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

IAEA
International Atomic Energy Agency

# SAFETY ASSESSMENT FOR THE DECOMMISSIONING OF FACILITIES USING RADIOACTIVE MATERIAL

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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 measures[1] 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

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

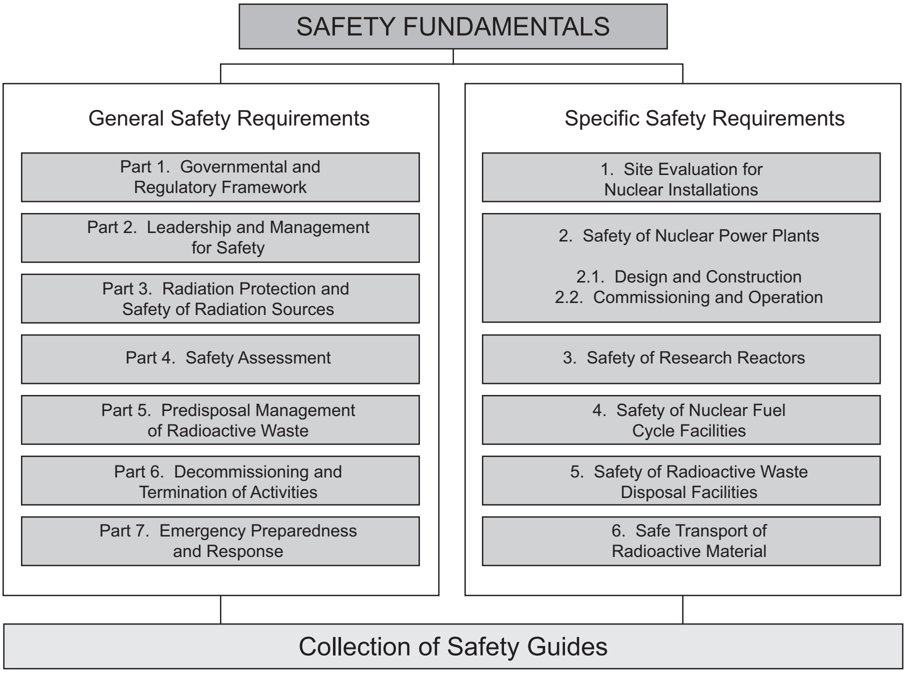


*FIG. 1. The long term structure of the IAEA Safety Standards Series.*

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

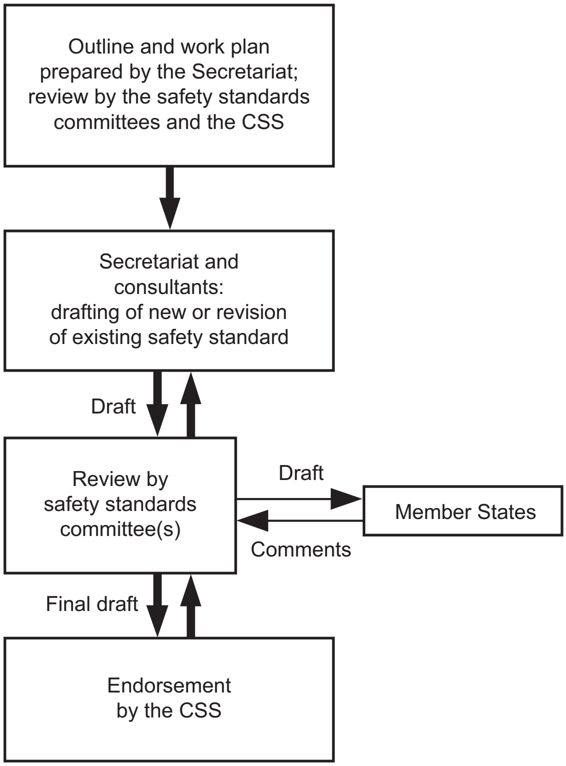


*FIG. 2. The process for developing a new safety standard or revising an existing standard.*

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.

## CONTENTS

# 1. INTRODUCTION

## BACKGROUND

1.1. There are a large number of facilities using radioactive material[1] 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 decommissioning[2] 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 accidents[3]); 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 risks[4] 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 authorization[5] 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, asphyxiants[6];
(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 events[7] 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 depth[8] 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.

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[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.

3.13. The types of safety measures used during decommissioning will often be different in nature to those in place when the facility was in normal operation. For example, instead of providing permanent engineered systems, structures and components (SSCs) to ensure the fulfilment of safety functions[9] during decommissioning, it may be appropriate (e.g. with account taken of the duration and nature of the proposed decommissioning activities, and the practicability of installing fully engineered SSCs), to place reliance on temporary engineered systems or on administrative controls and procedures to achieve an appropriate level of safety. For similar reasons, a greater reliance may need to be placed on mitigating measures (in lieu of preventive and protective measures) than would normally be acceptable in operational safety assessments. The appropriateness of adopting such an approach to the application of the concept of defence in depth should be justified in the safety assessment.

## SAFETY FUNCTIONS

3.14. As part of the safety assessment, safety functions and their associated SSCs should be identified, both for planned decommissioning activities and for accident conditions, and their suitability and sufficiency should be demonstrated. The safety functions required to be fulfilled during decommissioning comprise a combination of safety functions that were needed during operation of the facility and additional functions that will be needed as a result of the specific decommissioning activities proposed (e.g. fire detection and suppression during cutting and grinding activities). The effects of decommissioning on the safety functions at adjacent facilities should also be evaluated. In addition, dismantling of major facility structures during decommissioning may involve the deliberate destruction and removal of engineered SSCs that had fulfilled specified safety functions during operation of the facility (e.g. containment, shielding, ventilation, cooling). If these safety functions are still required, the associated SSCs should be maintained in an

[9] The term ‘safety function’ as used in this Safety Guide means a specific purpose that must be accomplished for safety. Its use here is more general than the three main safety functions for a nuclear power plant (control of reactivity, cooling of radioactive material and confinement of radioactive material), to reflect the wider range of hazards and scenarios that are relevant to decommissioning activities. Examples of safety functions during decommissioning include, in addition to these three main safety functions, shielding, radiation detection and actuation of alarms, fire suppression and ventilation.

appropriate state during decommissioning. If this is not practicable, these functions should be provided by suitable alternative means (e.g. tents, temporary facilities, fire systems, electrical systems, administrative procedures) for as long as is required on the basis of the safety assessment. The appropriateness of alternative means of fulfilling these functions should be demonstrated. Any change of safety functions during decommissioning should be justified in advance before its implementation.

3.15. If a deferred dismantling strategy is adopted, preference should be given to safety functions that are fulfilled by means of passive systems, devices and approaches, with minimal reliance on active SSCs, human intervention or the need for monitoring. The safety assessment should evaluate the suitability, sufficiency and reliability of these safety functions (e.g. the containment function) for the entire duration of the decommissioning (e.g. including deferral periods).

3.16. If an entombment strategy is adopted, the safety assessment for decommissioning activities prior to entombment (such as the dismantling of internal structures in preparation for entombment) should be consistent with the approach to other decommissioning strategies as set out in paras 3.14–3.16. Additionally, since entombment will result in the need for the long term management of radioactive waste, the facility's SSCs for fulfilling safety functions should be engineered to a standard that ensures that an appropriate level of safety will be maintained, for example, by means of natural barriers, for the duration of the proposed entombment [13, 19].

## OPTIMIZATION

3.17. The safety assessment should determine whether the decommissioning strategy, plans and activities will minimize exposures of workers and the public to levels as low as reasonably achievable and reduce the risks due to normal and/or accident conditions during decommissioning. The optimization of protection should consider both the magnitude of individual doses and the collective dose, taking into account the number of persons that could be exposed. To achieve these objectives, the safety assessment should determine whether the proposed preventive, protective and mitigating measures for radiological hazards provide the maximum safety benefit to workers, the public and the environment, as required in Ref. [3]. However, since risks from non-radiological hazards can make a significant contribution to overall risks during decommissioning, these risks should also be taken into account in the overall optimization process.

3.18. The optimization of protection should result in predicted doses and risks that, in addition to being as low as reasonably achievable, comply with the relevant limits and constraints. However, where it is permitted by national legislation, allowing higher risk activities for short periods during decommissioning may be appropriate in cases where these activities result directly in significant and long term reductions in effective doses, risks and/or hazards. In such cases, the safety assessment for decommissioning should provide a justification for the elevated risks and the period over which they will be present.

3.19. The optimization of protection should also consider the minimization of radioactive waste generated during decommissioning and the required activities for waste management that are necessary to ensure compliance with waste acceptance criteria for processing, storage, transport and disposal.

## LONG TERM SAFETY

3.20. The safety assessment should demonstrate that the decommissioning of the facility does not impose unacceptable hazards (e.g. hazards leading to effective doses in excess of relevant limits and constraints) or undue burdens on future generations [20] over the entire decommissioning period. In particular, the safety assessment should demonstrate that, where deferred dismantling or entombment is proposed, the facility will meet the relevant safety requirements and criteria [1, 3] in the deferred dismantling or entombment period and can be safely decommissioned in the future. If deferred dismantling or entombment is the option adopted, a periodic review of the safety assessment should be performed during the decommissioning period to account for various factors, such as facility ageing and monitoring results. The periodic review should be performed in accordance with national requirements.

