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EDITORIAL

What is ALARA? Why is ALARA difficult to implement? [according to Chat GPT]

ChatGPT is a large language generation model developed by OpenAI that can be used for a variety of tasks including natural language processing, text generation or language translation. The popularity of ChatGPT is increasing and a number of papers have already been published by scholars and researchers on the subject. Its use for tasks as diverse as scriptwriting for the film industry or target recognition military robotics has already been envisaged and prospectively discussed by researchers (Biswas, 2023). While some commenters say that this new tool will revolutionize every aspects of human beings, others are sceptical, unsettled (Rose, 2023) and call to limit it use (and abuse) (Chomsky, 2023).

We accessed ChatGPT Feb 13 version on 13 March and engaged conversation with a few questions about the ALARA principle. In this editorial, we report and discuss the ChatGPT content generated by OpenAI. Providing that the model is trained on a vast amount of data from various source including the internet, books, and other sources, the content should ultimately reflect the point of view and the concerns of the humans and the professionals.

Question: Do you know the optimisation principle in radiation protection?

: *Yes, the optimization principle is a fundamental concept in radiation protection that aims to minimize radiation exposure while still achieving a beneficial outcome. The optimization principle is based on the idea that there is no level of radiation exposure that is completely risk-free, so the goal of radiation protection is to keep radiation exposure as low as reasonably achievable (ALARA).*

The ALARA principle involves balancing the benefits of a particular activity or procedure that involves exposure to radiation against the potential risks of that exposure. In other words, the benefits of the activity should outweigh the potential risks, and the level of radiation exposure should be kept as low as reasonably achievable while still achieving the desired outcome.

To apply the optimization principle, radiation protection professionals use a systematic approach that involves assessing the radiation risks associated with an activity or procedure, identifying and implementing appropriate radiation protection measures, and continually evaluating the effectiveness of those measures.

The optimization principle is used in a wide range of applications, from medical imaging and radiation therapy to industrial and environmental radiation protection. By minimizing radiation exposure while still achieving the desired outcome, the optimization principle helps to protect both workers and the public from the harmful effects of ionizing radiation.

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Beside the quality of the text (the wording, the construction of the phrase, …) it is quiet startling to see how almost accurate the answer is: the scientific foundation of ALARA (§1), the description of the process (§ 3) and examples of application (§ 4) are correct.

However, in § 1 ChatGPT has used odd words: the "*minimization*" of exposure (it should be: their reduction ALARA) and described the Linear Non-Threshold hypothesis as an "*idea*" (which suggests less rationale and is maybe shedding a light on the absence of consensus on the topic). More conceptually, ChatGPT is mixing in § 1 and § 2 the justification principle ("*the benefit of the activity should do more good than harm*") and the optimisation principle (keeping exposures ALARA, the process being correctly described in § 3) and introduced an unidentified "*desirable outcome*" (industrial outcome? radiological outcome?).

Let's try another question.

Question: Why is the optimisation principle in radiation protection difficult to implement in practice?

: *While the optimization principle is a fundamental concept in radiation protection, it can be challenging to implement in practice for several reasons:*

1. *Balancing benefits and risks: One of the key challenges in implementing the optimization principle is balancing the benefits of an activity or procedure against the potential risks of radiation exposure. This requires a thorough understanding of the risks associated with different types of radiation exposure, as well as the benefits of the activity or procedure in question.*
2. *Trade-offs: In some cases, there may be trade-offs between radiation exposure and other factors, such as cost or convenience. For example, using more shielding to reduce radiation exposure may increase the cost or complexity of a procedure, which may not be feasible or practical.*
3. *Lack of knowledge or resources: Implementing the optimization principle requires access to appropriate knowledge, tools, and resources to assess and manage radiation risks. In some cases, these resources may not be readily available, particularly in low-resource settings.*
4. *Changing circumstances: The optimization principle requires ongoing evaluation and adjustment to ensure that radiation protection measures remain effective as circumstances change. This can be difficult to achieve in practice, particularly in dynamic or rapidly changing environments.*

Despite these challenges, the optimization principle remains an essential aspect of radiation protection, and efforts to improve its implementation can help to minimize radiation exposure and protect the health and safety of workers and the public.

Once again, ChatGPT is mixing the justification and the optimization (in the first point) but the difficulties in the methodology in finding the balance remains. The other remarks include that the answer is a bit focus on planned exposure situations and quite programmatic (*e. g.* ethical values are not mentioned) but the challenges are quite clear and accurate and do not call for specific comment.

Finishing with a major question.

Question: How to improve the application of the optimisation principle in radiation protection?

: *There are several ways to improve the application of the optimization principle in radiation protection:*

1. *Training and education: Providing comprehensive training and education to radiation protection professionals can help to ensure that they have the knowledge and skills necessary to implement the optimization principle effectively. This can include training on risk assessment, radiation protection measures, and evaluation techniques.*
2. *Standardization: Developing standardized approaches to implementing the optimization principle can help to ensure consistency and improve the effectiveness of radiation protection measures. This can include standard operating procedures, guidelines, and regulatory requirements.*
3. *Technology and innovation: Advancements in technology and innovation can provide new tools and techniques for implementing the optimization principle. For example, the use of real-time radiation monitoring can help to identify and mitigate radiation risks in real-time, while new radiation protection materials and technologies can improve shielding effectiveness.*
4. *Collaboration and communication: Effective collaboration and communication between stakeholders, including radiation protection professionals, regulatory bodies, and workers, can help to ensure that the optimization principle is implemented in a coordinated and effective manner. This can include regular communication of risks, feedback mechanisms, and engagement with stakeholders.*
5. *Continuous improvement: Ongoing evaluation and improvement of radiation protection measures can help to ensure that the optimization principle remains effective over time. This can include regular assessments of risks, performance indicators, and feedback mechanisms to identify areas for improvement.*

Overall, improving the application of the optimization principle requires a comprehensive and coordinated approach that involves ongoing evaluation and improvement of radiation protection measures. By working together and leveraging new technologies and techniques, stakeholders can help to minimize radiation exposure and protect the health and safety of workers and the public.

Difficult to argue against ChatGPT on this one!

The adherence of the answers of ChatGPT regarding ALARA, as the principle states in the ICRP recommendations and the regulatory texts, is sometimes low; possibly reflecting some (mis)interpretations about the optimization principle that are integrated without analysis by OpenAI. Even more, it can be sometimes hard to spot where the fallacies are (and even more difficult to understand why they appear).

