

IAEA Safety Standards

for protecting people and the environment

Safety Assessment for the Decommissioning of Facilities Using Radioactive Material

Safety Guide

No. WS-G-5.2



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SAFETY ASSESSMENT FOR THE
DECOMMISSIONING OF
FACILITIES USING
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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

IAEA SAFETY STANDARDS SERIES No. WS-G-5.2

SAFETY ASSESSMENT FOR THE DECOMMISSIONING OF FACILITIES USING RADIOACTIVE MATERIAL

SAFETY GUIDE

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2008

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FOREWORD

by Mohamed ElBaradei
Director General

The IAEA's Statute authorizes the Agency to establish safety standards to protect health and minimize danger to life and property — standards which the IAEA must use in its own operations, and which a State can apply by means of its regulatory provisions for nuclear and radiation safety. A comprehensive body of safety standards under regular review, together with the IAEA's assistance in their application, has become a key element in a global safety regime.

In the mid-1990s, a major overhaul of the IAEA's safety standards programme was initiated, with a revised oversight committee structure and a systematic approach to updating the entire corpus of standards. The new standards that have resulted are of a high calibre and reflect best practices in Member States. With the assistance of the Commission on Safety Standards, the IAEA is working to promote the global acceptance and use of its safety standards.

Safety standards are only effective, however, if they are properly applied in practice. The IAEA's safety services — which range in scope from engineering safety, operational safety, and radiation, transport and waste safety to regulatory matters and safety culture in organizations — assist Member States in applying the standards and appraise their effectiveness. These safety services enable valuable insights to be shared and I continue to urge all Member States to make use of them.

Regulating nuclear and radiation safety is a national responsibility, and many Member States have decided to adopt the IAEA's safety standards for use in their national regulations. For the Contracting Parties to the various international safety conventions, IAEA standards provide a consistent, reliable means of ensuring the effective fulfilment of obligations under the conventions. The standards are also applied by designers, manufacturers and operators around the world to enhance nuclear and radiation safety in power generation, medicine, industry, agriculture, research and education.

The IAEA takes seriously the enduring challenge for users and regulators everywhere: that of ensuring a high level of safety in the use of nuclear materials and radiation sources around the world. Their continuing utilization for the benefit of humankind must be managed in a safe manner, and the IAEA safety standards are designed to facilitate the achievement of that goal.

THE IAEA SAFETY STANDARDS

BACKGROUND

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial applications, ranging from power generation to uses in medicine, industry and agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must therefore be subject to standards of safety.

Regulating safety is a national responsibility. However, radiation risks may transcend national borders, and international cooperation serves to promote and enhance safety globally by exchanging experience and by improving capabilities to control hazards, to prevent accidents, to respond to emergencies and to mitigate any harmful consequences.

States have an obligation of diligence and duty of care, and are expected to fulfil their national and international undertakings and obligations.

International safety standards provide support for States in meeting their obligations under general principles of international law, such as those relating to environmental protection. International safety standards also promote and assure confidence in safety and facilitate international commerce and trade.

A global nuclear safety regime is in place and is being continuously improved. IAEA safety standards, which support the implementation of binding international instruments and national safety infrastructures, are a cornerstone of this global regime. The IAEA safety standards constitute a useful tool for contracting parties to assess their performance under these international conventions.

THE IAEA SAFETY STANDARDS

The status of the IAEA safety standards derives from the IAEA's Statute, which authorizes the IAEA to establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection

of health and minimization of danger to life and property, and to provide for their application.

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures 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 a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures¹ have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories (see Fig. 1).

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. The safety requirements use ‘shall’ statements together with statements of

¹ See also publications issued in the IAEA Nuclear Security Series.

