspect of reasonableness in the decision they identify the following elements

- Judgement call: *Understand that it is a judgement call, situation based on the prevailing circumstances*
- Proportionality: *Efforts allocated to optimization must be in proportion with the risk (graded approach)*
- Stakeholder engagement: *Involved in judging, giving judgements on reasonableness, based on the shared understanding of the risk*
- Holistic approach: *Taking into account all relevant hazards (not focusing on RP alone)*
- Avoid over conservatism: *Realistic assessments of risks and benefits*
- Optimal use of societal resources: *Good governance to optimal use of societal resources*
- Radiation safety culture: *Embed optimization in safety culture*
- Auditability: Transparency on the decision and de elements that led to the implemented optimisation

NEA/CRPPH came to a conclusion that is broadly in line with the current recommendation in ICRP 103(2007), but emphasis on the multidisciplinary, multi-dimensional nature of the complex circumstances to consider. The radiological risk is considered as a part of the overall risk vector.
The elements identified by IRPA [7] are intrinsically embedded in the ALARA process developed earlier in the presentation based on the process described in the practical guidebook [2]. The "art" of ALARA remains in applying this and reach a situation-based

judgement call, taking into account the knowledge of the risks and the prevailing circumstances. The structured approach makes clear how the different elements are considered to arrive at the acceptable level making the process auditable for all the stakeholders and makes them aware of the decision drivers.

Benefits of the optimisation principle

What are and what were the benefits of introducing and using the optimisation approach?
In fact, the optimisation approach can be seen as a reference framework, a state of mind and attitude:

- Allowing an individual and/or an organization to act in a responsible way in order to manage risks and giving safety the priority it should have
- Be inclusive of exposed individuals and stakeholders views and experience
- Characterized by risk awareness, balanced judgement of risk and benefits, and the capability to develop and use required skills and tools for risk assessment and management
- Realized through transdisciplinary education and training tailored at each level
- Supported by management commitment and management system
- Support feedback from the field and continuous improvement

Did the implementation of optimization lead to a reduction of exposure to ionising radiation of the worker, the public and the patients?

We can get an idea by analysing the feedback by different organizations that report on occupational exposure and/or optimisation such as UNSCEAR, ISOE, EAN, ISEMIR, EMAN, EFOMP …. When focusing on the three-year rolling average collective dose per reactor for all operating reactors included in ISOE by reactor type from 1992-2018 [9]; it can be seen that on average for all types of reactors (except the PHWR) the collective dose shows a downward trend, and, together with the reports and presentations on the [9], we see that there is a link with the optimisation process in the management of doses in these reactors.
Also the UNSCEAR reports that “the average annual effective dose for exposed workers decreased in the period 2000-2014” [10].

Similar influence of the introduction of the ALARA process in a research centre is illustrated in Figure 3 of the collective dose as a function of time. A clear downward trend is visible. The optimisation at this research centre is supported by an ALARA process and an ALARA committee that analyses past experiences and evaluates new operations.

In the medical field we see a further growing awareness and effort towards optimization for exposed workers and for patients. As an example, the Nuclear Safety Authority FANC in Belgium concludes after analyzing the dose results that