Most of the substance of the answer appears linked with the planned exposure situations, probably because most of the

published and available documents are dealing with this exposure situations, potentially leaving gaps in the answers provided. Unknown data set (which references are used?) and lack of transparency (how is the answer created?) are other hurdles in the confidence that can be granted to conversation with ChatGPT.

In this Newsletter, you will find an article about practical radiation protection in veterinary practices radiography provided by a UKHSA Radiation Protection Adviser with operational experience in the field [**p. 4**]. The next article [**p. 9**] deals with the emergent technique of theragnosis – the use of molecules bounded to radioactive isotopes for diagnosis and treatment. The reflections given by the three leading scientists is also paving the way for the EAN workshop n°20 planned 2-4 October 2023 at AGES, Vienna [**p. 11**]. The last article aims to synthetize the content of the EAN's first webinar on NORM and radon by summarizing the presentations, the answers to participants' questions and the round table discussions [**p. 12**]. The Newsletter concludes with information about future radiation protection events in Europe, notably the EUTERP conference in May 2023.

We hope that this Newsletter met *all* the ways to improve ALARA according to ChatGPT [tell us what you think!] and that you will enjoy the content, which is made possible through EAN Members support and contribution.

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**).

N.B. This editorial has been edited 18 March with further analyses of ChatGPT answers.

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ChatGPT Free Research preview is available at https://chat.openai.com/ (registration needed). The transcript of the conversation is available upon request to the Editorial Board.

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Restriction of exposure in veterinary practice

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Introduction

Uses of ionising radiation available in the field of human medicine are also available in veterinary medicine. These include both imaging and therapeutic techniques using X-rays and radioactive materials: conventional radiography, fluoroscopy, computed tomography, nuclear medicine and beam therapy. While the use of conventional radiography is widespread in veterinary practice, other techniques tend to be more specialised, and the use of radioactive materials carries additional considerations regarding the management of radioactive materials and wastes. We can broadly divide radiography into two groups: small animal and large animal. Small animal generally refers to family pets, cats, dogs, rabbits etc., and large animal to horses. In zoos, wildlife centres and other non-domestic settings, small animal can include anything from fish to primates and large animal from tiger to elephant! Small animal radiography would typically take place within the confines of the veterinary surgery while large animal radiography is most often conducted in the field or stable.

This article looks at some of the challenges encountered in the use of X-ray equipment for conventional radiography in veterinary practice from the perspective of a radiation protection adviser in the UK.

Legislative backdrop

The Ionising Radiation (Medical Exposure) Regulations 2017 (IRMER) [1] apply in Great Britain to the equipment used for human medical exposures and to the people who use that equipment, focussing on the exposure to the patient rather than the operator. They are one of the many reasons why veterinary radiography facilities should not be used for human radiography. Doing so has and is likely to lead to prosecution.

In contrast, while the Animal Welfare Act 2006 [2] legislates against causing unnecessary suffering to animals, there are currently no regulations (at least in the UK) specifically controlling the exposure of animals to ionising radiation. Ethical considerations in veterinary practice go far beyond this article but it is perhaps worth noting that the mandate of ICRP's Task Group 110 [3] includes radiological protection considerations of animals as well as humans. This is also considered in ICRP's draft report on Radiological Protection in Veterinary Practice [4] with, 'explicit attention to the protection of the exposed animals.'

In this article I will only consider the human aspects of radiation protection. The Health and Safety at Work Act 1974 (HASAWA) [5] remains the core legislation in Great Britain applicable to occupational health and safety. It places a general duty on all employers to protect their employees and members the public. While HASAWA remains the overarching health and safety legislation, the Ionising Radiations Regulations 2017 [6] form the principal legislation applicable specifically to work with ionising radiation. Moreover, they implement the Basic Safety Standards Directive 2013/59/Euratom [7].

Enough protection

According to UNSCEAR [8], 10,000 employees working in the veterinary sector were subject to personal dosimetry in the UK in 2001 and the average annual dose in that year was 0.2 mSv. Average doses have not exceeded this since 1985. Worldwide some 119000 employees were monitored between 2000 and 2002 and the average annual dose was 0.15 mSv with a general trend of reduction from 0.52 mSv since the period 1975 – 1979.

The concept of dose constraint was introduced in ICRP 60 [9]. If individuals exceed a dose constraint for a particular source, it's unlikely that optimisation of exposure is being achieved. A constraint of 0.3 mSv per year for a single new source is recommended [10] for members of the public and this constraint is often used when determining the level of shielding required around a veterinary radiography facility. Although

recommended for public exposure, it's reasonable to apply to all people within the veterinary practice, including ancillary staff.

Typical reported settings in small animal practice can range from 50 to 80 kV, 0.5-3 mAs, the higher mAs settings normally used for the lower kV settings.

The dose in the primary beam at 1 m from the tube focus at settings of 70 kV 2 mAs is typically of the order of 0.1 mGy. Older units may produce half that for the same settings.

Scatter from a water filled phantom on the couch top can be of the order of 0.8 - 1 % of the incident radiation scattered to 0.5 m and 0.2 - 0.25% scattered to 1 m. Depending on the exposure factors selected, X-ray field size and focus to patient entrance distance, scattered radiation at 0.5 m may be of the order of 1 or 2 µSv and a quarter of that at 1 m.

By taking into account the predicted workload, typical exposure factors, location of the X-ray set and levels of occupation in surrounding areas, it is possible to determine potential annual exposures in areas around the facility and the degree of shielding required to reduce them to less than 0.3 mSv a year for anyone. Often, standard building materials will suffice – brick, concrete block etc. In other cases, additional shielding may be required. There are many methods and data sources for calculating shielding that all broadly agree, always useful for double checking a calculation. Dose statistics from UNSCEAR seem to suggest that, even taking into account veterinary staff who may be exposed at greater levels than others in a veterinary surgery, exposures on average remain below the 0.3 mSv constraint

Practical protection

Restriction of exposure need not be complicated to be effective, and, with sensible planning, need not be prohibitively expensive. Detailed guidance on these matters is available to the veterinary practitioner [11].