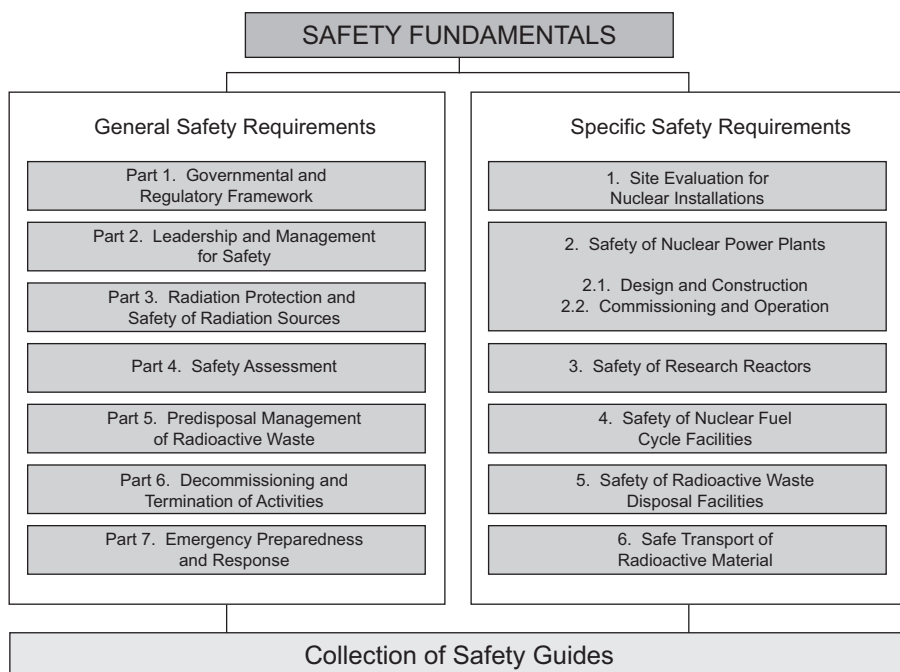


FIG. 1. The long term structure of the IAEA Safety Standards Series.

associated conditions to be met. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as ‘should’ statements.

APPLICATION OF THE IAEA SAFETY STANDARDS

The principal users of safety standards in IAEA Member States are regulatory bodies and other relevant national authorities. The IAEA safety

standards are also used by co-sponsoring organizations and by many organizations that design, construct and operate nuclear facilities, as well as organizations involved in the use of radiation and radioactive sources.

The IAEA safety standards are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes and to protective actions to reduce existing radiation risks. They can be used by States as a reference for their national regulations in respect of facilities and activities.

The IAEA's Statute makes the safety standards binding on the IAEA in relation to its own operations and also on States in relation to IAEA assisted operations.

The IAEA safety standards also form the basis for the IAEA's safety review services, and they are used by the IAEA in support of competence building, including the development of educational curricula and training courses.

International conventions contain requirements similar to those in the IAEA safety standards and make them binding on contracting parties. The IAEA safety standards, supplemented by international conventions, industry standards and detailed national requirements, establish a consistent basis for protecting people and the environment. There will also be some special aspects of safety that need to be assessed at the national level. For example, many of the IAEA safety standards, in particular those addressing aspects of safety in planning or design, are intended to apply primarily to new facilities and activities. The requirements established in the IAEA safety standards might not be fully met at some existing facilities that were built to earlier standards. The way in which IAEA safety standards are to be applied to such facilities is a decision for individual States.

The scientific considerations underlying the IAEA safety standards provide an objective basis for decisions concerning safety; however, decision makers must also make informed judgements and must determine how best to balance the benefits of an action or an activity against the associated radiation risks and any other detrimental impacts to which it gives rise.

DEVELOPMENT PROCESS FOR THE IAEA SAFETY STANDARDS

The preparation and review of the safety standards involves the IAEA Secretariat and four safety standards committees, for nuclear safety (NUSSC), radiation safety (RASSC), the safety of radioactive waste (WASSC) and the safe transport of radioactive material (TRANSSC), and a Commission on

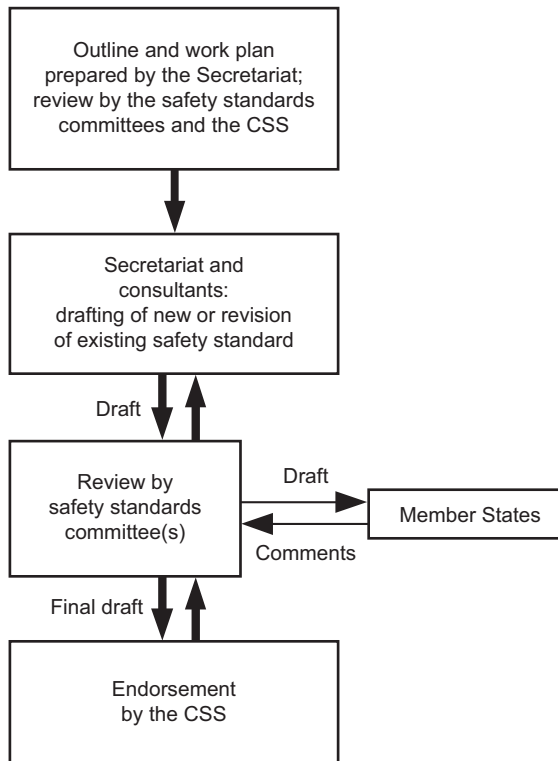


FIG. 2. The process for developing a new safety standard or revising an existing standard.