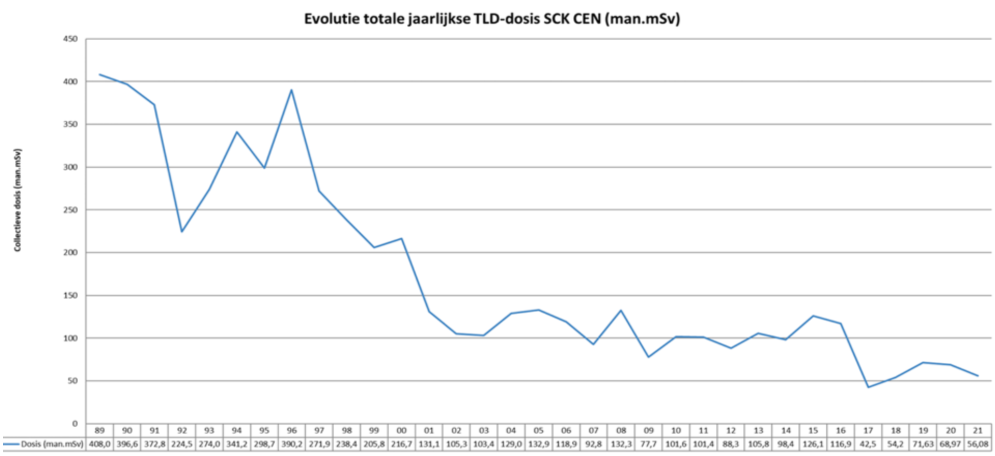

Figure 3. Evolution of the collective dose as function of time (1989-2021) in SCK CEN research centre, Belgium

although there is an increase in medical imagery there is a reduction of dose to the patients.

Exposures of workers in conventional radiology, both radio diagnostics and radiotherapy, are generally well controlled. There are, however areas of medical practice where we see an increase of interventional techniques, in which very high exposures are incurred. Ensuring that sufficient attention is paid to the control and reduction of such exposures requires continued efforts in post-graduate education and in awareness raising of the medical professionals involved. The participation of medical physicists in the implementation of optimization programmes in interventional radiology is strongly recommended

Conclusion

Do we benefit by using the optimisation approach for the management of occupational exposures?
We can answer this positively when we look at individual and collective occupational dose reductions achieved in the different fields involving the use of ionising radiation. The optimisation approach promotes a forward looking risk-aware attitude that supports safety and safety culture as a whole, the use of structured approach provides transparency to the stakeholders on the implemented protection measures and the acceptable risk level. The optimisation approach promotes a balanced judgement on the risks and the benefits allowing an optimal us of the resources. Optimisation is a cornerstone of protection and radiation protection. ■

This article is based on the presentation given at the Section on optimization in radiation protection of the International Conference on Occupational Radiation Protection: Strengthening Radiation Protection of Workers – Twenty Years of Progress and the Way Forward held from 5 to 9 September 2022, at Geneva, Switzerland.
The presentation is available on the EAN website: https://www.eu-alara.net/images/stories/EANdocuments/Presentations/1_vermeersch_rt4.pdf

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INVENTORY OF TERRITORIAL APPROACHES FOR THE MANAGEMENT OF RADON IN FRANCE'S HOMES
Difficulties, successes and ways forward

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Introduction

Radon gas is recognized as a carcinogen and the second cause of lung cancer after smoking [1], which motivates the need for specific attention in the context of houses[1]. For one decade, the French Institute of Radiation Protection and Nuclear Safety (IRSN) has been co-piloting two local approaches involving multiple partners dedicated to radon management at home. But despite positive feedbacks from these partnerships, the difficulty for residents to go beyond the measurement steps, namely, the diagnosis of the building (detecting how radon penetrates and transfers into the building) and the mitigation (any process or system used to reduce radon concentrations in buildings: sealing, ventilating; based on the diagnosis) remains a recurring issue. To obtain a global view of the situation and draw new perspectives, IRSN has begun collecting a large inventory of local approaches that have been implemented to manage radon in houses. This article presents the methodology of the collection, the generic strategy for radon management, the key elements of successes and the difficulties. It addresses several perspectives for further actions.

Methodology and first results

Methodology

In June 2020, IRSN initiated a series of more than 30 interviews with different stakeholders concerned by the management of radon at homes located in eleven regions (Fig.1), mainly in radon prone areas. These semi-directive interviews covered the following topics:

- The approach undertaken for radon management;
- The partners involved;
- The funding mechanisms;
- The risk perception of residents and their level of involvement;
- The successes;
- The difficulties encountered;
- And the ways forward.

