ALARA in the IAEA safety standards which are applicable to the management of radioactive waste

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Abstract

Optimisation of protection is one of the basic principles in radiological protection. It is recognized as such in the IAEA's Fundamental Safety Principles (IAEA SF-1) and applies to all circumstances that give rise to radiation risks. The Safety Requirements and Safety Guides build on these fundamental principles and elaborate on their application in specific practices.
Very recently, the IAEA has revised the overall structure (hierarchic and thematic) of the safety standards. Therefore, when standards are revised, the revised standard has to fit in the new structure. We shall briefly comment on this new structure and how the standards dealing with waste safety are linked.
In this paper we further give an overview of the application of the ALARA-principle in the safety standards that are applicable to the management of radioactive waste.

Introduction

In 2006, the IAEA has combined/integrated the three sets of fundamental safety principles (one for radiation safety, one for the safety of nuclear installations, one for the safety of radioactive waste management) into one set of fundamental safety principles (IAEA SF-1)[1]. The underlying fundamental safety objective was to protect people, individually and collectively, and the environment from harmful effects of ionizing radiation, without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. This safety objective applies for all facilities and activities, and for all stages over the lifetime of a facility (planning, siting, design, construction, commissioning, operation, decommissioning, closure), and includes the associated transport of radioactive material and management of radioactive waste.

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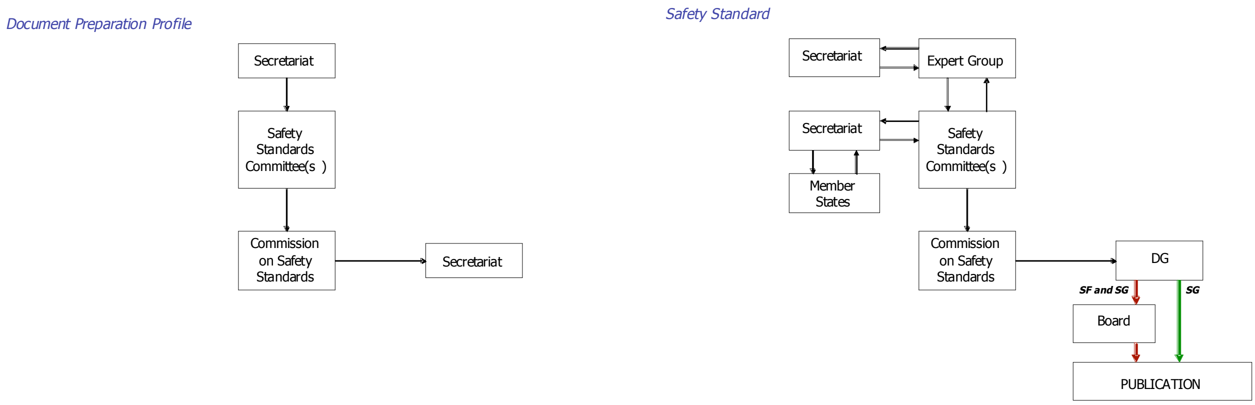
The overall structure of the IAEA safety standards

The IAEA Safety Standards cover nuclear safety, radiation safety, transport safety and waste safety, and also general safety (of relevance in two or more areas). They are categorized as follows:

- **safety fundamentals**, which present basic objectives, concepts and principles of safety and protection; they provide the basis for the safety requirements;
- **safety requirements**, which establish the requirements that must be met to ensure the protection of people and the environment, both now and in the future; they are expressed as 'shall' statements; they are governed by the objectives and principles presented in the safety fundamentals;
- **safety guides**, which provide recommendations and guidance on how to comply with the safety requirements, with the implication that it is necessary to take the measures recom-

mended or equivalent alternative measures to comply with the requirements; they present international good practices and increasingly they reflect best practices to help users striving to achieve high levels of safety.

For each area, a safety standards committee has been set up to supervise the drafting process. It starts with a ‘document preparation profile’, to be approved by the committee(s) involved and the Commission on Safety Standards (CSS), before development of the standard can be initiated. The committee(s) involved review the draft; when approved the draft is sent to member states for comment. Once the draft has been revised to take these comments into consideration, the committee(s) review it again and must approve it before it is forwarded to the Commission on Safety Standards (CSS). Following approval by the CSS, the safety guides are published under the authority of the director-general. Safety fundamentals and safety requirements are forwarded to the Board of Governors for final approval before publication. The development of a safety standard is schematically illustrated in the following figure.



The overall structure of the safety standards has been revised and must lead to a coherent set, comprising general requirements that are applicable to all facilities and activities and a series of facility or activity specific requirements.