3.21. If national or site specific release criteria for unrestricted use are not available, the safety assessment for decommissioning should demonstrate that the potential effective dose to a member of the critical group, once the site is released for unrestricted use, will be below 0.3 mSv in a year [7] and will be optimized. Guidance on such safety assessments is provided in Ref. [7].

3.22. If the site is intended for restricted use, the safety assessment should demonstrate that, with restrictions in place, the effective dose will not exceed 0.3 mSv in a year and that it is optimized. In addition, the safety assessment should demonstrate that if the identified dose restriction measures were to fail in the future, the effective dose to the critical group from all sources should not exceed 1 mSv in a year [7].

3.23. In cases where entombment is the preferred decommissioning strategy, long term safety should be assessed as required in national requirements for radioactive waste management. Guidance on such safety assessments is provided in Refs [13, 19].

## ENGINEERING ANALYSIS

3.24. To identify relevant existing and potential hazards, and to ensure appropriate levels of protection and accident mitigation during decommissioning, the safety assessment should consider:

(a) The physical, chemical and radiological state of the facility after shutdown, and the extent of ageing of the facility and its safety systems;
(b) The reliability of any existing engineered SSCs still necessary for fulfilling safety functions during decommissioning, and their compliance with appropriate current engineering codes and standards;
(c) The need for additional engineered SSCs to deliver safety functions that cannot be provided to an appropriate standard by existing SSCs, or that are needed as a result of the specific decommissioning activities being proposed (see paras 3.14–3.16).

3.25. The safety assessment should demonstrate that all SSCs that are necessary during decommissioning are engineered on the basis of appropriate engineering codes and standards. It should also demonstrate that the SSCs will be tested, inspected and maintained to a level commensurate with their associated safety functions, account being taken of the unmitigated consequences of their possible failure. In the case of pre-existing SSCs, this aspect of the safety assessment should draw upon experience and information (e.g. maintenance records) from the safety assessment that was used to justify these SSCs during operation of the facility.

3.26. The safety assessment should demonstrate that the facility and its SSCs are of suitable continuing integrity to withstand any demands (e.g. additional loads due to decommissioning equipment and personnel) placed on them during decommissioning while continuing to fulfil all necessary safety functions for the duration of the proposed decommissioning.

## MATERIAL MANAGEMENT

3.27. Material management constitutes a major part of the decommissioning activities and includes the segregation, categorization, quantification, processing, storage, handling and record keeping associated with radioactive and non-radioactive material on the site. To ensure the radiation protection of the workers, the public and the environment during the performance of these and other related tasks, material management should be considered in the safety assessment.

3.28. The safety assessment should assess the radiological consequences from:

(a) The management of material arising from decommissioning, including metal, building rubble, liquids and other material destined for release from regulatory control;
(b) The management of radioactive waste on the site, including any processing, handling and storage of the waste.

It should be noted that the management of materials from decommissioning should be addressed in the safety assessment, since separate assessments should be prepared for clearance [12], transport [17], predisposal [2] and disposal of radioactive waste [13]. Material management aspects (waste management and release of material) of the safety assessment can be documented in the safety assessment for decommissioning or can be addressed in other documentation, provided that this is consistent with, and linked to, the safety assessment for decommissioning.

3.29. The safety assessment for decommissioning should be consistent with relevant site and national strategies and requirements for the management of material and radioactive waste (see para. 2.2), and the following, in particular, should be taken into account:

(a) Clearance criteria and procedures [12];
(b) Criteria for the classification of material and radioactive waste;
(c) Acceptance criteria for the processing, storage, transport or disposal of radioactive waste;

(d) The flow and quantity of material and of radioactive waste at the site during decommissioning;
(e) The availability and capacity of processing and/or storage facilities (on and off the site), account being taken of material arising from other decommissioning activities (e.g. activities at other facilities or sites);
(f) The availability and capacity of disposal facilities.

## UNCERTAINTIES

3.30. In the safety assessment for decommissioning, due account should be taken of all known uncertainties. For example, the quality, reliability and availability of information from the characterization of the facility may be limited; cleanup activities may not be well defined (as the facility operator may need to revise the approach on the basis of changing conditions at the site); and scenarios and the stages in the decommissioning plan may need to be revised on the basis of knowledge gained from previous stages in the process or from other similar activities at other facilities or sites (including international experience).

3.31. In cases where such uncertainties are significant, the safety assessment should consider applying a phased approach to the safety assessment for decommissioning, addressing individual phases and/or stages of the decommissioning plan so as to reduce the uncertainties as decommissioning progresses. Such an approach:

(a) Is precautionary, proceeding only as far as input data, assumptions and approaches can be appropriately justified;
(b) Uses the safety assessment to determine suitable hold points for the decommissioning stages and work packages;
(c) Takes account of the best available sources of technical information (including feedback, relevant international experience and experimental trials);
(d) Allows for the review, revision and updating of the safety assessment, where necessary, as further information emerges from previous earlier stages of decommissioning.

## MANAGEMENT SYSTEM

3.32. A management system should be established for the development, review and internal approval of the safety assessment for decommissioning as part of the decommissioning plan. This management system should be commensurate with the complexity of the decommissioning activities and the associated hazards and risks at the site. Typically, the management system established for decommissioning is an evolution of the management system in place during normal operations.

3.33. The operator is required to establish an organization and to make provisions for the management and conduct of decommissioning to ensure that decommissioning will be conducted safely (Ref. [1], para. 7.1). The responsibilities of this organization should include, and provision should be made for, management of the development of safety assessments for decommissioning and, in particular, should address:

(a) The responsibilities of all staff undertaking safety assessment activities;
(b) The management of any subcontractors used to perform, or to assist with the performance of, the safety assessment;
(c) Skills, expertise and training of staff, including subcontractors, used to perform the safety assessment (see paras 3.35–3.38);
(d) The establishment of procedures governing the development, review and internal approval of the safety assessment for decommissioning by the operator, followed by implementation and future modification (e.g. in the light of emergent knowledge) of the safety assessment;
(e) The maintenance and storage of documents and records pertinent to the safety assessment;
(f) Engagement with regulatory bodies and other interested parties concerning the safety assessment;
(g) Quality management;
(h) Any interfaces with other decommissioning plans or other facilities.

3.34. The management system governing the development of the safety assessment for decommissioning should be applied using a graded approach with account taken of the factors identified in para. 3.3. The management system should be designed and implemented commensurate with the complexity of the facility, the radiological hazards and the complexity of the decommissioning activities. The management system should provide assurance that:

(a) The objectives and scope of safety assessments for decommissioning are adequately defined;
(b) Procedures governing the development of the safety assessments have been applied;
(c) Adequate strategies, methodologies (e.g. for hazard analysis) and procedures for safety assessments have been developed and implemented;
(d) Input data, assumptions, supporting information and supporting assessments are relevant and appropriate and have been documented;
(e) All relevant hazards have been identified, and appropriate normal scenarios and accident scenarios have been evaluated;
(f) Computer codes and other modelling tools are appropriate for the type of assessment and analysis being performed and have been suitably validated and verified[10];
(g) Reviews of the safety assessment and its supporting inputs, methodologies and modelling have been appropriately carried out, documented and reported, and any findings or recommendations have been taken into account in the safety assessment;
(h) Appropriate updating and maintenance of safety assessments are performed with due consideration of: changes in the state of the facility as decommissioning progresses; the decommissioning plan; the acquisition of new knowledge; new regulatory concerns; updates of the inventory on the basis of data from sampling and environmental monitoring; measurements of occupational doses; and radioactive releases during decommissioning activities;
(i) Personnel performing the safety assessment have appropriate qualifications, experience and training and also have clearly defined responsibilities.

[10] The term 'model verification' as used in this Safety Guide is the process of determining whether a computational model correctly implements the intended conceptual model or mathematical model. In relation to a computer code and other modelling tools, model validation is the process of determining whether a model is an adequate representation of the real system being modelled, by comparing the predictions of the model with observations of the real system.

## STAFFING AND TRAINING FOR DECOMMISSIONING

3.35. The transition from operation to decommissioning typically involves a significant change in the operator's management systems (e.g. due to the change from continuous routine operations to project based dynamic decommissioning activities with greater reliance on administrative and mitigating measures). Moreover, there is often increased reliance on contractors to perform the work. In addition, as the risks are different during decommissioning from the risks during operation, the staffing and training need to be adequate to address these different risks. All these issues should be reflected in the safety assessment (e.g. through consideration of an increased number of initiating events that are due to human error and the need for measures to prevent or to mitigate the associated consequences).