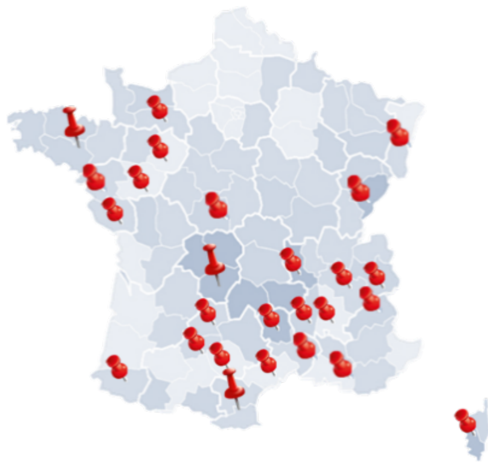

Figure 1. Radon prone areas where interviews were carried out

[1] Since 2018, buyers/tenants of real estate located in areas with significant radon potential must be informed by the seller/ owner of the existence of these risks (article L. 125-5 of the French Environment Code).

General framework for radon risk management in private housing

The "classical" steps for a given radon management campaign is summarized below. This description is generic and local adaptation to this scheme are frequent.

1. A Regional Health Agency (ARS) launches calls for tenders to subsidize radon operators. Most *radon operators* are non-profit associations, often devoted to environmental health or consumers' associations.
2. These non-profit associations contact communities located in radon prone areas and propose to support the coordination of a radon management campaign from the awareness phase to the mitigation (if needed) phase. Operators coordinate (fully or partly) the activities and finance communication with the media and provide rooms for public meetings.
3. Public meetings are organized between October and January. General information on radon is presented and a free *radon kit* (dosimeter for integrated measurement, a questionnaire on building characteristics and a pre-stamped envelope for return by post) is available for interested inhabitants.
4. After the winter measurement period, the dosimeters are sent to an accredited measurement laboratory. Each participant receives his/her result together with general recommendations for mitigation (aeration/ventilation, basic mitigation actions, etc.) based on the radon concentration in the house. For residents whose home have higher radon concentrations (ex. > 1000 Bq.m-3), a free *building diagnosis* can be proposed.
5. Participants are usually offered a free dosimeter for retesting.

Key elements for success

The inventory highlighted several elements of success.

First, **an "ecosystem" of local stakeholders with complementary roles needs to be in place**:

- The Regional Health Agencies (ARS) are the promoters of the action and the financial supporters of the non-profit associations. Their initiative is an essential condition for the commitment of others. ARS has also authority to implement actions in the environmental health field.
- Non-profit associations (radon operators) are local well-known and trusted partners, both being essential elements for the success of the approach and the enrolment of the public.
- Elected officials of the communities: the stronger their involvement, the more effective the communication campaign and the enrolment of the public will be.
- Institutional support from national radiation protection experts (IRSN, Nuclear Safety Authority - ASN) and public experts (Cerema2) provides the scientific legitimacy and the inclusion in a national programme.

A communication concerning only radon risk has appeared over-alarming and ineffective in some areas. Successful awareness actions are matched with **global ("holistic") building approach and indoor air quality policy**, which convey more positive and motivating messages of "*healthy home*" and comfort at home.

Local radon risk management actions must seek to be **included in sustainable territorial programs**, so that initiatives are not person-dependant but link to a territorial policy, which ensures continuity of the actions undertaken.

Several interviewees noted the importance of **face-to-face meetings,** particularly in small communities where public meetings are a social event and bind participants, especially since the residents know each other better than in the big cities. During the Covid-19 pandemic, webinars replaced face-to-face meetings. Even though the participation was lower, this format may have attracted younger people and couples, which until then had rarely attended public meetings (due to lack of time or childcare issues).

Fun awareness-raising materials such as mock-up and escape game can be presented in public meetings or in casual places: markets, science fair or home exhibitions to include other targets. Moreover, school activities are a way to raise awareness of

[2] Public expertise for the ecological transition and regional planning, including expertise in radon diagnosis, https://www.cerema.fr/en

indoor air quality from an early age and acquire durable habits (e.g. daily aeration) but also to pass the awareness to the grown-up.