The general safety requirements would comprise the following sections:

1. legal and regulatory system
2. leadership and management of safety
3. nuclear and radiation safety technical provisions and criteria
4. integrated safety assessment
5. radioactive waste management
6. decommissioning and termination of activities
7. remediation for existing situations
8. emergency preparedness and response

The facilities and activities specific additional safety requirements would deal with:

A. nuclear power plants
B. research reactors
C. fuel cycle facilities
D. waste disposal facilities
E. facilities and activities using radiation sources
F. transport of radioactive material
G. mining and milling of radioactive ores

It is planned to have the complete set of safety standards published in 2015.

The Safety Fundamentals (SF-1) [1]

The underlying fundamental safety objective was to protect people, individually and collectively, and the environment from harmful effects of ionizing radiation, without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks. This safety objective applies for all facilities and activities, and for all stages over the lifetime of a facility (planning, siting, design, construction, commissioning, operation, decommissioning, closure), and includes the associated transport of radioactive material and management of radioactive waste.

To achieve this objective, measures have to be taken:

- to control the radiation exposure of people and the release of radioactive material to the environment;
- to restrict the likelihood of events that might lead to a loss of control over sources of radiation;
- to mitigate the consequences of such events if they were to occur.

Ten safety principles have been formulated, on the basis of which safety requirements are to be developed and safety measures are to be implemented in order to achieve the fundamental safety objective. They are listed below and commented if relevant for the optimization of protection.

1. <u>Responsibility for safety</u>
   The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.

2. <u>Role of government</u>
   An effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.

3. <u>Leadership and management for safety</u>
   Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.

Safety has to be assessed for all facilities and activities, consistent with a graded approach.

4. <u>Justification of facilities and activities</u>
   Facilities and activities that give rise to radiation risks must yield an overall benefit.

It is a common understanding that waste management is not an activity that must be justified in its own. It is the activity that gives rise to the waste that must be justified, taking the associated waste management into consideration.

5. <u>Optimization of protection</u>
   Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

To determine whether radiation risks are as low as reasonably achievable, all such risks, whether arising from normal operations or from abnormal or accident conditions, must be assessed a priori and periodically reassessed throughout the lifetime of facilities and activities.

Where there are interdependences between related actions or between their associated risks, these must also be considered. This might be the case for different stages of the lifetime of facilities, for risks to different groups or for different steps in radioactive waste management. Account also has to be taken of uncertainties in knowledge.

The resources devoted to safety by the licensee, and the scope and stringency of regulations and their application, have to be commensurate with the magnitude of the radiation risks and their amenability to control.

In its publication 81, ICRP states that optimisation of protection is a judgmental process with social and economic factors being taken into account… the goal is to ensure that reasonable measures have been taken to reduce future doses to the extent that required resources are in line with these reductions.

6. Limitation of risks to individuals
   Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.

7. Protection of present and future generations
   People and the environment, present and future, must be protected against radiation risks.

The process for achieving an acceptable level of protection of human health should be constrained optimization, with emphasis – in particular for future generations – on taking all reasonable steps to achieve protection instead of relying solely on compliance with numerical criteria. The fact that specified numerical criteria may be assessed as being exceeded at some time in the future may not in itself imply rejection of the disposal option: the decision making process is judgmental particularly when considering the doses assessed for time periods greater than several hundreds of years into the future.

Radiation risks may transcend national borders and may persist for long periods of time. The possible consequences, now and in the future, of current actions have to be taken into account in judging the adequacy of measures to control risks.

Radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations, i.e. the generation that produce the waste must seek and apply safe, practicable and environmentally acceptable solutions for its long term management. This generation should do as much as it can to provide for the safe long-term management of the waste it generates, leaving as little as possible for future generations to do.

Institutional controls do not constitute an undue burden from a radiological protection perspective. They are a burden, but are seen by society as acceptable in the context of managing other types of hazardous (chemical) waste. The important issue is that the generation that generates the waste pass on to the next generation the knowledge, skills, records and societal judgments that led to the decisions as well as any financial resources to cover work that was intentionally deferred. This would allow the next generation to make decisions it regards as being appropriate and acceptable to it. This might include stopping any further action, reversing past actions or continuing to pass information on to its immediate next generation. It is not possible, reasonable or practicable for this generation to impose its will on future generations. It is the responsibility of each generation to consider, to decide and to act.

The generation of radioactive waste must be kept to the minimum practicable by means of appropriate design and procedures. Recycling and reuse of material are options to be considered.