3.36. Experience from decommissioning has shown that it is often more appropriate to rely on human based procedures for short term, non-repetitive decommissioning activities than on engineered safety systems. However, relying on human control of multiple, repetitive activities is generally less reliable and should be avoided. The safety assessment should consider the balance between human based and engineered measures so that preventive, protective and mitigating safety measures are optimized.

3.37. The safety assessment for decommissioning should be carried out by an experienced multidisciplinary team with expertise in all the relevant technical areas. The composition of the team may vary, depending on the safety assessment to be performed, but the team should normally include personnel with expertise in safety assessment (e.g. hazard analysis, probabilistic analysis, deterministic analysis), relevant engineering aspects (e.g. civil, process, control and instrumentation, electrical, chemical and mechanical), radiation protection; industrial safety and management of radioactive waste and other material generated during decommissioning. The team should also include members with knowledge of the design, operation and history of the facility, and specialist assessors as appropriate and necessary (e.g. in the areas of criticality safety, hydrogeology, human factors and computer modelling).

3.38. The safety assessment should specify the requirements for personnel competences, associated training and the minimum number of personnel for maintaining safety. The safety assessment should identify critical areas and tasks during decommissioning where staffing and training play a particularly important role. For these critical areas and tasks, the operator needs to ensure that personnel competences, staffing and training are sufficient to maintain safety under the conditions analysed and in compliance with the relevant safety requirements and criteria. The depth and degree of rigour of training and competence should be commensurate with the complexity of the facility and of the decommissioning activities.

## 4. DEVELOPMENT OF A SAFETY ASSESSMENT

### INTRODUCTION

4.1. The safety assessment should be developed in a systematic manner using a graded approach, commensurate with the hazards associated with the facility and with the possible consequences of the decommissioning activities under evaluation. Safety assessments for decommissioning should be based on the framework defined in Fig. 1. The steps outlined in Fig. 1 are interdependent and should be performed in an iterative manner, as discussed in the following sections.

4.2. The safety assessment should be based on a defined framework (see Fig. 1) in which all prerequisites, such as the scope and objectives of the assessment, are clearly defined. The safety assessment should draw on, or should include, appropriately detailed descriptions of the facility and of the decommissioning activities to be undertaken, consistent with the decommissioning plan. This information should be used to identify existing and potential hazards inherent in the facility and new hazards arising from the nature of the decommissioning activities to be undertaken. The relevant hazards should be further quantified and their associated consequences for workers and the public should be evaluated, complemented by an engineering analysis of the SSCs. The resulting effective doses and the risks associated with these hazards should then be compared with the relevant safety requirements and criteria, as prescribed in the national legislation, to determine whether these safety requirements and criteria will be met. Finally, the analysis and its results should be subject to independent review (e.g. by the operator) to provide confidence in the assessment methodology, the data used, the assumptions made, the results obtained and the conclusions drawn and recommendations made. If the comparison indicates that safety criteria are not met, the safety assessment should be revised. The revision could result in modifications to the decommissioning strategy, plan and activities; engineered

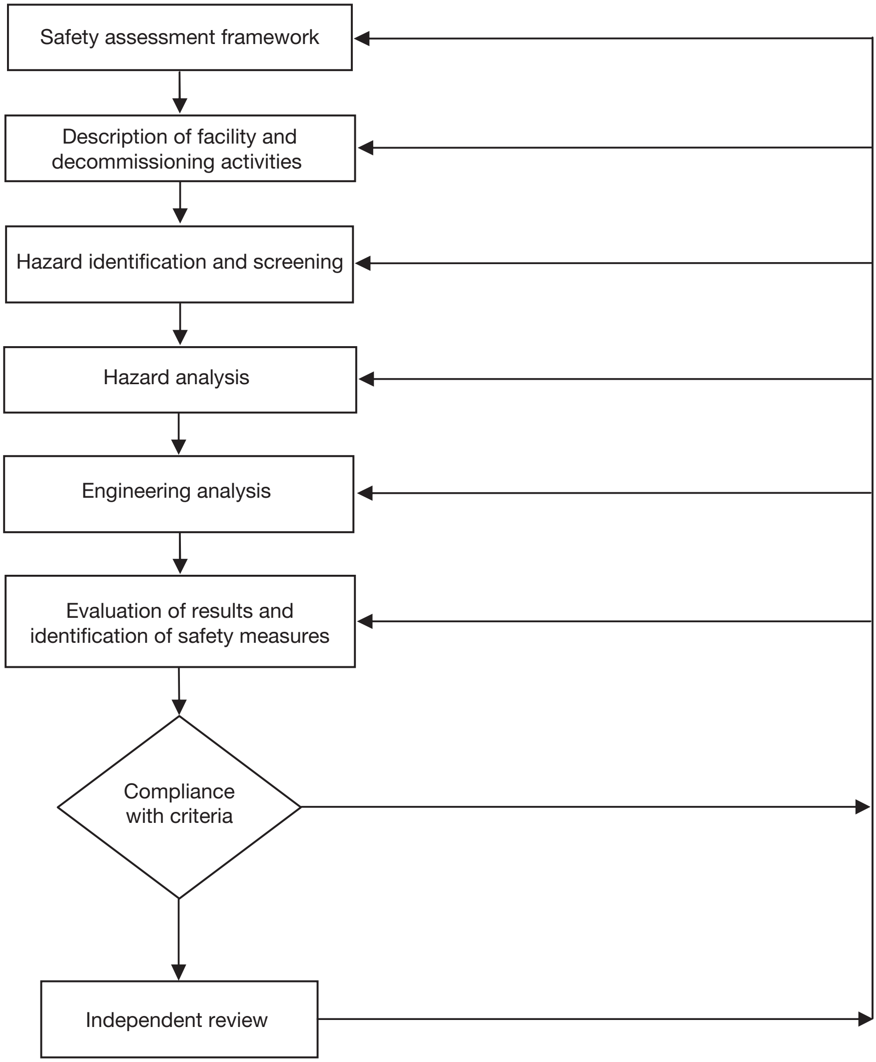


*FIG. 1. The safety assessment process.*

and protective measures; limits, controls and conditions or the treatment or reduction of uncertainties (e.g. in the assumptions of inventories); and in the consideration of new scenarios.

4.3. As discussed in Section 3, a graded approach should be used at each step of the safety assessment process.

4.4. If the decommissioning is divided into phases and the safety assessment cannot be performed to the same level of detail for all the phases (e.g. owing to a lack of information), the safety assessment should be updated at appropriate intervals (e.g. at least before the beginning of each new phase or as required by the regulatory body), taking into account new data, such as operational and decommissioning feedback.

## SAFETY ASSESSMENT FRAMEWORK

4.5. The framework of a safety assessment for decommissioning should be consistent with the decommissioning plan and should include:

(a) The scope of the assessment (e.g. a system or a facility; the site boundaries and interfaces with neighbouring activities such as the continuing operation of other units on the same site, or interfaces with the construction and operation of facilities for the management of radioactive waste) and its relation to the decommissioning plan;
(b) The objectives of the assessment (see Section 2, e.g. justification of the decommissioning strategy and activities; demonstration of compliance with safety criteria);
(c) Safety requirements and criteria to be met (e.g. for exposures of workers and the public and the likelihood of their occurrence; limits; constraints; risk criteria, clearance and site release criteria; waste acceptance criteria; and the minimization of waste generation);
(d) Assessment outputs (e.g. effective dose or risk). These outputs should correspond to the relevant safety requirements and criteria of the regulatory body, account being taken of assumptions for the assessment, such as timescales, critical groups and the defined end states of decommissioning phases;
(e) The safety assessment approach to be used (e.g. deterministic and/or probabilistic, conservative or realistic, generic or site specific). This approach should be based upon the nature of the hazards to be assessed and the time frames to which they relate, as described in the following sections. The approach should also specify the nature of the assumptions to be adopted, the availability and type of data (e.g. generic or site specific), and the approach to be adopted for the treatment of the various sources of uncertainty (e.g. the scenario, model and data);
(f) Time frames for decommissioning activities and their individual phases, for institutional controls (e.g. continuing restrictions on land use) and for the calculations;

(g) A clear definition of the decommissioning phases and their end points, including specific information about the physical, chemical and radiological end state objectives. The end point for each of the individual phases should not result in a condition that precludes achieving the final end state for the decommissioning of the facility;
(h) The final end state of the facility (e.g. unrestricted or restricted use, and any remaining buildings of the facility and their use);
(i) The use of relevant available data, safety assessments and feedback from experience (e.g. experience from operation of the facility, or from previous decommissioning activities at this facility or at other facilities at the national or international level);
(j) The involvement of interested parties (e.g. the regulatory body, other competent authorities, the public). See also Section 6.