Safety Standards (CSS) which oversees the IAEA safety standards programme (see Fig. 2).

All IAEA Member States may nominate experts for the safety standards committees and may provide comments on draft standards. The membership of the Commission on Safety Standards is appointed by the Director General and includes senior governmental officials having responsibility for establishing national standards.

A management system has been established for the processes of planning, developing, reviewing, revising and establishing the IAEA safety standards. It articulates the mandate of the IAEA, the vision for the future application of the safety standards, policies and strategies, and corresponding functions and responsibilities.

INTERACTION WITH OTHER INTERNATIONAL ORGANIZATIONS

The findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the recommendations of international expert bodies, notably the International Commission on Radiological Protection (ICRP), are taken into account in developing the IAEA safety standards. Some safety standards are developed in cooperation with other bodies in the United Nations system or other specialized agencies, including the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, the International Labour Organization, the OECD Nuclear Energy Agency, the Pan American Health Organization and the World Health Organization.

INTERPRETATION OF THE TEXT

Safety related terms are to be understood as defined in the IAEA Safety Glossary (see <http://www-ns.iaea.org/standards/safety-glossary.htm>). Otherwise, words are used with the spellings and meanings assigned to them in the latest edition of The Concise Oxford Dictionary. For Safety Guides, the English version of the text is the authoritative version.

The background and context of each standard in the IAEA Safety Standards Series and its objective, scope and structure are explained in Section 1, Introduction, of each publication.

Material for which there is no appropriate place in the body text (e.g. material that is subsidiary to or separate from the body text, is included in support of statements in the body text, or describes methods of calculation, procedures or limits and conditions) may be presented in appendices or annexes.

An appendix, if included, is considered to form an integral part of the safety standard. Material in an appendix has the same status as the body text, and the IAEA assumes authorship of it. Annexes and footnotes to the main text, if included, are used to provide practical examples or additional information or explanation. Annexes and footnotes are not integral parts of the main text. Annex material published by the IAEA is not necessarily issued under its authorship; material under other authorship may be presented in annexes to the safety standards. Extraneous material presented in annexes is excerpted and adapted as necessary to be generally useful.

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1. INTRODUCTION

BACKGROUND

1.1. There are a large number of facilities using radioactive material¹ around the world in a broad range, including nuclear power plants, research reactors, nuclear fuel cycle facilities, medical facilities and research facilities, that are undergoing decommissioning² or where decommissioning is planned in the near future. In particular, an increasing number of nuclear power reactors and research reactors will be ceasing operation over the next few decades. The associated decommissioning of facilities of all these types requires adequate planning and evaluation, and demonstration that decommissioning activities can be conducted safely.

1.2. Existing safety standards require that an appropriate safety assessment be performed to support the decommissioning plan for each facility (Ref. [1], para. 5.2; Ref. [2]). These facilities will vary in size and complexity (e.g. from reprocessing plants to small research laboratories); in existing and potential hazards; in the level of radioactive contamination; in their operational history (e.g. with radiological incidents and accidents³); and in the complexity of decommissioning activities. In addition, a facility undergoing decommissioning could be one of several interdependent facilities on one site. Similarly, the facilities will be subject to different decommissioning strategies (e.g. immediate dismantling, deferred dismantling or entombment) [1] and different approaches (e.g. single phase or multiphase decommissioning). Thus, a range of approaches to developing and reviewing safety assessments for the decommissioning of facilities could be adopted (e.g. single assessments for each facility, assessments for separate decommissioning phases, or parallel

¹ The term ‘facility’ as used in this Safety Guide means a facility with its associated land, buildings and equipment in which radioactive material is used, processed, handled or stored on such a scale that consideration of safety is required (Ref. [1], para. 1.1).

² The term ‘decommissioning’ as used in this Safety Guide refers to the administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a facility (except for a repository, for which the term ‘closed’ and not ‘decommissioned’ is used) (Ref. [1], para. 1.1).

³ The term ‘accident’ as used in this Safety Guide means any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

interrelated multiple facility assessments). In view of these considerations, a graded approach should be applied to the development and review of safety assessments for decommissioning.