Shielding of the X-ray tube head, adjustable collimation (Figure 1) and beam filtration (equivalent to at least 2.5 mm aluminium) are expected features of diagnostic X-ray equipment. The first feature is clearly aimed at reducing levels of radiation around the X-ray tube to which all persons may be exposed. It is recommended that leakage does not exceed 1 mGy per hour at one metre from the tube focus at the maximum rating of the set. In human radiography, the last two features are mandatory and are primarily intended to restrict exposure to the patient. Collimation limits exposure only to the part of the patient that needs to be imaged and filtration reduces unnecessary skin doses. Of course, these features also reduce exposures to animals. However, by reducing the amount of radiation incident on the animal, the amount of radiation scattered around the facility is reduced. Having a well maintained X-ray machine with accurate adjustable kV and mAs (figure 1), and reliable processing facilities, also reduces the risk of poor imaging and the need for repeat exposures. For these reasons, many of the design features and performance criteria we see applied to medical radiography are applicable at least to some degree to veterinary radiography.

Figure 1 – Adjustable beam collimation and adjustable kV and mAs

It is recommended that a 1 mm lead sheet be placed on the X-ray couch immediately underneath the imaging plate. The intention is to reduce scatter. It's true that lead produces less scattered radiation than materials, such as water, containing lighter elements for the X-ray energies typical of veterinary radiography. But as soon as a patient is placed on the couch and radiographed, the reduction in scatter from the lead may be outweighed by the increase in scatter from the animal. However, it's a simple measure and also potentially reduces the amount of radiation passing through the couch and possibly onto the feet of a person standing nearby. If the X-ray room is not on the ground floor it can also remove the need for shielding in the floor required to protect

people on the floor below. Many purpose-built veterinary radiography couches have lead fitted as standard. If not, then lead matting is available (Figure 2).

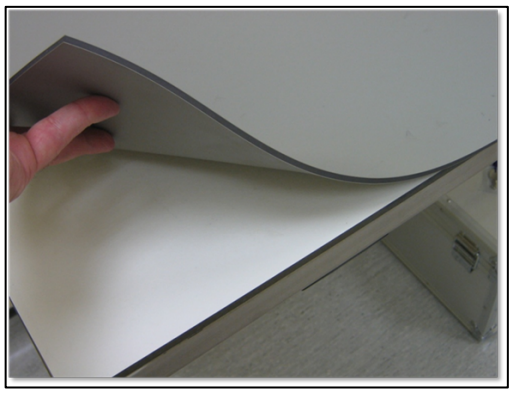


Figure 2 – Lead matting.

In some situations, distance alone can ensure that doses to operators are suitably restricted. This is achieved by fitting the exposure control to a long cable, usually at least 2 m long. However, this relies on the knowledge and understanding of the operators to essentially follow administrative procedures. A better solution might be to dictate by design that the operator stands either in a shielded area or at a distance by locating the exposure control in one of these fixed locations (Figure 3). This limits the position of the operator at least.

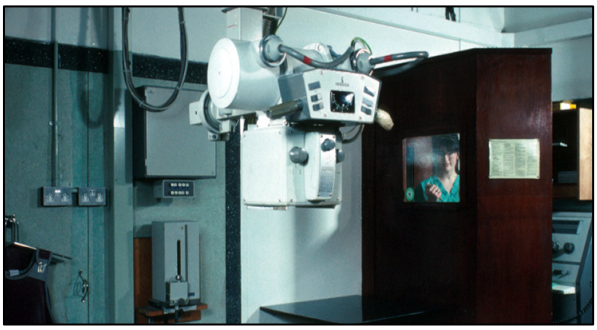
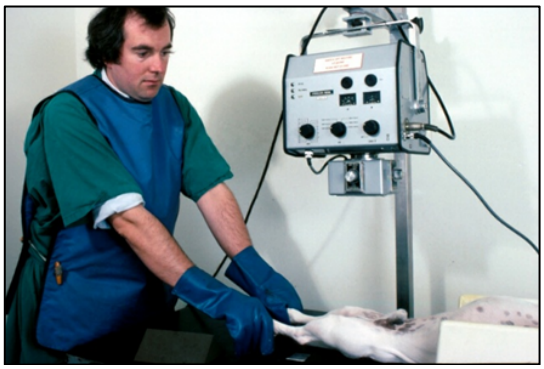


Figure 3 – Standing at a shielded console.

Nevertheless, there are circumstances where veterinary staff must remain close to the animal during a radiographic procedure (Figure 4). This may be because the animal must be restrained manually and the animal cannot be anaesthetised, sedated or otherwise restrained with tethers, sandbags etc (Figure 5). Manual restraint should only be used in exceptional circumstance dictated by the clinical needs of the animal, not simply for speed and convenience. In these cases, stricter administrative procedures are required: only trained staff should be involved, personal protective equipment and dosemeters worn, the animal carefully positioned and the X-ray beam coned down so that no part of a person is ever intentionally or accidentally exposed to the primary beam. Personal protective equipment is neither designed nor intended to protect the wearer from exposure to the primary beam and this must be understood by the person restraining the animal. The recommended minimum lead equivalence of aprons and gloves is 0.25 mm and 0.5 mm respectively.



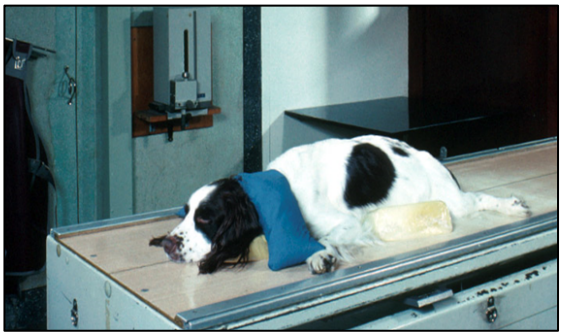


Figure 4, 5 – Manual(above) and non-manual restraint.

Imaging

An appropriate tube voltage needs to be selected to provide the optimum image contrast and this will depend upon the density and thickness of the anatomy being radiographed compared with that of surrounding tissues. Too high a kV and denser structures will not provide enough attenuation and too low a kV and softer tissues will provide too much attenuation. In either case the differential attenuation produced by varying thicknesses and densities will be reduced. Only the overall brightness of the image will be affected by the selected mAs and can be adjusted to offset the increase or decrease in intensity produced by adjustments in kV. Appropriate exposure factors have been established across the industry for a range of examinations and,

within a practice, exposure factors that produce satisfactory images will be developed through the experience of the radiographer, often through trial and error, and adopted.