## DESCRIPTION OF THE FACILITY AND OF THE DECOMMISSIONING ACTIVITIES

4.6. The safety assessment should use the following information from the decommissioning plan, in relation to the facility and its associated land, buildings and SSCs and their decommissioning:

(a) The facility and the existing hazards associated with it.
(b) The decommissioning activities to be performed. This information should be provided in sufficient detail to be able to establish a robust basis for the identification of potential hazards to workers, the public and the environment arising from the planned decommissioning activities in normal and accident conditions.
(c) The end points and the final state of the facility after decommissioning (e.g. land and buildings remaining on the site for unrestricted or restricted use). If the safety assessment applies only to phases of decommissioning, the end points of these phases should be defined. In such cases, the final state of the facility after the completion of decommissioning should be set out in as much detail as can be predicted.
(d) Existing and planned safety measures.
(e) Common systems with other operating facilities or facilities under decommissioning.

This information should be provided to a level of detail commensurate with the requirements of the safety assessment.

4.7. The description of the facility as presented in the decommissioning plan [9–11] should include all relevant details on:

(a) The site and local infrastructure: This should include sufficient information to enable dose and/or risk calculations to be performed (e.g. information on population distribution, present and future land use, meteorology, geology and seismology, surface water and groundwater hydrology and natural resources).
(b) The facility: This should include all existing safety functions and their associated SSCs, and should document their previous and present use; their physical and radiological state; any hazards they may present; and other items relevant for a safety assessment. The description of the facility should include all relevant information on the systems, large components and buildings.
(c) The inventory of radioactive material: This should include relevant radionuclides and calculated and measured activity; the radionuclide distribution in contaminated and (if applicable) activated components and building structures; and the dose rate distribution. The description should be based on radiological surveys, calculations and records of an adequate level of detail.
(d) The operational history: In all cases, operational records, post-operational on-site and off-site surveys and information from ongoing decommissioning activities should be included as information sources. This is particularly important for the specification of any modifications to the facility design, and for the identification of additional contamination of buildings, structures and systems above or below the ground, as well as contamination of land (including surface or groundwater) as a result of incidents, accidents or due to structures buried on the site.

4.8. The description of the decommissioning activities should cover:

(a) The decommissioning activities and the techniques to be used, the sequence of decommissioning tasks and their interfaces in terms of time, resources and utilization of common premises. The management of radioactive material, non-radioactive hazardous material and other materials on the site should also be described, including an inventory of material that will be generated.
(b) Supporting facilities — if any of these are necessary for the purpose of safe decommissioning, for example, facilities for electricity supply, or facilities used for the purposes of the management of radioactive waste, such as storage or conditioning facilities, laboratories and size reduction facilities.

(c) Common systems and services for the decommissioning of a facility that is on a site where other facilities may be located. The description of the facility to be decommissioned should also include information about common systems and services, their reliability for supporting the decommissioning, and the possible effects of the decommissioning activities on other facilities.

4.9. The end state of the facility after decommissioning should be defined. In some cases, this will be the unrestricted release of the site from regulatory control or its restricted release, administered through some form of institutional control.

4.10. The existing safety measures at the facility (e.g. work control procedures, use of personal protective equipment, training and testing programmes, radiation protection programmes) should also be described and should be considered in the hazard analysis.

## HAZARD IDENTIFICATION AND SCREENING

4.11. The safety assessment for decommissioning should account for all relevant hazards — existing and potential — arising from decommissioning activities, and for their interrelation and evolution over time [1, 7], as set out in the decommissioning plan and the assessment framework (see para. 4.5).

4.12. A systematic approach should be taken to the identification of hazards on the basis of the description of the facility and of the decommissioning activities. The following steps should be applied in an iterative manner to identify normal and accident scenarios that could lead to the exposure of workers and members of the public or could have adverse consequences for the environment:

(a) Identification of hazards and initiating events: The activity and location of the radioactive source term at the facility should be considered, together with any additional hazards arising from decommissioning activities or processes, and initiating events that create the potential for causing harmful consequences for workers, the public or the environment should be identified;
(b) Hazard screening: The hazards identified should be quantified and screened for, in order to direct the safety efforts towards all the significant and relevant hazards and initiating events for a facility;

(c) Identification of scenarios: The safety analysis should identify all relevant scenarios arising either from decommissioning activities or accident situations in which the screened hazards could be realized.

4.13. The hazard identification and screening process should consider the complexity of the facility and of the decommissioning activities, as well as the evolution and the reduction of hazards and risks as the decommissioning progresses.

**Identification of hazards and initiating events**

4.14. The hazard identification process should identify all locations in the facility where radioactive material is present (e.g. intentional and inadvertent accumulations of radioactive material and radioactive waste, surface contamination, contaminated ground, radioactive sources, activated components and ventilation system filters). Particular attention should be paid to radioactive materials which, due to the planned decommissioning activities, constitute new sources for the exposure of workers, for example, as a result of a change to a ventilation system due to loss of containment integrity during dismantling of the facility, or the removal of a shielding wall.

4.15. Future accumulation of material at the site should be taken into account, such as that at a storage area for radioactive waste which is gradually filled up and for which the assessment would need to be made on the basis of the maximum radioactivity envisaged to be present at any time. Consideration should also be given to the avoidance of inadvertent criticality in the waste storage area, in particular, during the decommissioning of a reprocessing facility.

4.16. All potential initiating events through which harm could be caused should be considered in the process, in particular:

(a) External initiating events:
   — Natural events such as adverse meteorological conditions (e.g. wind, snow, rain, ice, temperature, flooding, lightning), earthquakes or biological intrusion;
   — Human-made events such as aircraft accidents (with or without subsequent fires), explosions, fires, loss of electric power or other services, and human intrusion (mainly in cases where the facility is in a state of deferred dismantling).
(b) Internal initiating events at the facility or on the site, such as fire, explosion, structural collapse, leakage or spillage, failure of ventilation,

dropping of heavy loads and failure of protective measures (e.g. failure of shielding or of personal protective equipment).

(c) Human induced initiating events, such as operator errors and violations, and misidentifications leading to the performance of incompatible activities.

Experience has shown that internal and human induced initiating events are often the most important considerations in safety assessments for decommissioning. Initiating events with low probabilities should be considered, where appropriate, with account taken of the existing and potential hazards and the complexity of the decommissioning activities. A listing of potential hazards and initiating events relevant to safety assessments for decommissioning is presented in Annex I.

4.17. The identification of initiating events and the analysis of their evolution should be carried out using an appropriate technique (e.g. hazard and operability analysis (HAZOP) and event tree analysis), and appropriate sources of information, such as checklists, maps of dose rates for the facility, inventories of radioactive waste, and feedback of experience from the decommissioning of other facilities.

4.18. The hazards identified should be quantified and screened (see paras 4.20–4.24) to direct safety efforts towards all significant and relevant hazards for the facility. Hazards lacking the potential to cause harmful consequences for workers, the public or the environment to an extent that is not in compliance with relevant safety requirements or criteria, or hazards that could not be realized in view of the scope of the decommissioning activities being assessed, can be screened out from the subsequent hazard analysis.

4.19. Although the focus of this Safety Guide is on radiological safety, non-radiological hazards (e.g. exposure to chemicals, and the environmental impact of potentially hazardous non-radioactive material, such as asbestos or oil containing polychlorinated biphenyls (PCBs)) should also be addressed as specified in national requirements. It should be noted that non-radiological hazards (e.g. chemotoxic and industrial hazards) for which criteria exist may be assessed in similar ways and may be modelled along with the analysis of radiological hazards.

**Hazards screening**

4.20. The hazards relevant during decommissioning (see para. 4.16) should be quantified with no account taken of any protective or mitigating safety measures to be applied at the facility during decommissioning. However, the benefit deriving from intrinsic (passive) features of the facility (e.g. walls for shielding, engineered safety features) while these remain in place during the decommissioning process should be taken into account. Hazards with the potential to cause significant harmful consequences through any identified pathway, or hazards of high risk when compared with relevant criteria, should be considered further.

4.21. Hazards that lie outside the scope and/or the objectives of the safety assessment or that cannot lead to consequences in excess of relevant criteria should be screened out. This should lead to a reduced list of hazards to which the effort of the safety assessment should be directed. In facilities of low hazard or low complexity, or in cases where the planned decommissioning work has a very limited extent, there may be few relevant hazards, thereby limiting the scope of the safety assessment.

4.22. The screening process for hazards should involve consideration of all exposure pathways within the facility relevant to workers at the facility and to potentially affected members of the public. This aspect of the process should take into account radioactive releases and exposures from planned decommissioning activities (as such releases and/or exposures will occur continuously over a relatively long time interval) and from accidents, which are, typically, single events. Justification should be provided for excluded hazards.

4.23. All potential exposure pathways through which the identified hazards could cause harmful consequences for workers should be considered in the screening process, for example:

(a) External exposure due to contamination, activation of the structures (components, buildings, surfaces, etc.) or other radioactive material (e.g. sealed sources, radioactive waste packages), such as by direct radiation from gamma emitting radionuclides.
(b) Internal exposure due to inhalation or ingestion from airborne releases (e.g. particularly gases, aerosols and particulates) during the application of cutting techniques (e.g. thermal and mechanical cutting) or decontamination techniques, or in fires; from aerosols originating from chemical decontamination baths or the application of mechanical techniques for decontamination, and from other sources.
(c) A combination of radiological contamination and physical injuries (e.g. the contamination of wounds).