1.3. The safety assessment should employ a systematic methodology to demonstrate compliance with safety requirements and criteria for decommissioning throughout the decommissioning process, including the release of material, buildings and sites from regulatory control. In addition, the safety assessment should be used to help ensure that interested parties are confident of the safety of decommissioning. Once developed by the operator, the safety assessment should be reviewed by the regulatory body to ensure compliance with the relevant safety requirements and criteria.

1.4. Safety standards relating to the decommissioning of facilities have been agreed upon internationally [1]. They establish the safety requirements for protection against ionizing radiation and for the safety of radiation sources [3]; for the legal and governmental infrastructure relating to nuclear, radiation, radioactive waste and transport safety [4]; for the predisposal management [2] and the disposal of radioactive waste [5, 6]; for the release of sites from regulatory control on the termination of practices [7]; and for management systems [8].

1.5. This Safety Guide supports the Safety Requirements publication on the Decommissioning of Facilities Using Radioactive Material [1]. It also complements the Safety Guides on the Decommissioning of Nuclear Power Plants and Research Reactors [9], of medical, industrial and research facilities [10] and of nuclear fuel cycle facilities [11]; on Application of the Concepts of Exclusion, Exemption and Clearance [12]; and on the Release of Sites from Regulatory Control upon Termination of Practices [7]. In addition, it takes into consideration the relevant safety standards on predisposal [2] and disposal of radioactive waste [5, 13].

OBJECTIVE

1.6. The objective of this Safety Guide is to provide recommendations for the development and review of safety assessments for decommissioning activities. It also provides guidance on the review of safety assessments for decommissioning. Additionally, the Safety Guide is intended to assist regulators, operators and supporting technical specialists in the application of a graded approach to the development and review of safety assessments.

1.7. The Safety Guide provides guidance for a regulatory framework in which a safety assessment is prepared as part of the decommissioning plan for a facility. However, it is recognized that various approaches are in use internationally, for example, where safety assessments are documented in a stand-alone document, where they are integrated into the decommissioning plan, or where safety assessments are used to support the decommissioning plan but are not subject to separate regulatory controls. This Safety Guide provides guidance that can be used irrespective of how safety assessments are addressed or the safety assessment process is addressed in a national regulatory framework.

SCOPE

1.8. The guidance is intended for application in the development or review of safety assessments prepared in support of decommissioning strategies, plans or activities.

1.9. This Safety Guide provides guidance on a systematic methodology for the evaluation of radiological consequences for workers, the public and the environment of planned activities and of potential accidents during decommissioning. It applies to all types of facilities (e.g. nuclear power plants, research reactors, nuclear fuel cycle facilities, research laboratories and medical facilities). Therefore, a graded approach to the development and review of these safety assessments is recommended. It also applies to above ground supporting facilities (e.g. storage facilities) located at disposal sites for radioactive waste, which will ultimately require decommissioning. Specific aspects relating to the evaluation of safety when implementing different strategies for decommissioning (immediate dismantling, deferred dismantling or entombment) are also considered.

1.10. The Safety Guide addresses the application of the safety assessment methodology throughout the planning and implementation of decommissioning activities, including any deferred dismantling period after final shutdown, up to the final release of the site from regulatory control. Specific consideration is given in this Safety Guide to the changing radiological conditions, hazards and associated risks⁴ during the decommissioning process.

⁴ The term ‘risk’ used in this Safety Guide means a multi-attribute quantity expressing hazard, danger or chance of harmful or injurious consequences associated with actual or potential exposures. It relates to quantities such as the probability that specific deleterious consequences may arise, and the magnitude and character of such consequences [3].

1.11. This Safety Guide does not apply to disposal facilities for radioactive waste or to tailings from uranium mining and processing, which are addressed in Refs [5, 14]. In addition, the Safety Guide does not apply to the remediation of areas contaminated by past activities and accidents, for which guidance is provided in Refs [15, 16]. It does not provide guidance on environmental impact assessment, which is part of the decommissioning plan (see Refs [9–11]); nor does it apply to off-site transport, which is addressed in Ref. [17].

1.12. Although the management of material during the clearance process and the release of a site as part of decommissioning are referred to in this Safety Guide, no guidance is provided herein on the development of criteria for the release of material and sites from regulatory control. Guidance on these subjects is provided in Refs [7, 12].

1.13. Non-radiological hazards to workers, the public and the environment should be addressed as part of the safety assessment for decommissioning as required in the national legislation. However, the specific safety implications of and the appropriate protection of human health and the environment from these hazards are beyond the scope of this Safety Guide. Where non-radiological hazards are mentioned, this is either for illustrative purposes or because they could impact the radiological safety assessment.