8. Prevention of accidents
   All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.

To ensure that the likelihood of an accident (e.g. human intrusion in a repository) having harmful consequences is extremely low, measures have to be taken:

- to prevent the occurrence of failures or abnormal conditions;
- to prevent the escalation of any such failures or abnormal conditions that do occur;
- to prevent the loss (or the loss of control) of a source.

The primary means of preventing and mitigating the consequences of accidents is ‘defence in depth’, implemented primarily through the combination of a number of consecutive and independent levels of protection that would have to fail before harmful effects could be caused to people or to the environment.

An important element in defence in depth is an appropriate combination of inherent (passive) and engineered safety features.

9. Emergency preparedness and response
   Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.

10. Protective actions to reduce existing or unregulated radiation risks
    Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

The International Basic Safety Standards (SS 115) [2]

Optimization of protection and safety is one of the principal requirements of the BSS: protection and safety shall be optimized in order that the magnitude of individual doses, the number of people exposed and the likelihood of incurring exposures all be kept as low as reasonably achievable, economic and social factors being taken into account, within the restriction that the doses to individuals delivered by the source be subject to dose constraints.

The process of optimization of protection and safety measures may range from intuitive qualitative analyses to quantitative analyses using decision aiding techniques, but shall be sufficient to take all relevant factors into account in a coherent way so as to contribute to achieving the following objectives:

(a) to determine optimized protection and safety measures for the prevailing circumstances, with account taken of the available protection and safety options as well as the nature, magnitude and likelihood of exposures; and

(b) to establish criteria, on the basis of the results of the optimization, for the restriction of the magnitudes of exposures and of their probabilities by means of measures for preventing accidents and mitigating their consequences.

The licensee is responsible for the establishment, implementation and maintenance of measures for ensuring the optimization of the protection of members of the public whose exposure is attributable to sources under his responsibility. Such measures are in particular related to the discharge of radioactive substances to the environment.

Safety Requirements for near surface disposal (WS-R-1) [3]

In paragraph 2.2 it is stated that the disposal of radioactive waste in a near surface repository is part of a practice and that therefore radiation protection considerations are governed by the concepts of justification, optimization and dose limitation. The generation and the management of radioactive waste does not need to be justified separately since it should have been taken into account in the justification of the entire practice giving rise to the waste. The principles of optimization and dose limitation are applicable.

In particular, during the operational phase, the radiation protection of persons who are exposed as a result of operations at the waste repository shall be optimized.

Safety Requirements for predisposal management, including decommissioning (WS-R-2) [4]

Similar text can be found in WS-R-2: the radiation protection of any persons who are exposed as a result of activities in predisposal management of radioactive waste shall be optimized, with due regard to dose constraints.

Safety Requirements for geological disposal (WS-R-4) [5]

The optimization of protection (during the operational period) is required to be considered in the design of the repository and in the planning of operations above and below the ground. Relevant considerations include: the separation of mining and construction activities from waste emplacement activities; the use of remote handling equipment and shielded equipment for waste emplacement, when necessary; the control of the working environment, reducing the potential for accidents and their consequences; the minimization of maintenance needs in supervised and controlled areas. Contamination is to be controlled and avoided to the extent possible.

Repositories are to be sited, designed, constructed, operated and closed so that protection in the post-closure period is optimized, social and economic factors taken into account.

Constrained optimization is the central approach adopted to ensure the radiological safety of a waste disposal facility. In this context, the optimization of protection is a judgemental process, with social and economic factors being taken into account, and it should be conducted in a structured but essentially qualitative manner, supported by quantitative analysis. Safety assessments support judgements with regard to alternative management options as an element of optimizing safety and protection.

The operator is required to develop, throughout the development of a geological disposal facility, an appropriate understanding of the relevance and implications for safety of the available options, with the ultimate goal of providing an optimized level of operational and post-closure safety.

The appendix of these safety requirements deal with assurance of compliance with the safety objective and criteria, in particular optimization of safety and protection. It is reproduced as an appendix to this paper.

Outlook

The safety requirements reviewed in this paper are all under revision, in order to bring them in line with the safety fundamentals and the 2007 recommendations of the ICRP [6], as well as to make them fit within the overall structure. The revision of the waste safety requirements is near to completion: decommissioning is dealt with in a separate document [7]; there will be only one set of requirements for disposal, supplemented by a number of safety guides related to specific types of disposal installations. The revision of the BSS is intended to be completed in 2009.