Difficulties

While radon is a public health issue and despite numerous initiatives, **it remains largely unknown**. This is regularly confirmed by the IRSN Barometers which monitor, through annual survey, the French population's opinion toward various risk, including nuclear and radiological risks [2]. Since its introduction in the Barometer in 1997, radon risk is located at the very end of the list [3]. Moreover, despite the launch of new radon campaigns each year, regional Barometers on the perception of environmental risks, including radon, confirm the lack of knowledge among the population. For example, the 2018 regional Barometer of *Occitanie* [southern region] indicated that 75% of interviewees did not know about the radon risk and only 6% of residents in radon prone areas knew that their community had a radon issue [4].

Some communities categorically refused any initiative about radon (especially those located on the coast or near former uranium mines). The reasons for refusal can be the potential loss of the image of the area.

Young people are hard to attract (because of work or childcare constraints) and participants are mostly retirees. It also remains difficult to involve tenants (participants in public meetings being mostly owners) and apartment blocks inhabitants.

Healthcare professionals (e.g. general practitioners) are unaware of this risk. In some areas, only 5% of practitioners are aware of radon risk [5].

Participants very rarely choose to go for a *building diagnosis* (even if the costs are covered) and even fewer remediate and retest. The reasons cited are:

- Fear of devaluation of the property;
- The cost of mitigation work (especially if they have already invested in energy retrofit);
- They do not know which building professionals to contact for the work;
- There is also a certain detachment in managing a natural risk to which no responsibility can be attached.

Due to the low mitigation rate, feedback of experience is scarce, up to the point that some interviewees fear that radon risk will no longer be considered a priority due to the limited results.

In general, **building professionals are unaware and uninterested in the management of radon**. The obstacles generally mentioned by building professionals are:

- The absence of strong regulation in dwelling resulting in the absence of a potential market for them;
- Overload of building standards and diagnoses;
- The fear of legal proceedings if the mitigation fails to reduce radon concentration;
- No time for awareness/training sessions.

The building professionals whose action could have an impact on radon concentration are numerous: electricians (who generally install mechanical ventilation), heating installer, plumbers, window and doors fitters etc. Therefore, without coordination, it is possible that energy retrofit increases radon concentration and even that new buildings are not radon-free. And conversely, the lack of building professionals with competence in radon diagnosis/mitigation has even prevented several local communities from repeating their radon management campaign.

Yet, it was reported that some communities have managed to adapt by providing training to pre-existing organizations who can take over the diagnosis. At this point, it appeared crucial to further investigate these specific experiences. In 2021, the IRSN mandated the CEPN (Nuclear Protection Evaluation Centre) to interview these newcomers in the field of radon diagnosis and assess the reproducibility of their experience to others places.

Complementary investigations

Methodology

In the first semester of 2021, CEPN interviewed a pre-selected pool of stakeholders: ARS, Cerema, non-profit associations trained in the field of diagnosis, communities and also building professional federations.

Approaches in the diagnosis

The interview allows to identified the following approaches:

1. The recommendation to use a free-to-use on-line self-assessment tool[3].
2. The planning of collective workshops dedicated to building diagnosis.
3. Short term training of a non-profit association. A public expert (in this case: Cerema) looks for non-profit associations ideally with experience in buildings retrofit and already performing in-home visits and trains them on diagnosis with ½ -1 day of theory and ½ to 1 day of practice (visit to house(s) with high radon concentration).
4. Long-term training. A radon operator trains building professionals (architects, project managers, etc.) in a long-term training perspective: 1 day/month of theory for a year and a practical module including several visits. The training is based on a mentoring format. A radon working group, composed with trainer and trainees at different stages, meet regularly and collectively write the diagnosis reports of cases submitted. To date, 15 professionals (*radon diagnosticians*) have been trained that way and 120 diagnoses performed. The *diagnosticians* are listed on the website of the non-profit association.