STRUCTURE

1.14. Section 2 of this Safety Guide describes the objectives and scope of safety assessments for facility decommissioning. An overview of general considerations for safety assessments for decommissioning is presented in Section 3. Section 4 provides guidance on a systematic methodology for the development of safety assessments for decommissioning activities and the application of a graded approach. Section 5 provides guidance on approaches for the regulatory review of safety assessments for decommissioning. Section 6 addresses the involvement of interested parties in safety assessments for decommissioning. The annexes provide an example of a generic checklist for the identification of hazards and an example of a generic methodology for conducting reviews.

2. OBJECTIVES OF SAFETY ASSESSMENT

2.1. As part of the operator's responsibility for all aspects of safety and environmental protection during all phases of decommissioning, as required in Ref. [1], para. 3.8, an appropriate safety assessment should be performed:

- (a) To support the selection of the decommissioning strategy, the development of a decommissioning plan and associated specific decommissioning activities;
- (b) To demonstrate that exposures of workers and of the public are as low as reasonably achievable (ALARA) and do not exceed the relevant limits or constraints [3].

2.2. The safety assessment for decommissioning should be consistent with the decommissioning plan [1, 9–11] and with other relevant national and site specific strategies and requirements, for example, with requirements for radioactive waste management and for the release of material and sites from regulatory control.

2.3. The safety assessment for decommissioning should:

- (a) Document how regulatory requirements and criteria are met to support the authorization⁵ of the proposed decommissioning activities;
- (b) Include a systematic evaluation of the nature, magnitude and likelihood of hazards and their radiological consequences for workers, the public and the environment for planned activities and for accident conditions;
- (c) Quantify the systematic and progressive reduction in radiological hazards to be achieved through the conduct of the decommissioning activities;
- (d) Identify the safety measures, limit controls and conditions that will need to be applied to the decommissioning activities to ensure that the relevant safety requirements and criteria are met and maintained throughout the decommissioning;
- (e) Where relevant, demonstrate that the institutional controls applied after decommissioning will not impose an undue burden on future generations;
- (f) Provide input to on-site and off-site emergency planning and to safety management arrangements;

⁵ The term 'authorization' means the granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities.

- (g) Provide an input into the identification of training needs for decommissioning and of competences for staff performing decommissioning activities.

2.4. The safety assessment for decommissioning should be reviewed and updated, as appropriate, to ensure that it remains an accurate representation of the physical, chemical and radiological state of the facility as the decommissioning activities proceed.

3. GENERAL CONSIDERATIONS IN SAFETY ASSESSMENT FOR DECOMMISSIONING

GRADED APPROACH

3.1. The range of decommissioning activities for which a safety assessment is required is broad, and the scope, extent and level of detail of safety assessments should be commensurate with the types of hazards and their potential consequences. A graded approach should therefore be applied to the development and review of safety assessments. A graded approach is a process by which the level of analysis, the documentation and the actions necessary to comply with the safety requirements and criteria are commensurate with the factors listed in para. 3.3.

3.2. The graded approach should be applied in such a way that it does not compromise safety but ensures compliance with all relevant safety requirements and criteria.

3.3. In the application of the graded approach, account should be taken of:

- (a) The purpose of the safety assessment (e.g. for the final decommissioning plan or a phase of the decommissioning, or for a stage of the decommissioning plan);
- (b) The scope of the assessment (e.g. for a part of a facility, a single facility at a multifacility site or an entire site);
- (c) The size and type of the facility (including its complexity);
- (d) The physical and radiological state of the facility at the commencement of decommissioning activities (e.g. shutdown after normal operation or

shutdown after an incident or accident; shutdown following a long period of poor maintenance; uncertainty about the state of the facility) and in particular the extent to which ageing may have compromised building structures or engineered safety measures;