Poor selection of kV and mAs can produce a poor radiograph and the need for a repeat. This is especially so for conventional film. If retakes are a regular occurrence, this can have a significant impact on the workload and on the potential exposures to persons in and around the X-ray facility. In addition, poor film processing can lead to the selection of higher settings – rather than dealing with the processor, replenishing chemicals and using appropriate film speeds and intensifying screens, an easy, and inappropriate, fix is to increase the beam output. Digital processing is more forgiving of poor selection of exposure factors, and image contrast, brightness and other factors can be digitally manipulated to produce a diagnostically acceptable image from one that would otherwise be unusable. Processing of images is also much more straightforward, not least because no dark room is required, and there is no longer the need for regular maintenance, set up and replenishment of chemicals. This has the benefit of keeping workload down. It has the disadvantage that the operator can get away with poor practice and selected exposures may be higher than necessary, again, potentially increasing the exposure of persons to radiation. Nevertheless, digital processing has the great advantage that output settings can be reduced and still provide diagnostically acceptable images, and, overall, the greater potential for dose reduction than conventional film.

Large animal radiography

Large animal radiography has its own unique challenges. Generally conscious and standing – where sedation or anaesthesia are not in the best interests of the animal - a horse, often very nervous of unfamiliar objects placed close by such as X-ray tubes and imaging cassettes, will need to be restrained and calmed by a familiar person. Considerable damage can be caused to the animal, equipment and personnel if the animal becomes agitated or aggressive. While it's possible to support imaging screens in blocks it is very easy for the animal to kick over this equipment. By holding the screen, the radiographer can move it away before damage is done (Figure 6). However, holding blocks are an important consideration and work well depending on the anatomy and animal being imaged.

Figure 6 – Equine radiography of the distal limb

Equipment designed for use in the field is light and portable. With a convenient carrying handle, it's tempting to assume that the X-ray unit is designed for hand held use. Again, stands, tripods and other supports are available and should be used. There may be exceptional circumstances where this is not possible, and both the X-ray unit and imaging plate need to be held, for example, where radiographs are taken at height or at awkward positions for example during radiography of the equine stifle. In zoos and wildlife parks, elephants and large primates can be trained to helpfully offer a limb, nevertheless, there are many other less obliging animals, some having to be radiographed in situ under the influence of tranquiliser darts. Here the priority is to see to the animal and get the job done quickly without the luxury of a lengthy set up. But it's not impossible to support the X-ray set on the end of a counterbalanced boom, even a plank of wood and this can provide a simple, practical solution. Not to use supports or stands, where it is reasonably practicable to do so, would be unacceptable.

Final thoughts

In this article, I have highlighted some of the practical ways in which ALARA is achieved in the field of veterinary radiography. As an RPA I have encountered many veterinary professionals all dedicated to the care and welfare of animals. Without question there are far reaching benefits to humanity by caring for other species. We think of ALARA as a balance between the benefit and detriment to us from exposure to ionising radiation. Here, uniquely, ALARA is also a balance between the benefit to the animal and the detriment to those persons involved in treating that animal. By taking account of the principles and measures that I have outlined above, this balance can readily be achieved.

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Future challenges in theragnostic centres taking into account all the radiological protection measures

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Introduction

The use of molecules bounded to radioactive isotopes for diagnosis and treatment, theragnosis, is a new therapeutic tool for treating diseases in nuclear medicine.

Peptide receptor radionuclide therapy (PRRT) with somatostatin analogs has been used for two decades in the treatment of well differentiated neuroendocrine tumours (NET) that express somatostatin receptors. The promising results of the phase III NETTER-1 clinical trial in patients with small bowel NETs treated with lutetium-177 (^{177}Lu) have undoubtedly helped promote the concept of theragnostics. PRRT in this group of patients improves the quality of life of these patients, as well as the rate of objective response and survival. The results of the first analysis of this clinical trial led to the approval of the use of [^{177}Lu]Lu-oxodotreotide[1] by the European Medicines Agency (EMA) in 2017.

Another revolution that has recently emerged in the field of theragnosis is the use of radiopharmaceuticals for the diagnosis and treatment of prostate cancer. Compared to neuroendocrine neoplasm, patients with metastatic castration-resistant prostate cancer (mCRPC) have a bad prognosis and may present rapid tumoral progression and a greater probability of symptomatic disease. One of the most relevant molecules localized in the tumour cells of patients with prostate cancer is the prostate-specific membrane antigen (PSMA). This consists in a type II transmembrane glycoprotein that internalizes in the cells and is overexpressed in most prostate tumours.

From the therapeutic perspective, the most used ligand is PSMA-617 labelled with ^{177}Lu, known as PSMA radioligand therapy (PRLT). While the NETTER-1 clinical trials were a fundamental study in well differentiated neuroendocrine neoplasms, the VISION (NCT03511664) trial is fundamental in prostate cancer.

A tremendous increase in the demand for theragnostics procedures will be expected after FDA and EMA approval of [^{177}Lu]Lu-PSMA-617. The existing infrastructure will be insufficient to meet the growing demand. The design, construction and subsequent development of a theragnostics centre have to be guided by the fundamentals of radiation protection established by the appropriate regulatory agencies. In Europe, the International Atomic Energy Agency (IAEA) through the International Basic Safety Standards (BSS) are a set of consensus requirements derived from knowledge of radiation biology and radiation protection, respectively. The European Commission Directive 2013/59/EURATOM is a legal act that establishes the recommendations and requirements of the BSS and ICRP for EU countries, which have been transposed into national law by the Member States. The regulatory basis for operating a theragnostics centre is a radioactive material license (RAM), in accordance with the national regulations and laws governing the handling of radioactive materials for medical applications, as defined in ICRP Publication 105. Prerequisites for applying for a RAM license include the existence of adequate infrastructure, sufficient personnel (including trained physicians, technologists, nursing staff, a radiation safety officer (RSO), a medical physics expert (MPE), sufficient

[1] ([^{177}Lu]Lu-dodecanetetraacetic acid - tyrosine-3-octreotate [DOTA-TATE])

means of radiation protection, processes for discharge management of treated patients and handling of radioactive waste and sewage.

Release of patients after diagnostic procedures does not require any measures, since the physical and effective half-life of radiotracers involved is usually only a few hours. The situation is somehow different from patient discharge after therapeutic administration, as the activity levels here are significantly higher. ICRP Publication 94 and IAEA Safety Report No.63 comment on the release of patients after radionuclide therapy. A dose limit of 1 mSv/y for the public and a dose constraint of 5 mSv/episode for caregivers (a family member or paid helper who regularly looks after a child or a sick, elderly, or disabled person) have been proposed as acceptable limits.

