

Optimization of protection, the Cornerstone of Radiation Protection

FERNAND VERMEERSCH

Chairman of the European ALARA Network
SCK CEN, Mol, BELGIUM

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 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 develop 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).

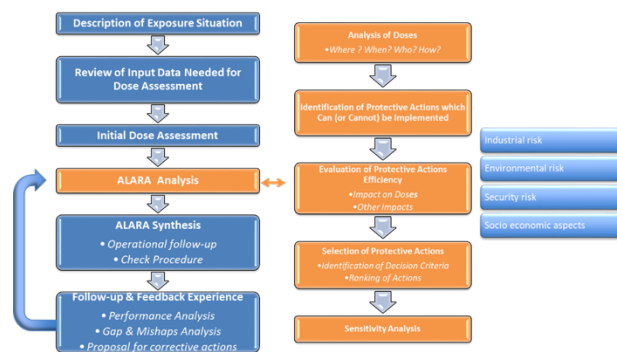


Figure 1. Steps in the ALARA process.

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.

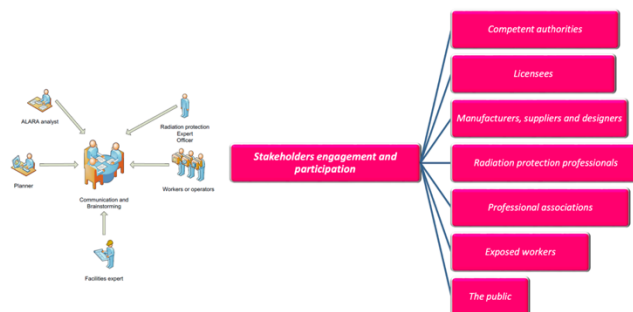


Figure 2. Stakeholders

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] and 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 the 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?

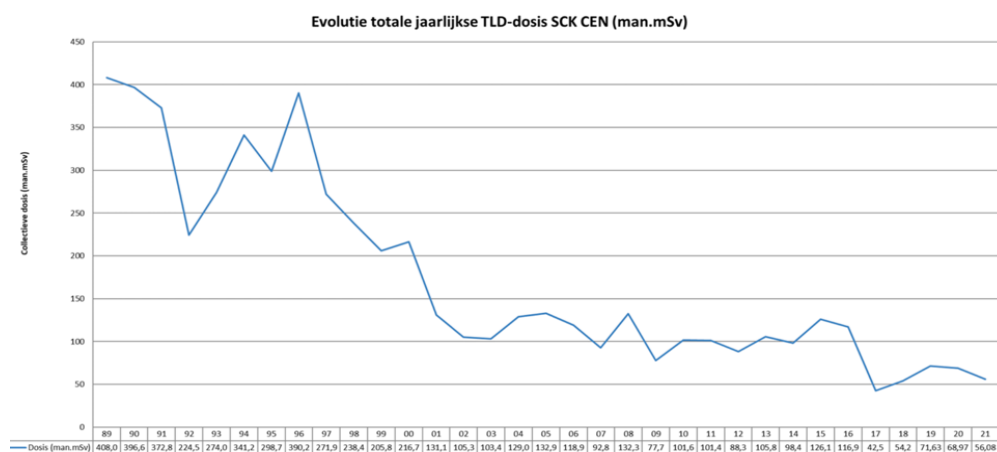


Figure 3. Evolution of the collective dose as function of time (1989-2021) in SCK CEN research centre, Belgium

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 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 use of the resources. Optimisation is a cornerstone of protection and radiation protection. ■

This article is based on the presentation given at the BVS-ABR scientific meeting on ALARA on June 17th, 2022.

REFERENCES. —

- [1] ICRP, 2007. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. *Ann. ICRP* **37** (2-4).
- [2] Optimisation of radiation protection ALARA: a practical guidebook, ISBN:978-2-9569796-0-9, 2019, Available at: <https://eu-alara.net/index.php/activities/documents-related-to-alara/330-optimization-of-radiological-protection-alara-a-practical-guidebook.html>
- [3] ICRP, 2006. The Optimization of Radiological Protection - Broadening the Process, Annexe 1 Assessing dose of the representative person for the purpose of radiation protection of the public, ICRP Publication 101b. *Ann. ICRP* **36** (3).
- [4] ALARA- from theory towards practice, 1991, EUR 13796
- [5] Development and dissemination of ALARA culture, Economides, S.; Hardeman, Frank; Vermeersch, Fernand; Nuccetelli, C.; Risica, S.; Schieber, C.; Schmitt-Hannig, A., European ALARA Newsletter, No. 31, 09.2012, p. 3-9, *presented at IRPA 13 Congress* 13-18 May 2012, Glasgow
- [6] ICRP, 2018. Ethical foundations of the system of radiological protection. ICRP Publication 138. *Ann. ICRP* **47**(1)
- [7] An IRPA perspective on ‘Reasonableness’ in the optimization of radiation protection, edition 2021
- [8] Optimisation: Rethinking the Art of Reasonable, NEA/CRPPH/R(2020)2, October 2021, Workshop Summary Report, Lisbon, Portugal, 14-15 January 2020
- [9] Occupational Exposures at Nuclear Power Plants, Twenty-Eighth Annual Report of the ISOE Programme 2018.
- [10] UNSCEAR, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Sixty-seventh and sixty-eighth sessions (2–6 November 2020 and 21–25 June 2021).