4.24. Exposure pathways to members of the public and releases to the environment should be considered wherever applicable (e.g. lack of containment or fires could lead to the inadvertent spread of radioactive substances beyond the site). In addition to the three pathways listed in para. 4.23, for workers, the potential for off-site exposure pathways to the public through water, airborne courses and/or the food chain should be considered.

**Identification of scenarios**

4.25. The above considerations of initiating events, hazards and exposure pathways should lead to the identification of a list of scenarios. The scenarios should describe how the hazards identified could be realized, either as anticipated operational occurrences in normal operation or as accidents. Those hazards that cannot cause significant harmful consequences (as assessed against the relevant safety criteria), since no realistic and relevant scenario can be identified, should not be considered further. However, since the consideration of normal and accident scenarios has the potential to give rise to further release pathways and initiating events than were identified initially (such as scenarios with potential effects on operations at nearby facilities), an iterative approach to the identification of initiating events, pathways and scenarios should be adopted.

4.26. The likelihood of particular scenarios in conjunction with their consequences should be analysed as a basis for scenarios to be screened out.

4.27. The identification of scenarios should consider the on-site management of material intended either for clearance or for processing, storage and disposal as radioactive waste. The assessment should cover such activities as segregating, characterizing, categorizing, quantifying, processing (e.g. volume reduction, packaging), handling and storage of waste at the facility, in normal conditions, as well as in accident situations where activity could be released or shielding may be reduced (following the failure of equipment or the rupture of waste packages, etc.).

## HAZARD ANALYSIS

4.28. The hazard analysis should be performed with the following objectives:

(a) To quantify the radiological consequences for workers and the public resulting from normal scenarios;
(b) To quantify the radiological consequences for workers and the public resulting from accident scenarios;
(c) To identify limits, controls and conditions necessary to reduce exposures to acceptable levels during planned decommissioning operations;
(d) To identify further measures necessary to prevent and protect workers and the public against accident scenarios and/or to mitigate their consequences.

4.29. These objectives should be achieved by using deterministic analysis and probabilistic analysis as appropriate, applied in a complementary manner. Deterministic methods should be applied in cases where it is difficult to assign realistic probabilities to selected relevant scenarios. Probabilistic methods should be applied in cases of complexity or where there is a requirement for compliance with risk criteria. For accident scenarios, or where national regulations require the comparison of certain scenarios against dose criteria for workers or the public, a deterministic approach should be used. Where risk criteria are applicable, probabilistic methods taking into account the likelihood of incidents and accidents should be used.

4.30. The hazard analysis should identify, address and document the following aspects:

(a) The sources and magnitude of radiological hazards (e.g. inventory characteristics and source terms: locations, dimensions, spatial distribution, constituents and quantities);
(b) Scenarios that could lead to these hazards being realized (e.g. frequency of occurrence, exposure pathways, assumptions necessary to support the calculation of frequencies, and consequences during normal and accident conditions);
(c) Consequences (e.g. occupational exposures and public exposures) with and without protective/mitigating measures (e.g. shielding against radiation at high dose rates or the use of respirators, or the use of additional ventilation or other means of controlling contamination);
(d) Uncertainties and the approach adopted in the hazard analysis (e.g. performance of bounding calculations or use of sensitivity studies);
(e) Measures to be put in place to prevent, to protect against or to mitigate the consequences of each scenario.

4.31. While insignificant hazards and scenarios are eliminated by the screening process, a graded approach should be used and appropriate methods should be chosen for an analysis of the remaining scenarios and hazards. In cases where the overall exposure is certain to be low, it may be sufficient to use an approach by which the scenarios that are expected to result in the highest exposures of workers or of the public (the bounding approach) are evaluated and other scenarios are excluded from calculation. For simple facilities, relatively few normal and accident bounding scenarios may be needed (this could be as few as one limiting scenario). For more complex facilities or facilities for which the estimated exposure is close to the relevant safety criteria, additional scenarios should also be considered.

4.32. When bounding scenarios are used, it is important to ensure that they include the maximum impacts from all the individual scenarios. For example, the bounding scenario may be a fire that releases large amounts of radioactive material to the environment, however, if another scenario (e.g. an accident in which a worker inhales radioactive material during the handling of waste) resulted in a higher dose to the worker, this estimated dose should also be evaluated and appropriate safety measures should also be specified.

4.33. For safety assessments addressing the release of sites where site specific or generic site release criteria are not available, the safety assessment should include an evaluation of the end state scenario, for both normal and accident situations.

4.34. A more detailed assessment should be applied to those scenarios that have been identified as having the potential to give rise to on-site or off-site releases, consistent with the national legal and regulatory framework.

4.35. The consequences arising from normal and accident scenarios should be assessed by calculating effective doses or risks using appropriate mathematical models (Fig. 2). These doses or risks can then be compared with criteria (e.g. dose limits, dose constraints, risks). Alternatively, the authorities can prescribe activity concentrations in environmental media with which the results of the models should be compared.

4.36. The complexity and extent of the calculations should be commensurate with the hazards associated with the facility and the decommissioning activities.

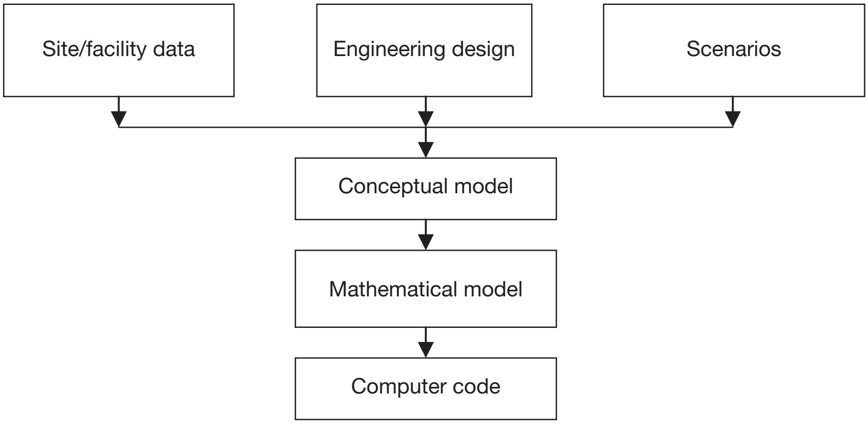


*FIG. 2. Generic model development.*

4.37. The methods for modelling and calculation should use verified/validated existing models and computer codes, where available, to facilitate the assessment. If new models or computer codes are used, they should be validated and verified prior to their use, to ensure their applicability and accuracy.

4.38. Assumptions used in the calculations (e.g. the fraction of activity present in the facility that is suspended into air; the fraction that is retained in filters or the fraction that is deposited on surfaces) should be justified and documented.

## ENGINEERING ANALYSIS

4.39. The assessment of safety functions and the associated SSCs should be performed by applying appropriate engineering codes and standards, commensurate with the importance of the safety functions (e.g. the unmitigated consequences of their failure).

4.40. The safety assessment should determine whether the existing SSCs are suitable and sufficient to achieve all that has been assumed of them in the hazard analysis and whether they will achieve the required reduction of doses and risks to an appropriate level of confidence.

4.41. The safety assessment should demonstrate that existing SSCs will continue to ensure associated safety functions for as long as is required by the decommissioning plan, with due account taken of ageing and other degradation mechanisms, and of invasive decommissioning activities (e.g. demolition of supporting walls, creation of a dusty environment).

4.42. The safety assessment should identify any safety functions that require new engineered SSCs, and should confirm that these will be suitable and sufficient to meet the relevant safety requirements and criteria. The safety assessment should also identify any ongoing engineering requirements that need to be applied during decommissioning (e.g. requirements for the inspection, maintenance and testing of SSCs) and services that need to be maintained, including those at other related facilities.

## EVALUATION OF RESULTS AND IDENTIFICATION OF SAFETY MEASURES

4.43. The results of safety assessments should serve to demonstrate compliance with regulatory requirements and criteria expressed in terms of effective dose (e.g. individual annual effective doses due to normal decommissioning operations, individual effective doses for single incidents or accidents) or in terms of risk. To achieve this, the results should be expressed in the same units as the associated safety criteria (see Section 3).

4.44. Sensitivity analyses should be performed to identify and assess those parameters and values with the highest impacts on assessment results. If the outcome is particularly sensitive to an input parameter or assumption, the operator should direct efforts towards reducing the uncertainties and repeating that part of the safety assessment.

4.45. The safety assessment should demonstrate that there are adequate safety measures in place that are commensurate with the likelihood of the occurrence of accidents and their possible radiological consequences, to demonstrate compliance with safety criteria. These safety measures can be:

(a) Engineered measures: Technical or physical measures in place during decommissioning work, such as the provision of additional shielding or the installation of new filters, a new ventilation system or a water treatment plant, the erection of temporary tents, the use of cutting tools with low aerosol generation, the installation of an alarm system set at a fraction of the level for compliance with the safety criteria, the use of protective equipment such as respirators, or the provision of other mitigating systems.