We already have a great deal of experience in the treatment of thyroid cancer with ^{131}I, which requires special installations to guarantee the minimal length of stay, especially from the radiological protection point of view. A significant portion of the ^{131}I administered to patients is eliminated via the urinary tract, making the storage of urine necessary in special containers for several weeks. In addition, mainly due to its emission of relatively elevated energy, radioprotection of the patient's environment is obligatory, requiring a stay within a radioactive installation during the time recommended by the guidelines of the scientific societies and the Forum for Radiological Protection in Health Care endorsed by the Nuclear Safety Counsel, the Spanish Society of Radiological Protection and the Spanish Society of Medical Physics. However, the current treatments are aimed to use more manageable isotopes from the radiological point of view, although also with diagnostic quality (returning to the concept of theragnosis). ^{177}Lu, which is also a β and γ emitter, has a lower half-life than ^{131}I (6.7 days vs. 8.02 days, respectively) and a lower proportion of gamma emissions (208 keV (11%) vs. 364 keV (81%) for ^{131}I). To understand the restrictions necessary when treating a patient with one isotope or another, not only the type and proportion of radiation emitted is important but also the elimination of the isotope, mainly by the urinary tract. Different dosimetry studies published about treatments involving [^{177}Lu]Lu-DOTA-TATE and [^{177}Lu]Lu-PSMA-617 have demonstrated that treatment is possible in an outpatient setting, requiring a stay of 6-8 hours after the injection of the radiopharmaceutical in duly authorized nuclear medicine installations. Nonetheless, the regulatory bodies of each country establish the legal limits with respect to both the dose and the activity excreted, which vary among

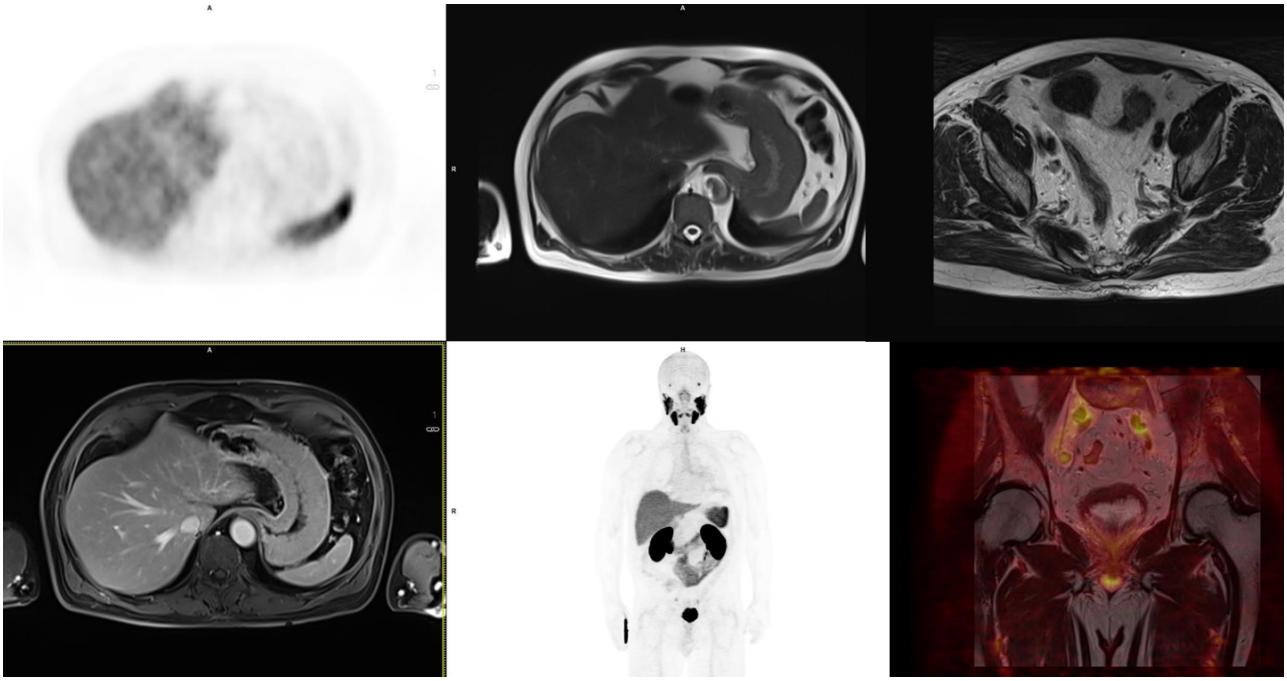

Figure. 1 – Image of a PET-CT scan using prostate-specific membrane antigen (PSMA)

European countries, with, for example, greater restrictions in Germany, Austria and Italy.

Perhaps we need a reconversion and/or investment in our installations, a commitment to different types of rooms based on the needs and types of radiopharmaceuticals used. For example, in addition to the classical admission rooms in which patients with thyroid cancer are treated with ^{131}I or pheochromocytoma with [^{131}I]I-MIBG, we need other treatment rooms or treatment boxes based on the concept of the Day Hospital with the requisite of the necessary radiological protection. Many international centres have already developed this type of outpatient rooms. Both the EAMN and the American Society of Nuclear Medicine and Molecular Imaging (SNMMI) have recently published guidelines to facilitate the creation or reconversion of nuclear medicine services into theragnostic centres of excellence with the aim of preparing for the demand of oncological patients and facilitating understanding among the physicians requesting these treatments, society and other interested parts, such as health care institutions, govern mental entities and the pharmaceutical industry for establishing theragnosis centres of excellence.

Conclusion

The interest in therapies with radionuclides has increased enormously. The foreseen increase in demand for these treatments as well as the need for greater investment in infrastructure and duly qualified professional personnel will be both a challenge and an opportunity for the health care systems. Theragnostics will become an important pillar in the personalized treatment of cancer.

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Note from the Editorial Board

The article EAN 20th workshop – ALARA in interventional radiology and nuclear medicine by A. Perez-Mulas *et al.* in *EAN Newsletter* **48**, 2022, ignited a reflection about the application of ALARA principle in interventional radiology and new radiopharmaceuticals. This article, from three leadings scientists in Spain, is part of these reflections that will be continue at the **EAN workshop n°20 in Vienna from 2-4 October 2023**.

Challenges in applying the radiation protection system in the management of NORM and radon. A synthesis of the European ALARA Network webinar

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Introduction

Context

The International Commission on Radiological Protection system of protection is based on three fundamental principles: justification, optimisation and dose limitation; they apply to three types of situations of exposure to ionizing radiations: planned (when the source is deliberately introduced and operated), (in case of) emergency and existing (from sources that already exist when decisions to control them are made) along with three categories of exposures: occupational (i.e. workers), medical patients and the public (ICRP, 2007, ICRPaedia).