ANNEX

(reproduced from the appendix to the IAEA Requirements for geological disposal of radioactive waste, IAEA WS-R-4)

ASSURANCE OF COMPLIANCE WITH THE SAFETY OBJECTIVE AND CRITERIA

A.1. A well designed and located geological disposal facility will provide a high level of assurance that radiological impacts in the post-closure period will be low, both in absolute terms and in comparison with the impacts expected from any other options for waste management that are available at present. A host geological formation and site will be identified that provide favourable conditions for isolation of the waste from the biosphere and the preservation of the engineered barriers (e.g. low groundwater flow and a favourable geochemical environment over the long term). The geological disposal facility will be designed with account taken of the characteristics offered by the host geological formation and site so as to optimize protection and not exceed the dose and/or risk constraints. The geological disposal facility will then be developed according to the assessed design so that the assumed safety characteristics of both the engineered and the natural barriers are realized.

A.2. The optimization of protection for a geological disposal facility is a judgemental process that is applied to the decisions made during the development of the facility's design. Most important is that sound engineering and technical solutions are adopted and sound principles of quality management are applied throughout the development, operation and closure of the geological disposal facility. Given these considerations, protection can then be considered optimized provided that:

- Due attention has been paid to the long term safety implications of various design options at each step in the development and operation of the geological disposal facility;
- There is a reasonable assurance that the assessed doses and/or risks resulting from the generally expected range of the natural evolution of the disposal system do not exceed the appropriate constraint, over time frames for which the uncertainties are not so large as to prevent meaningful interpretation of the results;
- The likelihood of events that might disturb the performance of the geological disposal facility, so as to give rise to higher doses or risks, has been reduced as far as is reasonably possible by the siting or design.

A.3. It is recognized that radiation doses to individuals in the future can only be estimated and that the uncertainties associated with these estimates will increase for times farther into the future. Nevertheless, estimates of doses and risks for long time periods can be made and used as indicators for comparison with the safety criteria.

A.4. In estimating the doses to individuals who will be living in the future, it is assumed that humans will be present locally, and that they will make some use of local resources that may contain radionuclides originating from the waste in the geological disposal facility. The representation of future human behaviour in assessment models is necessarily stylized, as it is not possible to predict behaviour in the future with any certainty. The rationale and possible approaches to the modelling of the biosphere and the estimation of doses arising from waste disposal facilities have been considered in the IAEA BIOMASS Project.

A.5. In the event of inadvertent human intrusion into a geological disposal facility, a small number of individuals involved in activities such as drilling or mining into the facility could receive high radiation doses. The doses and risks to any individuals who take part in activities to disturb deliberately the geological disposal facility or its waste need not be taken into consideration, as such actions would be planned. In general, the likelihood of inadvertent human intrusion into the waste will be low as a consequence of the chosen depth of the geological disposal facility and the decision to site it away from known mineral resources. While the doses received from such an inadvertent intrusion could be high, the associated risk is likely to be more than outweighed by the higher level of protection afforded by geological disposal in comparison with other strategies, since the likelihood of human intrusion is low.

A.6. A geological disposal facility may be affected by a range of possible evolutions and events, with some judged to be relatively likely to occur over the period of assessment, while others are considered rather unlikely or very unlikely to occur. With a view to optimizing protection, the design process will focus on ensuring that the disposal system provides for safety (i.e. on compliance with dose and/or risk constraints), in consideration of the expected evolution of the disposal system, and with account taken of uncertainties concerning that evolution and the natural events that are likely to occur over the period of assessment.

A.7. The achievement of a level of protection such that calculated doses are less than the dose constraint is not in itself sufficient for the acceptance of a safety case for a geological disposal facility, since protection is also required to be optimized. Conversely, an indication that calculated doses could, in some unlikely circumstances, exceed the dose constraint need not necessarily result in the rejection of a safety case. In very long timeframes, radioactive decay will reduce the hazard associated with the geological disposal facility; however, uncertainties could become much larger and calculated doses may exceed the dose constraint. Comparison of the doses with doses from naturally occurring radionuclides may provide a useful indication of the significance of such cases. It is recognized that radiation doses to people in the future can only be estimated and the uncertainties associated with these estimates will increase for times further into the future. Care has to be exercised in applying the criteria for periods beyond the time where the uncertainties become so large that the criteria may no longer serve as a reasonable basis for decision making.

A.8. The evaluation of whether or not the design of a geological disposal facility will provide an optimized level of protection may require a judgement in which other factors would also be considered. These factors may include, for example, the quality of the design and of the assessment, and the presence of significant qualitative or quantitative uncertainties in the calculation of long term exposures. In general, when irreducible uncertainties make the results of calculations for the safety assessment less reliable, then comparisons with dose or risk constraints have to be treated with caution. For a geological disposal facility, this is likely to be the case in considering human intrusion events and very low frequency natural events, as well as events far in the future. The robustness of the geological disposal system can be demonstrated, however, by undertaking an assessment of reference events that are typical of such very low frequency events.

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