(b) Procedural measures: Administrative measures for a certain decommissioning task, such as the prescription of certain work procedures for specific tasks, the use of activity reduction by radioactive decay, the restriction of access to radiation areas, or the positioning of fire watches during cutting operations.

4.46. All relevant assumptions and the results of the assessment should be adequately documented. This includes uncertainties and assumptions that have been made in cases where no site specific data were available. In particular, it should be made clear in the documentation where assumptions have been made that rely on the provision of new safety measures or on the continuation of existing safety measures. The level of confidence in the evaluation results or the safety margin, as well as future actions if needed, should be identified.

4.47. If the results of the safety assessment do not demonstrate compliance with safety requirements or criteria, the assessment should be revised in accordance with the framework shown in Fig. 1. The results should be used to identify proposed amendments to the existing decommissioning strategy, plan or activities, as well as engineering measures and protective safety measures, and where appropriate, to identify additional safety measures to ensure compliance with the safety requirements and criteria. The treatment or reduction of uncertainties should be reviewed and, where necessary, revised. If the decommissioning plan is revised, the safety assessment should be reviewed or revised as necessary to evaluate the revisions to the decommissioning plan.

## INDEPENDENT REVIEW OF THE SAFETY ASSESSMENT

4.48. An independent review should be conducted by or on behalf of the operator, consistent with the national regulatory framework, prior to finalizing the safety assessment and before submitting it for regulatory review.

4.49. The safety assessment is an important contributor to the demonstration of safety during decommissioning and, therefore, the operator's independent review should ensure that:

(a) The input data and assumptions used are valid;

(b) The assessment accurately reflects the actual state of the facility and the decommissioning activities;
(c) The safety measures derived from the safety assessment are adequate for the decommissioning activity;
(d) The safety assessment is kept updated to reflect the evolution of the facility and the development of knowledge and understanding about it.

4.50. Suitably qualified and experienced persons, organizationally independent of the decommissioning activities, should perform the review. The independent review team should include specialists with expertise in all relevant areas (see paras 3.35–3.38) and should be independent of the team carrying out the safety assessment. The review should be undertaken in a systematic manner and the approach, findings and recommendations should be clearly documented and, if required, should be provided to the regulatory body.

4.51. Where a phased approach to decommissioning is used, an independent review should be performed to ensure that the safety assessment for each phase and stage is consistent with the overall safety assessment. Prior to commencing a new phase of decommissioning, an independent review should be performed to ensure that the safety assessment has been appropriately updated.

# 5. REGULATORY REVIEW OF THE SAFETY ASSESSMENT

## REGULATORY REVIEW OF THE SAFETY ASSESSMENT

5.1. The regulatory review of the safety assessment should be coordinated with the review of the decommissioning plan to ensure consistency, and should be carried out in accordance with national legislation. The parts of the decommissioning plan that are particularly relevant to the safety assessment include the description of the facility; the decommissioning strategy; the relevant safety requirements and criteria; the proposed decommissioning activities; the management system; the decommissioning techniques; the availability of supporting services; and the plan for the management of radioactive waste.

5.2. The regulatory review process, including the process of the review of the safety assessment for decommissioning, should be conducted in accordance with relevant national regulations and international recommendations [1] and should follow a graded approach (see paras 3.1–3.5). The regulatory body should set out its approach for the review of safety assessments for decommissioning (e.g. for screening or for detailed technical review) and it should communicate with the operator and other interested parties to state its expectations and to promote confidence in the regulatory process.

5.3. In cases where decommissioning is conducted in phases, regulatory reviews should be performed for each phase, for the entire decommissioning and for the interrelation of the phases.

5.4. The principal objectives of regulatory reviews of safety assessments should be:

(a) To consider whether the safety assessment provides an appropriate basis to support the proposed decommissioning strategy, plan and activities;
(b) To support the authorization process for the decommissioning strategy, plan and activities by confirming that all relevant safety requirements and criteria have been met;
(c) To identify any regulatory limits and conditions that will need to be applied during decommissioning or before decommissioning activities may be commenced;
(d) To provide an input into the process of releasing the site (together with any remaining buildings and/or structures) from regulatory control.

5.5. The results of the review of the safety assessment should demonstrate to the regulatory body that:

(a) The safety assessment is consistent with the decommissioning plan and other related safety assessments;
(b) Decommissioning activities are optimized with due regard to dose and risk constraints for planned activities;
(c) Suitable and sufficient safety measures (procedural measures and engineered safety features) will be in place so that the decommissioning activities can be carried out safely and in accordance with all relevant safety requirements and criteria, and in an optimized manner;
(d) Surveillance measures and maintenance measures are adequate to ensure safety;

(e) Emergency planning and preparedness during decommissioning are adequate;
(f) Good engineering practice has been used in developing the proposals for decommissioning.

## USE OF A GRADED APPROACH BY THE REGULATORY BODY

5.6. The level of scrutiny and the scope of the regulatory review of safety assessments should follow a graded approach. In the graded approach adopted by the regulatory body, account should be taken of the following:

(a) All relevant safety requirements and criteria derived from national legal and regulatory frameworks;
(b) The potential (e.g. in terms of likelihood and magnitude of consequence) for the proposed decommissioning activities to lead to an uncontrolled or accidental release of radioactivity (e.g. in working premises, on the site, off the site or at nearby facilities);
(c) The safety assessment's estimates of radioactive release and dose to workers arising from planned decommissioning activities;
(d) The complexity and novelty of the proposed decommissioning activities;
(e) Operator aspects (e.g. the operator's — or the contractor's — past performance and relevant experience, both in decommissioning and in producing safety assessments for decommissioning; the complexity of the organization);
(f) Relevant incidents and events at other facilities or at similar facilities during decommissioning;
(g) The scope of the decommissioning activities being assessed (e.g. a stage of a larger project, a single large project, a proposal leading to the final release of the facility from regulatory control);
(h) Technical or safety related concerns of other competent authorities (e.g. authorities having oversight over physical protection, security or non-radiological hazards).

5.7. The strategy adopted by the regulatory body for the review of the safety assessment for decommissioning should be focused on safety significant aspects of the decommissioning.

5.8. To assist with this graded approach, the regulatory body should consider establishing a set of deterministic screening criteria to categorize facilities or practices in accordance with their safety significance (i.e. the highest category of hazard during decommissioning). Here, safety significance includes consideration of the amount and form of radioactive material at the site; past activities and accidents and/or spills; the potential for fires, criticality and explosions; the effects of ageing of the facility; the competence and past performance of the operator and any subcontractors to be used; and the potential for releases of radioactive material or hazardous material during normal decommissioning activities as well as from accidental occurrences. When feedback of experience from decommissioning is available from similar facilities, the regulatory review should focus on the main differences between the safety assessments of these facilities.

## CONDUCT OF THE REGULATORY REVIEW

5.9. Regulatory reviews of safety assessments for decommissioning should be undertaken in a structured, traceable, accountable and systematic manner with clear acceptance criteria. The regulatory body should appoint suitably qualified and experienced staff to manage and undertake such reviews. The approach taken and the findings and recommendations resulting from such reviews should be clearly documented. Annex II contains an example of a checklist of aspects that are likely to be of importance for the regulatory review.

5.10. The following factors should be considered in regulatory reviews of safety assessments for decommissioning:

(a) The input assumptions and, where appropriate, the models used to evaluate the consequences of normal and accident scenarios;
(b) The identification and screening of hazards, initiating events and scenarios so that all potential safety concerns are adequately considered;
(c) The analysis and the supporting justification that the proposed decommissioning strategy and activities will minimize doses and keep risks as low as reasonably achievable and in accordance with national legislation;
(d) Whether the hazard analysis used appropriate techniques, assumptions and models;
(e) How uncertainties were addressed, and in particular whether they had been incorporated into the hazard analysis in an appropriately conservative and defensible manner;
(f) How the specification, justification and optimization of safety measures, limits, controls and conditions were performed so that operational doses are minimized, accidents are prevented, appropriate protective measures

are identified and consequences of accidents will be appropriately mitigated;

(g) How all necessary safety functions are correctly identified and considered; how all periods of elevated risks are appropriately justified (see Section 4); and how all relevant codes and standards are correctly applied;

(h) Whether appropriate strategies at the site level and national level for the management of radioactive material and radioactive waste are followed;

(i) The approach to and results of independent reviews and how the operator ensured independence of the reviews;

(j) The application of the management system to instil regulatory confidence in the quality of the operator's safety assessment and to address all relevant factors (e.g. audit, verification and validation; use of suitably qualified and experienced personnel; training; control of subcontractors; implementation of conclusions and recommendations);

(k) The proposed application of the results of the safety assessment (e.g. in measures for emergency response, training and project management);

(l) Whether compliance with relevant safety requirements and criteria has been correctly interpreted by the operator.

5.11. In addition to information provided in the operator's safety assessment and other documentation supporting the decommissioning plan, the regulatory body should consider the extent to which experience from the decommissioning of other facilities (including international ones) could be used as supporting information to inform the regulatory review.