Exposure from radon and NORM (naturally occurring radioactive materials) have been regarded as existing exposure situations by ICRP (ICRP 2014; 2016; Lecomte, 2016; ICRP, 2019) leading to exposure of members of the public and workers (be they regarded as "members of the public" or occupationally exposed workers). However, both sources present specificities, making the choices about the type of exposure situation and the categories of exposure somewhat challenging and areas of confusion (Cool, 2013). For example in the Euratom Directive, radon and NORM exposures of workers are to be managed "as planned exposure situations […] at workplaces where the exposure of workers is liable to exceed an effective dose of 6 mSv/y" (§ 25, Euratom, 2013). Recently, ICRP has recognized that further clarity is needed on the interpretation of exposure situations (Clément, 2021).

Context

The application of the optimisation principle is the cornerstone of the activities of the European ALARA Network (EAN). Furthermore, the EAN also aims to assist ICRP in the practical implementation of its recommendations and to monitor the development of the new general recommendations (EAN, 2021), as a Special Liaison Organization. In January 2022, the EAN Steering Group decided to examine how the optimisation principle has been applied in the case of NORM and radon (at workplace or in other circumstances) and whether the decision of exposure type and exposure categories could have affected the practical implementation of ALARA. It was proposed to plan a webinar to present an overview of experiences and discuss if the elements of the optimisation process could be influenced by the type of exposure situation/categories of exposure, notably the:

- selection of the appropriate dose criteria (dose constraint, reference level);
- dose assessment;
- identification of the protective options and selection of the best option;
- implementation, monitoring of exposure and iteration of the process.

Organization

The webinar was announced in the EAN Newsletter (EAN, 2022) and organized with the in-kind support of AGES (Austrian Ministry of Health and Food

Safety – member of EAN) and took place 8 December 2022 from 09h30 to 12h00 on Zoom. More than 100 participants attended the event live.
The webinar was opened by the Chairperson of the EAN, Mr. Fernand Vermeersch (SCK CEN, Belgium) and co-chaired by Mr. Franz Kabrt (AGES, Austria) then by Mr. Sylvain Andresz (CEPN, France).

This article aims to synthetize the content of the presentations and also the moments of interaction between the speakers and the participants and during the round table.

The philosophy of the ICRP system applied to radon and NORM

Mr. Jean-François Lecomte was the chair of the ICRP Task Group engaged in the writing of ICRP Publication 126 on radon (ICRP, 2014) and Publication 142 on NORM (ICRP, 2019). He presented the philosophy of the ICRP with regard to radon and NORM.

First and foremost, radon and NORM are regarded by ICRP as existing exposure situations and potentially leading to occupational, public and environmental exposures. The justification principle applies to the decision to implement a protection strategy (not on the decision to expose individuals).
Considering the very specific characteristics of radon and NORM: already existing, ubiquitous but variable, not bound to emergency situation, requiring characterization, lack of pre-existing radiation protection culture of most of the concerned parties and, for NORM radiological risk is rarely dominant compared with the other hazards and the waste management options are limited – a graded and integrated approach tailored to the circumstances is promoted.

For radon, the graded approach is illustrated by:
- The selection of a unique Reference Level (RL) in concentration (between 100–300 Bq/m^3) and, if necessary, a RL in exposure (around 10 mSv/y) for workers;
- The identification of priority area ("radon prone area" or equivalent);
- Differentiating between remediation (of existing buildings) and prevention (of new ones).

And the integrated approach means that:
- Radon shall be managed at the level of the building whatever the individuals inside (sex, age, smoking habit, occupation…);
- The management strategy should be combined with indoor air quality and energy saving (but separated from the exposure from other sources of ionizing radiations).

For NORM, the selection of a relevant RL based on the actual distribution of exposure of the workers and the public (around a few mSv/y in most cases) will help to drive the optimization strategy. For workers, the protection strategy should benefit from pre-existing health and safety management (H&S) and should be based on collective protection measures first, then on individual ones and specific radiation protection measures being needed only in some cases. Exposure to the public can arise from discharge/release/waste and will be optimized through their control after a characterization step. The characterization is also needed to assess if NORM has the prospect to expose the environment and the ICRP has proposed tools to evaluate the radiological exposure of the environment (ICRP 2014a). Considering that NORM can also be a non-radiological stressor, ICRP recognized that decision about the protection of the environment might be reached not (only) because of radiation issues.

The application of the dose limit is not relevant a priori for optimization purposes but ICRP recognized it might be applied for workers classified as exposed and for regulatory purpose.

Questions from the participants

Can a proposed NORM installation/activity be deemed 'not justified' because is it known that exposure to NORM will occur, therefore the justification applies on the decision to exposure individuals or not, like in a planned exposure situation? Mr. Lecomte answered that the exposure remains unknown until the situation is characterized and added that the radiological risk is rarely dominant in such kind of installations, therefore it is very unlikely that the installation/activity could be stopped (not authorized) based on radiological considerations only.

Another participant has noted that workers in NORM are sometimes considered as members of the public as a whole and sometimes as exposed workers as a whole, irrespectively of the actual situation (e.g. the last view being UNSCEAR Subgroup 2's position). Mr Lecomte indicated that ICRP has always considered the application of the specific requisites generally associated with exposed workers possible for NORM workers and relevant in some cases but reminded that these requisites come from the nuclear industry and the medical sector which also have their own specificities: Therefore, their blunt transposition in all NORM cases does not seems adequate while a graded approach using existing H&S with adaptations based in the circumstances is more relevant.

Practical experiences from Norway in NORM remediation

Mrs. Marte Holmstrand started by reminding the audience that there are many NORM industries in Norway, each producing wastes and the largest volume of radioactive waste is Potentially Acidifying Rocks (PAR) constituted with black shales with an acid forming potential (so chemically reactive) and containing many heavy metals including uranium and thorium (and their decays products like radium and radon).

The regulators DSA faces many challenges associated with PAR:

- PAR is potentially everywhere: their localization and the total volume are unknown;
- The responsible parties are not always keen to engage expensive managing;
- Alternative (cheaper) waste management can be damaging for the environment;
- It is not easy to balance the costs of remediation with the value of the environment;
- PAR is a multi-stressor with acid, heavy metal, toxicity, radiation … and the consequences are difficult to predict and correlated (e.g. the higher the acidity, the higher the potential radiological consequences):
- The chemical behaviour of NORM in PAR requires specific rare knowledge and more research;
- There is currently no measure of the radiological and chemical risks of PAR and how they compare between each other's;
- Hazards, risks and countermeasures are difficult to communicate.