Discussion: Self-assessment tools and collective workshops are regarded not sufficient and not efficient by most promoters and operators and cannot trigger the remediation. Short-term training is a more sustainable and effective solution, yet without guarantee of the quality of the diagnosis; it was reported that an expert (ex. Cerema) has to review anyway the diagnosis. In addition, new diagnosticians were often unaware of the actions carried out by their counterparts, even in the same region, resulting that they feel isolated and without support. The long-term training with a mentoring scheme and the establishment of a network was recognized as an outstanding success, but it requires time (full time job for the trainer), financial support (from ARS in this case) and a "fertile ground" of building professionals to grow.

Perspectives

Based on the results of the inventory, perspectives for actions can be suggested.

Sharing experiences and networking

Almost all interviewees mentioned the importance of sharing experiences and good practices at departmental, regional or even national levels. The key successes, the difficulties and the perspective coming from this inventory are also meant to be presented and discussed with concerned stakeholders and parties, providing the opportunity to initiate intra and inter-regional networking activities.

Raising the information level and knowledge of specific audiences

To promote the involvement of the public, it is necessary to target several groups:

- Elected representatives located in radon prone areas, by organizing dedicated radon session, inclusive of testimonies from elected representatives who participated in radon management campaigns. Other audience could be the National Association of Mayors or other comparable associations gathering elected representatives.
- Raising awareness of associations of healthcare professionals, ex. general practitioner, will be more effective than an individual approach (which has often proved unsuccessful).
- Scientific mediation or environmental associations working with young people are well positioned to raise their awareness on radon, support specific activities and tools with an educational perspective.

[3] https://jurad-bat.net/auto-evaluation/

Encourage building professionals to find interest in the radon management process

Building professionals will be more inclined to train on radon if they feel “a potential market/business”. It would therefore be appropriate to align the timing of a communication for radon measurement with the opening of a training for building professionals. Moreover, taking into account the busy schedule of building professionals, the format of these training should be planned as a casual after-work (also useful for networking). Developing networking to share good practices, carry on collective thinking on complex cases and mentorship programme are among the possible ways to reach a (minimum) quality-standard in the diagnosis and mitigation.

Encourage the population to undertake mitigation work

Do It Yourself (DIY) for mitigation. In general, simple actions of sealing and restoring ventilation/air exchange can be sufficient to reduce radon concentration and these can be implemented by inhabitants if they know what actions to implement and how. Educational kit for DIY in a video format (like those generally offered by DIY stores) could be jointly created with parties having experience in the management of radon. But the efficiency of the DIY corrective actions has to be evaluated by a retesting.

Financial support. Currently, the criteria for obtaining a subsidy for radon mitigation are restricted to unhealthy houses and low-income population. These subsidies are hard to obtain and do not cover all the work. The introduction of higher and easier to access subsidies would support more inhabitants to mitigate.

Conclusion

This inventory aims to draws a picture of the situation about radon risk management in private housing in France. Radon risk remains largely unknown. Awareness campaigns targeting different groups, especially elected representatives, healthcare professionals, younger generation, non-profit associations specialized in environmental health, building/energy efficiency and scientific activities need to be developed in cooperation with national public experts in radon risk management. Communication on radon risk should insist on the improvement of indoor air quality and on the fact that radon is manageable. A major difficulty lies in the lack of building professionals to carry building diagnoses and mitigation. This obstacle has even blocked some local actions, but adaptations have proven to be possible and efficient when a long-term training format was implemented for those professionals.

Whatever the (new) initiatives that will come, they will be more efficient if they are supported by the growth of intra and inter regional networking, that will help to collect and share experiences as well as to join initiatives to manage radon. ■

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EAN 20th WORKSHOP – ALARA IN INTERVENTIONAL RADIOLOGY AND NUCLEAR MEDICINE

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Introduction

Interventional radiology (IR) encompasses those medical procedures performed inside the body with minimally-invasive instruments and using medical image guidance like X-ray or fluoroscopy. Diagnostic IR procedures intend to narrow a diagnosis or guide further medical treatment and include image-guided biopsy or the injection of a contrasting agent (iodine, barium, ...) for computed tomography, radiography or fluoroscopy. Therapeutic IR procedures provide direct treatment including catheter-based medicine delivery, medical device placement and image-guided operation in cardiology or oncology … Diagnostic and therapeutic IR replace complicated and invasive surgical procedures (and their complications) but also bring the potential for elevated exposure for both the patients and the medical staff, notably their hands and eyes.