5.12. The regulatory review of the safety assessment for deferred dismantling should ensure that the hazards and risks associated with this phase have been adequately considered and that the maintenance and surveillance programme is adequate. The review of the safety assessment for entombment should demonstrate compliance with the relevant requirements for the long term management of radioactive waste. In cases where the safety assessment relies on data and results from previous safety assessments, the regulatory body should consider the applicability of such data and results. Where relevant, it should be confirmed that the scope and assumptions of the safety assessment remain pertinent and that any engineered safety measures and procedural measures can continue to be relied on.

# 6. INVOLVEMENT OF INTERESTED PARTIES

6.1. As required in Ref. [1], para. 5.13, interested parties shall be provided with an opportunity to provide comments on the final decommissioning plan prior to its approval. This should include information about the safety assessment for the planned decommissioning activities, in accordance with national legislation. The involvement of local municipalities will be particularly important during the decision making process associated with the end state of the site (or facility) following the completion of decommissioning (e.g. its redevelopment for future, possibly restricted, use). Thus the process of involvement of interested parties should include provision for engagement of local municipalities in the safety assessment for end states.

6.2. As such, a process should be established so that interested parties can be provided with information, in an understandable and useful form, from the safety assessment for decommissioning so as to enable them to provide input into the regulatory body's decision making process for approval of the decommissioning plan (e.g. via public hearings or the solicitation of comments via the Internet).

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## Annex I

## EXAMPLE OF A CHECKLIST OF HAZARDS AND INITIATING EVENTS

| Events | Relevant for planned work | Relevant for accidents |
|---|---|---|
| **Internal initiating events** | | |
| *Radiological initiating events* | | |
| Criticality | | |
| — Residue of fissile material in equipment and process lines | | |
| — Residue of fissile radioactive liquid in tanks | | |
| — Presence of moderators (e.g. water, polyvinyl chloride) in the vicinity of fissile material | | |
| Spread of contamination | | |
| — Loss of containment integrity, loss of barriers | | |
| — Dismantling of containment or barriers | | |
| — Dropping of radioactive material and packages and radioactive waste | | |
| — Cleanup of buildings (e.g. activated or contaminated) | | |
| External exposure | | |
| — Activated material and equipment | | |
| — Direct radiation sources | | |
| Internal exposure | | |
| — Physical and chemical state of the radioactive material | | |
| Contamination, corrosion, etc. | | |
| — Spectrum, activity, emitters (e.g. presence of alpha emitters) | | |
| — Gaseous and liquid effluents | | |
| *Non-radiological initiating events* | | |
| Fire | | |
| — Thermal cutting techniques (e.g. using zircaloy) | | |
| — Decontamination process (e.g. chemical, mechanical or electrical methods or mixed methods for removing contamination from metal, concrete or other surfaces) | | |

| Events | Relevant for planned work | Relevant for accidents |
|---|---|---|
| — Accumulation of combustible materials and radioactive waste | | |
| — Flammable gases and liquids | | |
| Explosion | | |
| — Decontamination process | | |
| — Dust (e.g. graphite, zircaloy) | | |
| — Radiolysis (e.g. in the storage or transport of radioactive waste) | | |
| — Compressed gases | | |
| — Explosive substances | | |
| Flooding | | |
| — Leakage of liquid storage | | |
| — Leakage of pipes | | |
| — Pipe breaks | | |
| Toxic and hazardous materials | | |
| — Asbestos, glass wool in thermal insulation systems | | |
| — Lead in paint shielding | | |
| — Beryllium and other hazardous metals | | |
| — Polychlorinated biphenyls | | |
| — Oils | | |
| — Pesticides in use | | |
| — Biohazards | | |
| Electrical hazards | | |
| — Loss of power supply | | |
| — High voltage | | |
| — Non-ionizing radiation (e.g. lasers) | | |
| Physical hazards | | |
| — Falling of heavy loads | | |
| — Loads falling on SSCs important to safety | | |
| — Loads falling on radioactive material (e.g. packages) | | |
| — Collapse of structures (e.g. due to ageing) | | |
| — Demolition activities | | |

| Events | Relevant for planned work | Relevant for accidents |
|---|---|---|
| — Working at heights | | |
| — High noise levels | | |
| Human and organizational initiating events | | |
| — Operator errors, violations | | |
| — Inadvertent entry into radiation areas | | |
| — Misidentification of actions | | |
| — Actions by contractors and subcontractors | | |
| — Performance of incompatible actions | | |
| — Disabling of services to other facilities | | |
| — Poor ergonomic conditions | | |
| *External initiating events* | | |
| Earthquake | | |
| External flooding | | |
| — River | | |
| — Sea | | |
| — Infiltration of groundwater | | |
| External fire (e.g. oil storage) | | |
| Extreme weather conditions (e.g. temperature, winds, snow) | | |
| Industrial hazards (e.g. explosion) | | |
| *Other initiating events* | | |
| High temperatures and pressures | | |
| Corroded barriers | | |
| Unknown or unmarked materials | | |

## Annex II

## EXAMPLE OF A METHODOLOGY FOR GENERIC REGULATORY REVIEW

The safety aspects listed in Annex II are intended to assist the regulatory body in the conduct of a structured and systematic review of safety assessments for decommissioning. The content is not intended to be exhaustive, rather an illustration of the main aspects that need to be addressed in such a regulatory review. The aspects listed provide guidance to assist reviewers in identifying safety aspects relevant to decommissioning and to the associated safety assessment for decommissioning that is being reviewed. It is recognized that some aspects will be relevant also to the review of a decommissioning plan, and that the approach to regulatory review can differ in accordance with the national legal and regulatory framework.

### ASPECTS FOR HIGH LEVEL, PRELIMINARY REVIEW

Aspects for high level, preliminary review include a determination about whether:

- The decommissioning strategy is clear.
- The scope and objectives of the assessment are clear (see para. 2.3).
- The relevant safety requirements and criteria are clearly specified, and whether the results and conclusions of the assessment correspond to these requirements and criteria.
- The relationship with and references to the decommissioning plan and other relevant documents are clear.
- The identified hazards and initiating events appear reasonable and complete.
- The results of the safety assessment appear reasonable in view of the context.
- The safety assessment is documented in a form in which it can be referred to later and that meets the relevant requirements for a formal report.

SAFETY ASSESSMENT FRAMEWORK

**Context of the safety assessment**

The context of the safety assessment involves determining whether the safety assessment is consistent with:

(1) The description of the facility;
(2) The decommissioning strategy;
(3) Decommissioning activities;
(4) Plans and strategies for the management of radioactive waste.

**Scope of the safety assessment**

The scope of the safety assessment involves determining whether:

— The scope is clear and unambiguous (e.g. whether the assessment covers the entire decommissioning or a phase and/or stage of the decommissioning; whether the assessment includes material management aspects).
— The safety assessment interfaces with previous and successive decommissioning phases and/or stages.
— The relation with and dependence on neighbouring structures and facilities are described clearly and taken into account.

**Objectives of the safety assessment**

Objectives of the safety assessment involve determining:

— Whether the stated objectives are appropriate and whether they address all relevant aspects of para. 2.3.
— Whether the stated objectives are mutually consistent and whether they support the objectives of the decommissioning plan.

**Time frames**

Time frames involve determining whether:

— The safety assessment takes adequate account of the length of time for which the facility or site will need to be under regulatory control and

could pose a hazard to the public and the environment, including associated uncertainties.
- The safety assessment takes account of all the relevant safety requirements and criteria relating to time frames.
- The time frames for institutional controls, if required, are defined and appropriate.

**End points and end state of decommissioning**

End points and end state of decommissioning involve determining whether:

- The safety assessment includes a clear statement on the state of the facility or site at the end of the assessed decommissioning activities, including specific information about the physical, chemical and radiological end points of the individual decommissioning phases.
- The safety assessment is consistent with the end state of decommissioning as set out in the decommissioning plan.
- The inputs match the outputs of the previous stage or phase, for phased decommissioning, and the outputs are consistent with plans for the next stage or phase.
- The safety assessment includes adequate consideration, for phased decommissioning, of whether the end point of one phase could preclude reaching the intended end state of the facility.

**Requirements and criteria**

Requirements and criteria involve determining whether all relevant requirements and criteria are specified and whether adequate margins are clearly defined, for example, for:

- Effective doses and risks to workers and the public, both for normal operations and for accidents;
- Collective doses, etc.;
- Release of material from regulatory control;
- Release of sites (for restricted or unrestricted use);
- Criteria for the acceptance of radioactive waste for processing, storage and disposal;
- Discharges (liquid and gaseous);
- Optimization (e.g. keeping exposures as low as reasonably achievable, minimization of radioactive waste);
- Design and engineering (e.g. relevant engineering codes and standards);

— Non-radiological hazards;
— The involvement of interested parties in accordance with national legislation.