It is clear that many uncertainties lie in the management of PAR, yet Mrs. Holmstrand stated that the knowledge-limited context shall not prevent decision-making (although the decision may be subject to complaint). DSA has been involved with the development of guidance documents for PAR management based on former experiences and input from external experts, which are about to be published.

Feedback on radiation protection for NORM facilities and underground workplaces

Mrs. Katerina Navratilova Rovenska is a RadoNorm Partner. Her presentation focused on NORM facilities and underground workplaces.

The mitigation process shall be based on the characterization of data and the identification of sources of exposure. But this is an arduous step ("*all the times, the discussions start and end at the collection of data issues"*) because of the challenges and the many questions that can arise to obtain sufficient and reliable data to describe the situation. Table 1 presents (some) of the questions applicable for radon and also NORM.

Table 1. Challenges and questions for the characterization of sources of exposure and exposure.

Challenges	Example of questions
The variability of radon progenies concentrations	• Selection of the measurement points: where and how many? (the radon national protocol might need to be adapted in some case); • Duration of the measurement: based on the season, the presence of workers, …

What should be measured at the workplaces	From RadoNorm WP5.4 survey: [^{222}Rn], γ dose rate and possibly: humidity, T, [Rn progenies], [^{220}Th], unattached fraction (f_p).
Choice of the measurement devices	• Environmental monitoring vs. individual monitoring; • Issue with short term and randomly visited workplaces; • Very large number of parameters associated with the detector: sensitivity, time resolution (frequent, rapid and steep changes of [Rn] are possible), environmental conditions, cost, …
Assessment of the exposure	• Workers' behaviour, time spent at each location, typical activities at the workplace, … • Environmental condition: aerosol condition; equilibrium factor F • Which dose conversion factor to choose between ICRP 65, 115, 126, ICRP137, UNSCEAR, site-specific factor,
What is the air exchange rate?	Gas tracer technique [A] can be used to evaluate air exchange rate and also radon entry rate and pathway.

[A] This technique not applicable in all countries.

Mrs. Rovenska concluded by presenting a case study of a family house built in 2016 where the [^{222}Rn] was above the national reference level valid at that time (200 Bq/m^3) and the owner initiated a law suit against the builder. SURO was mandated by the court to provide an external expertise and performed a radon diagnosis as well as an air exchange rate measurement and used both results to conclude that increasing the ventilation will help sort out the radon problem.

Questions from participants.

Two short technical questions were asked about the number of measurements points in underground workplaces (answer: measurements were performed at all locations occupied by individuals) and the use of the H*(10) for individual monitoring (answer: was: this unit was used for research in this project only).

Radon potential map of the UK – Updating and implementation

Ms. Tracy Gooding presented the evolution of the radon map(s) for the UK.

- The first map (1980's) was based on the radon measurement results performed in households (national protocol: 2 passive detectors/house, 3 months-measurement any time of the year with seasonal correction factor) but the map was function of the number of measurements.
- The first radon prediction map was introduced in 1990 and based on a statistical analysis of measurements results to delineate free form ("potato") affected areas where "At least X% of the houses being above the Action Level" and X can take 4 values/bands. A Scottish radon affected areas map was based on the same mathematical analysis but the delineation followed district boundaries. Recommendations for the implementation of radon protective measures for new buildings was introduced at that time in the Building Regulations.
- During the 1990's and 2000's the results of extensive measurement programme were integrated into the map allowing the reduction of the grid square, yet measurements were missing for some parts of the map and, at some point, the colours scheme and number changed (blue was abandoned because it was confusing).
- In 2002, a new map was published with a 5 km^2 resolution (even 1 km^2 in some parts) and it included a smoothing method of the data (log-normal modelling) and a new colour scheme.
- In 2008, the Scottish map was updated (with another colour scheme) and it was reported that the colour of the unmapped areas was confusing. In 2009 a Northern Ireland map was published.

All these maps were based on the radon measurements, not the geology. A Joint Data Set (JDS) mapping technique inclusive of the geology and the radon measurement was proposed to produce estimates of the percentage of homes above the Action Level (especially where the number of measurements is scarce). The National Geology service was a key partner in the development of the new map.

From 2007-2015, the country was (re)mapped entirely based on the JDS methodology with 1 km^2 grid square.

Finally, by integrating the new data from radon measurements (> 500,000 in UK), new knowledge in

the geology and an evolution of the statistical technique, the 2022 map indicates for the whole country with a highly precise 25 m^2 square the radon potential using 6 bands and a (new) new range of colours.
The communication strategy of the new map – and notably explaining the evolutions compared with the former one – is a challenge in it-self and Ms. Gooding presented the on-going communication campaign which is addressed to a variety of public audiences.

Optimisation in protection from radon: problems and proposals

Mr. Francesco Bochicchio focused his presentation on the challenges in the process of optimization of radon protection strategy and ways to improve it. According to ICRP, the Reference Level (RL) is defined as "the level of dose/risk above which it is inappropriate to plan exposure to occur and below which the optimization of protection (based on the ALARA principle) should be implemented" (ICRP, 2007) and represents a key tool for the optimization process against radon (as well as for other existing exposure situations). Yet, regulations and practical experience showed that the RL is applied like an Action Level (AL) in most cases, meaning that remediation actions are required only when radon concentration] is above the RL, whereas no significant action is required below, resulting in non-effective implementation of optimization and lower protection (especially if the chosen value of the RL is higher than a former AL).

However, it is not feasible to reduce any radon reference level. Therefore, Mr. Bochicchio indicated that guidance on the radon level below which no further action is required is missing, and that such a level, in combination with the RL, will be easy and practical to implement. He proposed to introduce a No Action Level (NAL, this is working name), significantly lower than the RL, which should be chosen by each Member State based on the radon concentration distribution (before optimization) and the national remediation capabilities. Remediation should aim to reduce radon concentration below the NAL, giving priority to radon levels above the RL. Therefore, the NAL will support the optimization below the RL in accordance with its original definition and participate to the graded approach (e.g. different options can be thoughts whether the initial exposure is > RL or simply > NAL).
Mr. Bochicchio indicated that a NAL was proposed (but never implemented) in ICRP Publication 103: "Regulatory authority might wish to specify level of protection below which protection against radon can be considered optimized, where no further actions are required".