The last years have seen a notable increase in the use of new radioisotopes in nuclear medicine, both in diagnosis and therapy as well - as in the combination of both, that is being called "theranostics". Though most of these isotopes can be handled in a similar manner to those long-established isotopes, and therefore not present new hazards in Nuclear Medicine Services (NMS), it is not always the case. For example, some of these new isotopes do present specific characteristics that need new approaches or studies, like Ra-224, that includes in its decay chain Rn-220 in gaseous form. The analysis of this new trend provides a new chance to revisit old issues related to radiation protection in nuclear medicine, that might have not been closed.

In this article, the authors detail some of the questions that will compose the basis of the next EAN workshop on Interventional Radiology and Nuclear Medicine planned in September 2023.

Operational ALARA in IR: why is it a challenge?

The doses in IR account for one of the most important sources of occupational exposure in medicine and have the potential to increase as the number and the complexity of procedures do and several issues remain open and challenging to manage in practice.

ICRP Publication 139 (2018) laid out the latest recommendations on occupational radiation protection for interventional radiology (IR) procedures. However, there is still a long road to cover to make sure that these recommendations are fully implemented.

One issue deals with the lack of radiation protection training of those (new) medical professionals using IR procedures. Some professionals don't feel part of the IR "world" and are not implementing RP measures in a satisfactory manner for them and/or for the patient. Some questions raised are the following:

- How to disseminate effective RP education and training among all interventional radiology professionals?
- How to improve the radiation protection culture in IR?
- How to improve occupational radiation protection by the use of post procedure analysis?

Another issue concerns worker dose monitoring in IR, its scope and the relevant measurement techniques:

1. Scope. Which participants in the procedure need dose monitoring? Should everyone in the room be monitored? If so, is that a realistic and practical approach? How to ensure the registration of the total individual exposure of professionals working in different hospitals?

2. Techniques. The question on whether using direct (active) vs. indirect (passive) monitoring (or both) is still an issue. A specific, but important problem lies also in the eye lens dosimetry where the techniques and protocols are still under development and should be assessed. Furthermore, the perspectives of innovative dose assessments such as computational dosimetry need to be investigated.

Finally recording of patient dose associated with IR procedures is also a challenge. One question is how to ensure first the measurement and then the registration in the medical file of each patient of the doses received during these procedures? A key issue when the patients undergo several procedures in different hospitals.

ALARA for patients

There is an increased number of isotopes and procedures that require participation of several hospital services: nuclear medicine, radio physics, oncology, nursing…. These procedures are usually performed in conventional operational rooms, not dedicated ones, so not only do they require participation of many professionals not used to working with radioactive materials, but they also involve transporting these materials across the hospital, or even to a different facility.

Questions deal also in this field with raising RP culture for professionals who were never trained in RP. Furthermore it seems necessary to develop new protocols for the safe transport of the materials or for their use (ex. cleaning-up of rooms post procedure).
From the regulatory point of view, some regulatory bodies are overwhelmed by numerous applications to use new radioisotopes and sometimes the regulator does not have a clear picture of the actual distribution, composition and procedures in nuclear medicine services.

Radiation protection issues in nuclear medicine

The increased numbers of isotopes and procedures that require participation of several hospital services: nuclear medicine, radio physics, oncology, nursing… are usually performed in conventional operational rooms, not dedicated ones. They not only require participation of many professionals with little or no previous experience of working with radioactive materials, but also the transportation of these materials across the hospital, or even to a different facility. There are also the matters of cleaning-up and accounting for all the radioactive material after the procedure is finished.

From the regulatory point of view, some regulatory bodies are overwhelmed by numerous applications to use new radioisotopes and NMS are becoming very "live" entities, in which before a modification to use a radioisotope has been licensed, they need to change something to implement the next isotope they are thinking on. This results in that sometimes the regulator does not have a clear picture of the actual distribution, composition and procedures in an NMS.