- (e) The complexity of the decommissioning activities;
- (f) Uncertainty issues, for example, the quality of the characterization of the facility, and the reliability and availability of relevant supporting information (e.g. drawings, records of modifications) to be used as input data for the safety assessment;
- (g) The radiological hazard (source term), for example, the activity inventory of the facility (e.g. surface contamination, bulk contamination); radiological characteristics (e.g. presence of short lived or long lived radionuclides, presence of alpha emitting radionuclides); the chemical and physical state of the radioactive material (e.g. solid, liquid, gaseous; sealed sources; heat generating material, combustible material);
- (h) The likelihood of hazards and their potential unmitigated consequences, with account taken of site characteristics (e.g. seismic events, flooding, influences from or dependence on any neighbouring facilities) and the presence and type of potential initiating events of incident/accident sequences (e.g. human error, fire, flood, dropped loads, collapse or failure of buildings or structures, chemicals, extreme temperatures);
- (i) The nature and reliability of safety measures (e.g. engineered safety systems, operational controls) that could be put in place, or that are in place, to protect against or to mitigate the consequences of accidents;
- (j) The safety requirements and criteria against which the results will be assessed;
- (k) The end state of the decommissioning of the facility (e.g. unrestricted or restricted use);
- (l) The availability of applicable safety assessments for this or other similar facilities and the novelty of the proposed decommissioning activities;
- (m) The extent to which decommissioning could adversely affect ongoing operations with safety significance elsewhere at the facility or at nearby facilities (e.g. those with shared services).

3.4. At facilities for which a phased (step by step) approach to decommissioning has been selected, account should be taken in the safety assessment of the phases, the nature of the decommissioning activities and the hazards they entail, which may differ for each phase. A graded approach should be applied to each decommissioning phase.

3.5. The graded approach outlined in this Safety Guide addresses radiological aspects. However, the operator should also take into account relevant non-radiological hazards that may lead to the higher grading of the safety assessment. Consideration of the non-radiological hazards in the context of the graded approach is beyond the scope of this Safety Guide.

HAZARDS DURING DECOMMISSIONING

3.6. All relevant hazards (e.g. sources of harm) to workers, the public and the environment should be considered in the decommissioning safety assessment, including:

- (a) Radiation exposures, for example, external exposure from direct radiation and other radiation sources (including criticality), internal exposure due to inhalation, ingestion or cuts and abrasions, and loss of containment leading to the uncontrolled release of radionuclides;
- (b) Toxic and other dangerous materials, for example, asbestos, flammable materials, carcinogens, chemicals used for decontamination purposes, asphyxiants⁶;
- (c) Industrial hazards, for example, dropped loads, work at heights, fires, high temperatures, high pressures, noise, dust and asbestos.

3.7. These hazards should be considered for their combined and additive effects and for the extent to which they could give rise to radiological consequences (e.g. fire leading to a loss of containment) for workers, the public and the environment.

3.8. Initiating events⁷ and event sequences that could lead to these hazards realizing their harm potential should be identified and evaluated by means of a systematic process, as described in Section 4.

3.9. The initiating events considered should include both those arising internally from the decommissioning activities or other activities within the

⁶ The term ‘asphyxiants’ as used in this Safety Guide means gases which, when present in an atmosphere in high concentrations, lead to a reduction of the oxygen concentration by displacement or dilution (e.g. acetylene nitrogen).

⁷ The term ‘initiating event’ means an identified event that leads to anticipated operational occurrences or accident conditions and that challenges safety functions.

operator's overall control, and those arising externally, such as extreme weather (e.g. flooding, tornadoes), off-site industrial accidents (e.g. flammable vapour clouds leading to fires and explosions, or releases of toxic chemicals from nearby facilities) and seismic events.

3.10. The safety assessment should consider the potential consequences arising from foreseeable initiating events during decommissioning and, where necessary, should recommend appropriate safety measures to minimize risks and consequences.

DEFENCE IN DEPTH

3.11. Decommissioning should be conducted using the defence in depth⁸ principle for safety appropriate to the degree of hazard. This should include:

- (a) The definition of appropriate operational limits, controls and conditions to prevent adverse consequences occurring during planned activities or arising as a result of accidents;
- (b) The provision of protective measures which ensure that any accidents will not result in significant harm to workers, the public or the environment;
- (c) The use of additional measures to mitigate the consequences of accidents that could occur during decommissioning.

3.12. The safety assessment should identify necessary preventive, protective and mitigating measures and should justify that these will be suitable and sufficient to ensure safety during decommissioning, in compliance with the relevant safety requirements and criteria.

⁸ The term 'defence in depth' means a hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions. The International Nuclear Safety Advisory Group (in INSAG-10 [18]) defines five levels of defence in depth: (a) Level 1: Prevention of abnormal operation and failures; (b) Level 2: Control of abnormal operation and detection of failures; (c) Level 3: Control of accidents within the design basis; (d) Level 4: Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents; and (e) Level 5: Mitigation of radiological consequences of significant releases of radioactive material.