**Outputs of the safety assessment**

The safety assessment involves determining whether the outputs:

— Are clear and demonstrate compliance with the relevant safety requirements, criteria and the objectives of the safety assessment, including allowances made for uncertainties.
— Are suitable to support the decision making framework.
— Allow direct comparison with regulatory and/or other requirements and acceptance criteria.

**Approach to safety assessment**

The safety assessment involves determining:

— The approach to safety assessment (e.g. deterministic and/or probabilistic approach, conservative or realistic approach, generic or site specific approach) and evaluating whether this is appropriate for achieving the defined objectives.
— Whether the approach used to treat the uncertainties is adequate.

**Existing safety assessments and feedback of experience**

Existing safety assessments and feedback of experience are involved in determining:

— How information from previous safety assessments and/or from the feedback of experience is used or referenced in the safety assessment, taking into consideration whether the scope, assumptions, etc., remain relevant to the current analysis.
— Whether other safety assessments and feedback of experience (e.g. from the operation of the facility, from previous decommissioning activities at the facility or at other facilities, from national and international experience) are relevant.

## DESCRIPTION OF THE FACILITY AND OF THE DECOMMISSIONING ACTIVITIES

### Description of the facility

It is necessary to determine whether:

- An adequate description of the facility is provided, covering, for example, the site location; the population distribution; current and future land use; the local infrastructure; meteorology and climatology; geology and seismology; surface water hydrology; groundwater hydrology; and natural resources.
- The information presented is sufficient to support the input data and the assumptions made in the safety assessment.
- Existing SSCs that are needed during decommissioning are specified, together with their associated safety functions, and whether they are adequately described.
- Other existing safety measures at the facility that will be needed during decommissioning (e.g. work control procedures, use of personal protective equipment) are adequately described.
- The presence of common systems and other interdependences with operating facilities and with other facilities undergoing decommissioning are identified and adequately described.
- The radiological inventory of the facility and its contents (including any contaminated land) is presented in sufficient detail, with allowance made for associated uncertainties.
- Relevant aspects of the facility’s operational history are presented to an adequate extent (e.g. design changes, contamination events).
- Supporting facilities and services are identified and adequately described.

### Description of the decommissioning activities

It is necessary to determine whether:

- The decommissioning tasks, and their sequence and interrelations, are clearly presented.
- The decontamination techniques and dismantling techniques to be applied are presented comprehensively and are consistent with the decommissioning plan.
- The description of the decommissioning activities demonstrates a good understanding of their potential consequences for safety.

— The management of radioactive waste and other materials is clearly and consistently described to support an analysis of their impact on safety during decommissioning. If the management of radioactive waste and other materials is not taken into account, it is necessary to determine a justification.

## HAZARD IDENTIFICATION AND SCREENING

### Identification of hazards and initiating events

The identification of hazards and initiating events involves determining whether:

— A systematic approach to the identification of hazards has been followed that is suitable for the circumstances.
— All relevant existing and potential hazards have been suitably considered in the safety assessment (see para. 4.14), including their interrelations and their evolution over time.
— The accumulation of radioactive material, including inadvertent criticality, has been considered to an adequate extent.
— The initiating event identification method(s) used is/are validated, proven and suitable for the situation.
— Adequate consideration has been given to internal and external initiating events, including natural events and human induced events.
— Adequate consideration has been given to non-radiological hazards, where relevant to national requirements.

### Hazard screening

Numerous screening processes for hazards are involved and it is necessary to determine whether:

— The screening approach for the identification of hazards is justified and summarized in the safety assessment, and whether it addresses all relevant hazards.
— The screening process for hazards provides an appropriate estimate of the unmitigated consequences of the relevant hazards (e.g. taking no benefit for any protective or mitigating safety measures other than intrinsic (passive) features of the facility (see para. 4.20)) for workers and the public.

- The hazard screening process takes into account all relevant pathways of exposure (e.g. direct radiation, external exposure, inhalation, ingestion, contamination through injuries) of workers and the public.

**Identification of scenarios**

In the identification of scenarios, it is important to determine whether:

- Scenarios involving hazards that occur during normal operations are adequately addressed in the safety assessment.
- Accident scenarios that could occur during decommissioning are adequately addressed in the safety assessment.
- The on-site material management (see para. 4.27) has been considered in the identification of scenarios.
- New potential sources of exposure arising from the planned decommissioning activities have been considered.
- The approach to screening out scenarios is justified and is adequately summarized in the safety assessment, with due account taken of, for example, the risks in individual scenarios.
- The approach taken to identifying hazards, initiating events and scenarios is iterative and the completed safety assessment presents a fully self-consistent and appropriate set of scenarios for further analysis.

## HAZARD ANALYSIS

Hazard analysis involves determining whether:

- The type of analysis methodology adopted is appropriate to the situation (see para. 4.29).
- Where more than one methodology has been applied (e.g. deterministic and probabilistic), these methodologies have been applied in a complementary and suitably consistent manner.
- The level of detail of the analysis is appropriate for each scenario considered.
- A more detailed approach has been applied to scenarios having the potential to give rise to off-site consequences.
- The analysis of bounding scenarios, where this is carried out, includes the maximum impacts from all individual scenarios.
- The analysis of end state scenarios, where relevant, is adequate.

- The consequence analysis applies an appropriate mathematical model in which appropriate account is taken of data from the site or the facility and of the engineering design.
- The data and assumptions used are appropriate, justified and documented.
- The complexity and extent of the hazard analysis calculations are commensurate with the hazards associated with the facility and with the decommissioning activities to be undertaken.
- The methods adopted for modelling and for calculation have been validated/verified to an appropriate degree to ensure their applicability and accuracy.

## ENGINEERING ANALYSIS

Engineering analysis involves determining whether:

- The engineering analysis of SSCs is commensurate with the level of hazard associated.
- Relevant engineering codes and standards commensurate with the importance of the safety functions of the SSCs have been applied in the engineering analysis.
- The planned/inadvertent removal of existing SSCs as the decommissioning proceeds has been adequately analysed, with due account taken of the invasive and dynamic nature of the decommissioning.
- Adequate account has been taken in the analysis of ageing related degradation and other degradation mechanisms.
- The hazard analysis demonstrates that existing SSCs will be suitable and sufficient to achieve all that has been assumed of them in the hazard analysis and that they will achieve the required reduction in doses and risks to an appropriate level of confidence.
- The analysis of safety functions that require new engineered SSCs is suitable and sufficient.
- The safety assessment has identified all relevant engineering requirements that will need to be applied during decommissioning (e.g. maintenance, inspection and testing of SSCs).
- The safety assessment has identified any services (e.g. electric power supply or water supply) that will need to be maintained during decommissioning, including services for other facilities.

## EVALUATION OF RESULTS AND IDENTIFICATION OF SAFETY MEASURES

The evaluation of results and identification of safety measures involve determining whether:

- The results of the assessment demonstrate compliance with the relevant safety requirements and criteria with an adequate margin for safety.
- A sensitivity analysis has been performed to identify and assess parameters and values with the highest impact on the assessment results.
- The approach taken to dealing with unknowns and uncertainties is adequate.
- Adequate engineered and procedural safety measures (including the application of limits and conditions) have been identified to control normal operations and to prevent accident scenarios.
- Adequate engineered/procedural safety measures have been identified to protect against reasonably foreseeable accident scenarios.
- Adequate engineered/procedural safety measures have been identified to mitigate the consequences of reasonably foreseeable accident scenarios.
- The operator has identified safety measures for the decommissioning activities to reduce exposures to as low as reasonably achievable.
- Procedural safety measures identified in the safety assessment can be implemented without impediments.
- The outcomes of and bases for the safety assessment have been adequately documented.
- If the safety assessment relates to deferred dismantling, the approaches to future maintenance and surveillance have been adequately specified and are commensurate with the hazards and risks associated with the long term storage of radioactive waste.

## INDEPENDENT REVIEW

Independent review involves determining whether:

- The operator has established an adequate management system for the development, review and internal approval of the safety assessments for decommissioning, as part of the decommissioning plan, that is commensurate with the complexity of the decommissioning activities and associated hazards and risks at the site.

— The operator has undertaken an adequate, systematic and independent review of the completed safety assessment consistent with the relevant safety requirements and criteria.
— The operator's independent review was carried out by suitably qualified and experienced persons, including specialists in all relevant areas, with an appropriate degree of organizational independence.
— The operator's independent review has considered the validity of input data and assumptions.
— The operator's independent review has demonstrated that the safety assessment was made on the basis of an accurate representation of the actual state of the facility.
— The operator's independent review confirmed that the assessed decommissioning activities are consistent with the decommissioning plan.
— The operator's independent review considered the adequacy of the proposed safety measures.
— The operator's independent review considered how the safety assessment would be kept up to date to reflect the evolution of the facility and, where relevant, changes in knowledge and understanding.
— The operator's independent review has included adequate consideration of consistency between the safety assessments for each phase and consistency with the overall safety assessment, where a phased approach to decommissioning is taken.
— The approach taken, findings and recommendations of the operator's independent review have been appropriately documented and considered by the operator.

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