Paving the way for EAN workshop

More than 10 years after workshop n°13 'ALARA in Medical Sector' and with regard to the issues identified in this article, the European ALARA Network would like to focus EAN workshop n°20 on the application of the optimization principle in interventional radiology and nuclear medicine. The programme of the workshop intends to cover some of the challenging areas presented in this article and provide insightful talks that lead to productive workshop discussion.

The programme will develop the current ALARA challenges identified in the fields of interventional radiology and new radiopharmaceuticals by crossing different point of views; current and foreseen ALARA tools and including a discussion on RP culture, education and training. The programme committee will endeavour to contact the major European players such as PODIUM and MEDIRAD research platforms, the professional medical associations representing the practitioners, authorities, manufacturers, experts etc. ■

A RADIOLOGICAL INCIDENT HAS OCCURED?

SHARE IT TO THE COMMUNITY

USE THE OTHEA/RELIR DATABASE

https://relir.cepn.asso.fr/en/

relir othea

Image: The Broken Vase 1913, Ludwig Strimpl (1880-1937)

To submit an incident report for inclusion on OTHEA, download the questionnaire, http://relir.cepn.asso.fr/en/docs/divers/170-questionnaire.html (.doc, 78 ko) complete it and send it to: Sharon.ely@phe.gov.uk

Lorem Ipsum

Trenz Pruca

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Life of EAN and next events

EAN communications and events

September On behalf of the EAN working group on ALARA for Radon At the Workplace (A-RAW), two EAN Representatives took part in the ROOMs conference planned by the European Radon Association in collaboration with the Norwegian Radiation Protection Authority in Bergen, Norway. This was the opportunity to present the achievements of the working group and gain knowledge about the trends in radon mitigation techniques and solution in Europe.

October 9. As a Special Liaison Organization with ICRP, the EAN has contributed to the Workshop on the Review and Revision of the System of Radiological Protection: A Focus on Research Priorities that took place 9 October 2022 at the European Radiation Protection Week in Estoril, Portugal.
From the meeting, the EAN has identified several topics that are in line with its Strategic Agenda and is prepared to further support the ICRP in its review of the current system of radiological protection on the practical implementation of the optimisation principle, reasonableness and acceptability and also help in the tuning of the next Recommendations, based on the data and experience from the field.
This meeting was successful in exploring a broad range of views on research needed to support radiological protection and to share this information more broadly, the ICRP would like to prepare an open access paper.

October 14. The members of the EAN working group on ALARA for Radon At the Workplace (A-RAW) have published in the Journal of Radiological Protection the article "The Application of the ALARA Principle for Radon at Work: Feedback from the European ALARA Network". The article presents the analysis of the survey about the national regulations for the control of radon at the workplace and case studies showing its implementation and discusses the practical implementation of ALARA in these circumstances.
The article is an accepted manuscript available on-line: https://doi.org/10.1088/1361-6498/ac9b46

December 6 is the Administrative Board and Steering Group meeting of the EAN. The meeting is planned at CEPN, France and will be the first in-person meeting since 2019.

December 8 With the technical support of AGES, Austria, the EAN organizes its first webinar on the "Challenges in applying the radiation protection system in the management of NORM and radon", These questions are emanating from questions pertaining to current reflection at ICRP.
Information, programme and registration https://www.eu-alara.net/images/stories/pdf/programe19prime/1_EAN_Webinar_.pdf

September 2023 EAN workshop n°23 about 'ALARA in interventional radiology and nuclear medicine', Vienna, Austria.

Did you check the new ORPNET website? https://www.iaea.org/services/networks/orpnet

Other events in sight

- **ICRP 2021^{+1}**, 7-10 November, Vancouver, https://icrp.org
- **9th Organically Bound Tritium Workshop**, 10-12 May 2023, Antwerp
- https://www.icrer.org
- **ICRP 2023,** 6-9 November 2023, Tokyo, https://icrp.org/page.asp?id=579

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