Round Table

The round table gathered all the speakers. A set of questions was prepared in advance but it was proposed by the chair to use the many questions asked by the participants within the chat window.

Q1. Given the complexity of the situation, is it even possible to perform a pragmatic evaluation of the situation and the exposure (the necessary characterization step)? Mr. Lecomte declared that if every situation seems particular, the key point in ALARA is the process itself and it shall not focus on numbers or the array of possible parameters. Mrs. Rovenska reacted by saying that currently only a few companies (in each European country) have the competence to perform remediation actions efficiently, which strongly limits the application of the optimization principle and this situation should change (e.g. the economic market should change).
She also indicated that measurement/characterization is complex and shall follow a graded approach: from simple measurements to more detailed dose evaluation if required, but recognized that this would make the characterization not replicable (sometimes the protocol is site-specific) and that detailed evaluation are sometimes asked/mandatory to sort out conservatism and future questions. Mr Lecomte replied that the subject of the optimization should be the building, not the people; making detailed dose evaluation somewhat not necessary. Mr. Rovenska indicated that the regulation can mandate detailed dose evaluation and that margin for remediation actions are limited in a few cases (e.g. forced ventilation is not possible), so organizational measures are the last, but still valid, resort.

Q2. The risk assessment of the PAR and the UK radon map are different in many ways: level of knowledge available, precision, multi-risks vs. single

risk, etc. How does these two very different approaches can influence the application of the optimization principle? Ms. Gooding indicated that the radon map has different objectives: support radon measurement, prevention, remind about radon … - it is a big driving force, but it ceases to be applicable as soon as a measurement is performed. She specified that the regulation in UK is distinct from most of Europe: at the workplace: the ionizing radiations regulations apply as soon as the measurement is > RL: 300 Bq/m^3 and in homes a RL of 200 Bq/m^3 is recommended with a target level of 100 Bq/m^3 for higher risk population (smokers).
Mrs. Holmstrand indicated that real measurements in the environment are the only way to assess the risk (the uranium can leach from the PAR and contaminate the ecosystem) and also promote a graded approach in the measurement strategy. She indicated that dose limits to the biota are currently absent and might be needed to promote and drive the remediation.

Q3. Are there NORM situations that could be deemed automatically a planned exposure situation? Mrs. Holmstrand indicated that the Norwegian regulation does not differentiate clearly between the type of exposure situation and that her understanding of the regulation is that a planned exposure situation is a facility with discharges that must apply for a permit but even then there are exceptions and difficult cases (legacy site) and it can always be discussed whether a situation is planned, existing (or neither). Ms. Gooding also indicated that the UK regulation does not coincide well with the ICRP's types of exposure situations and supports the management of the problem whatever the type of situation. For Ms. Gooding, the case of legacy sites (in that case: from radium industry) scattered all over the country and whose memory is lost is another example where the ICRP system does not fit with all the situations coming from the field and might not allow for practical management.

Q4. The NAL for radon was introduced and presented during the webinar. Should the NAL be differently applied in case of existing vs. planned situations? Mr. Bochicchio does not see a considerable difference for using the tool and promotes a practical approach in both cases. He confirms that this two-levels approach (whatever the names of the levels) would drive the application of the optimization and indicated that some countries having already a two-level approach in place.

Mr. Lecomte concluded the round table by reminding that the ICRP system was not designed as an administrative framework: ICRP has insisted that the optimisation principle is a systematic process that apply irrespectively of the exposure situation. Nonetheless, the protection strategy should be designed based on the characteristics of the situation and the circumstances, hence the difference between existing and planned but this system has appeared somewhat too narrow for radon and NORM where there are no evident clear-cutting elements to decide in which categories the exposure falls (but sometimes clear delineation is mandated for regulatory purposes).

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The workshop immediately precedes the ETRAP 2023 conference (28-30 June, Groningen, NL).

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Registration: www.euterp.eu

Following on from a key recommendation from the last workshop in Malta in 2018, the aim of this next workshop is to kick-start the development of guidance on "best practice" and the necessary trainer competences for those wishing to deliver radiation protection training. Trainers are in a position of influence and it was concluded in Malta that guidance detailing the expected professional criteria for such trainers would be of value. The adaptations to, and innovations in, radiation protection training that has been seen as a result of the challenges posed by the COVID-19 pandemic have further added to the benefit of having such guidance.

Short updates and scene-setting content will be presented on the afternoon of the 26th June. This will be followed by a full day of working group sessions on the 27th June during which participants consider the target audience for, the optimum format and structure of, and topics to include in a guidance document.

The outcome of the Workshop will be presented at ETRAP 2023

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Do you have practices in ALARA to share?
change in regulation?
event to broadcast?
....

Contact the Editorial Board

Life of EAN and events

EAN communications and events

November 10 2022. The members of the EAN working group on ALARA for Radon At the Workplace (A-RAW) have published in the *Journal of Radiological Protection* **42**(4) "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 now available on-line: https://doi.org/10.1088/1361-6498/ac9b46

December 8 2022 Did you notice that the presentations and the video recording of the EAN first webinar "Challenges in applying the radiation protection system in the management of NORM and radon" are on-line?
https://www.eu-alara.net/

June 7 2023 is the Administrative Board and Steering Group meeting of the EAN. The meeting is planned at CEPN, France.

2-4 October 2023 EAN workshop n°20 about 'ALARA in interventional radiology and nuclear medicine', AGES, Vienna, Austria.

Other events in sight

- **ConRad 2023: Global Conference on Radiation Topics - Preparedness, Response, Protection and Research**, 8 - 11 May 2023, Munich (Germany) - https://express.converia.de/frontend/index.php?sub=987
- **International Conference on Nuclear Decommissioning: Addressing the Past and Ensuring the Future** 15-19 May 2023, Vienna, Austria, - https://www.iaea.org/events/decom2023
- **9th Organically Bound Tritium Workshop**, 10 - 12 Mai 2023 (Anvers) - https://www.sckcen.be/fr/OBTW9
- **ETRAP Conference/EUTERP** 27 - 30 June 2023, Groningen (The Netherlands) - https://www.etrap.net/
- International Radiation Protection School (IRPS), 14-18 August 2023, Stockholm University, Sweden - https://www.oecd-nea.org/jcms/pl_27499/international-radiological-protection-school-irps-2023-edition
- **7th ICRP international symposium** 6 - 9 November 2023 (Tokyo) - https://icrp.org/page.asp?id=579

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